Addressing Climate Change and grassroots level adaptation measures to food security in Northwestern Bangladesh

by

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A B S T R A C T

Climate change is no longer a new phenomenon; it is one of the foremost challenges of the 21st century and is a dire threat to all of humanity. Although it is an international spectacle, its impacts are not equally distributed throughout the world. Several factors make the Global South more vulnerable to its impacts, such as extreme population pressures, rural-urban and refugee migration, and lower financial resources, amongst many other dynamics. It is known that in developing countries such as in Bangladesh, which is commonly known as the 'ground zero for climate change' and where four fifths of the land is floodplains, the consequences of climate change will be devastating. In Dhaka there are approximately 1,115.62 people per square kilometer, which makes it rank tenth highest in the world, in terms of its population density (World Population Review, 2017).

It has been predicted by the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2014) that global sea levels will rise by up to ~60cm by the year 2100. Therefore, the need to find solutions to climate change has become acutely urgent. Adaptation measures in developing countries, such as Bangladesh include "any adjustment - passive, reactive, or anticipatory - that can respond to anticipated or actual consequences associated with climate change" (Alam et al, 1999). This paper has relied on extensive literature review, case studies and long distance telephone interviews to explore the following: i) observed climate change in Bangladesh: ii) climate change impacts on crop productivity, mainly on rice: iii) Bangladesh's government policies on climate change: iv) local grassroots level adaptation measures in the agriculture sector. Overall, I have found that there has been a very positive trend towards adopting adaptation measures such as floating gardens, high yielding varieties of rice and sand bar cropping; however only certain regions have been using such measures. The challenges climate change poses for Bangladesh remain staggering.

F O R E W O R D

This Major Research Paper (MRP) is the final document to satisfy the requirements of my Plan of Study in the Masters in Environmental Studies Program (MES) at York University. The basis for this research began with my interest in studying the impacts of climate change on vulnerable nations with a particular focus on Bangladesh. The research that I have undertaken for this major paper relates to my Area of Concentration, to the components listed and also fulfills the majority of my learning objectives stated in my Plan of Study (POS), which I have developed during my studies at York University.

Overall, this paper contributes to my understanding of the socio-economic impacts of climate change induced flooding in Bangladesh, which is the first component of my POS. As this work progressed, I learned about the grassroots level adaptation measures in the agriculture sector, which is the second component of my POS. The specific learning objectives this paper addresses are the following: i) To learn about the agricultural practices of Bangladesh with a particular focus on food security ii) To learn about the different flood mitigation techniques that have been established in Bangladesh over the past decade to mitigate their floods (including structural and non structural methods) and why they are mostly failing: iii) To gain an overview of what the government of Bangladesh along with local and foreign NGOs are doing to engage and educate the local people about climate change and lastly: iv) To learn about the local grassroots adaptation measures.

A C K N O W L E D G E M E N T S

The past two years have perhaps been some of the toughest times of my life. However, I thank some people very close to my heart who have helped me tremendously and provided me with precarious support and as a result I gained a lot of strength and grew as a person.

First and foremost, I would like to thank God who is also known as 'Al Muizz' the Bestower of Honours and 'Al Wadud' the Most Loving One for being there for me in the pursuit of my ambitions and for guiding me throughout this perplexing yet robust phase of my life. I would also like to thank my Ammu and Abbu from the bottom of my heart for providing me with unconditional love and unwavering support in every possible way. Their confidence in me has paved a way for my future and without their wisdom and encouragement none of this would be possible. A thank you to my siblings Tasnim and Aaishah for their continuous love, humour and heart-to-heart conversations. To my closest friends Preyanka, Lamis, Sakina and Jennifer I would like to say thank you for always being there for me, listening to my woes and rants and showering me with encouragement, buoyant words and importantly confidence.

At York University, I would sincerely like to thank my supervisor Professor Ellie Perkins, for her continuous support and kindness. I am very glad as well as grateful to have had the opportunity to work with someone as sincere and kind as her. Thank you so much. I would also like to thank Professor Jose Etcheverry for his confidence in me and my abilities, for his thoughtful words of encouragement, as they have been of support to me. I would also like to thank my colleagues at Environment and Climate Change Canada for accommodating me to finish writing this paper. Also, I'd like to thank the participants from Bangladesh who agreed to become an integral part of my research via the interviews. Their honesty and willingness to share private and often painful memories from their lives is genuinely appreciated. Their extreme hard work, vigour for working hard and their fight for survival despite going through challenging situations such as severe flooding has helped me to see life in a new light. Thank you all.

"Life will find a way."

-Dr. Ian Malcolm, Jurassic Park

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List of Abbreviations

CRI Climate Risk Index
IPCC Intergovernmental Panel on Climate Change
GCM General Circulation Model
CPD Country Program Document created by UNICEF
UNICEF United Nations International Children's Emergency Fund
FAO Food and Agriculture Organization
IFRC International Federation of Red Cross
UNDP United Nations Development Programme
USAID United States Agency for International Development
JICA Japan International Cooperation Agency
FAP Flood Action Plan
IMF International Monetary Fund
NGOs Non Government organizations
PA Practical Action (NGO)
BARI Bangladesh Agriculture Research Institute
BRRI Bangladesh Rice Research Institute
BAU Bangladesh Agriculture University
DAE Department of Agriculture Extension
AIS Department of Agricultural Information System
BMD Bangladesh Meteorological Department
GHG Green house gas
NAPA National Adaptation Program
UNFCCC United Nations Framework Convention on Climate Change
BCCSAP Bangladesh Climate Change Strategy Action Plan
BCCTF Bangladesh Climate Change Trust Fund
BCCRF Bangladesh Climate Change Resilience Fund
ICCCAD International Centre for Climate Change and Development
DRC Domestic Resource Cost

CHAPTER 1: INTRODUCTION

1.1 Global Climate Change

Climate change is the foremost global challenge of the twenty-first century and its impacts are being witnessed worldwide from local to global scales. Climate related disasters such as storms, droughts and floods cause more loss and casualties than any other natural disasters such as volcanoes or earthquakes. In the early 1980's, floods replaced droughts as the most life-threatening global hazard (O'Hare, 2005). A key finding from the recent report 'Who Suffers Most From Extreme Weather Events? Global Climate Risk Index 2017' found that "Between 1996 and 2015, more than 528 000 people died worldwide and losses of US$ 3.08 trillion were incurred as a direct result of almost 11 000 extreme weather events" (CRI 2017, pg.5). In the article 'Climate Change and implications for food production, plant diseases and pests' by Rosenzweig et al, an 'extreme weather event' is described as "weather events that include spells of very high temperature, torrential rains, and droughts". In their research, they have also stated that "relatively small changes in mean temperature can result in disproportionately large changes in the frequency of extreme events", (pg.91).

It has been predicted by the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2014) that global sea levels will rise by up to ~60cm by the year 2100. One of the main factors that contribute to sea level rise is the thermal expansion of seawater due to the warming of the oceans. There has already been a rise in sea levels by an average of 1.7 ± 0.3mm/year since 1950 due to the accelerated decline of polar ice sheet mass. Furthermore, scientists have found that 25% of the observed sea level rise since the year 1960 is specifically due to thermal expansion and about 50% from the years 1993 to 2003 (Nicholls et al, 2010). One of the direct impacts of sea level rise due to climate change is flooding. It has also been predicted by the IPCC 2014 report that along with a rise in sea levels, there will also be an increase in the frequency and amount of precipitation; this is because a warmer atmosphere can hold much more water vapor (Rosenzweig, 2001). Other impacts include salt-water intrusion of surface water, increased erosion and decline

of coastal wetlands such as of mangrove ecosystems like the *Sundarbans* of Bangladesh and India.

1.2 Bangladesh: Country Background

The Global South is much more at risk and vulnerable to the effects of climate change due to several reasons such as high population densities and lower financial and technological resources. Authors O'Hare et al (2005) have defined the term vulnerability as "the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard" (pg.352). They have further specified that communities with minimal infrastructure, limited economic resources, weak institutions and low levels of empowerment and technology are highly vulnerable to climate change. They define risk as "the probability of occurrence of a climate hazard multiplied by the vulnerability of the target group" (pg.353). Vulnerable people, based on their livelihoods, include "rural smallholder agriculturalists with limited land and labour resources and rural wage labourers especially in marginal agricultural lands" (pg.352). This is strongly connected to the situation in Bangladesh because agriculture is one of the most important sectors of the economy; it comprises approximately 65% of the country's labour force and 48% of rural employment. Therefore, the people are highly vulnerable to climate variability and change and the economy is also highly sensitive to it (Winston et al, 2010).

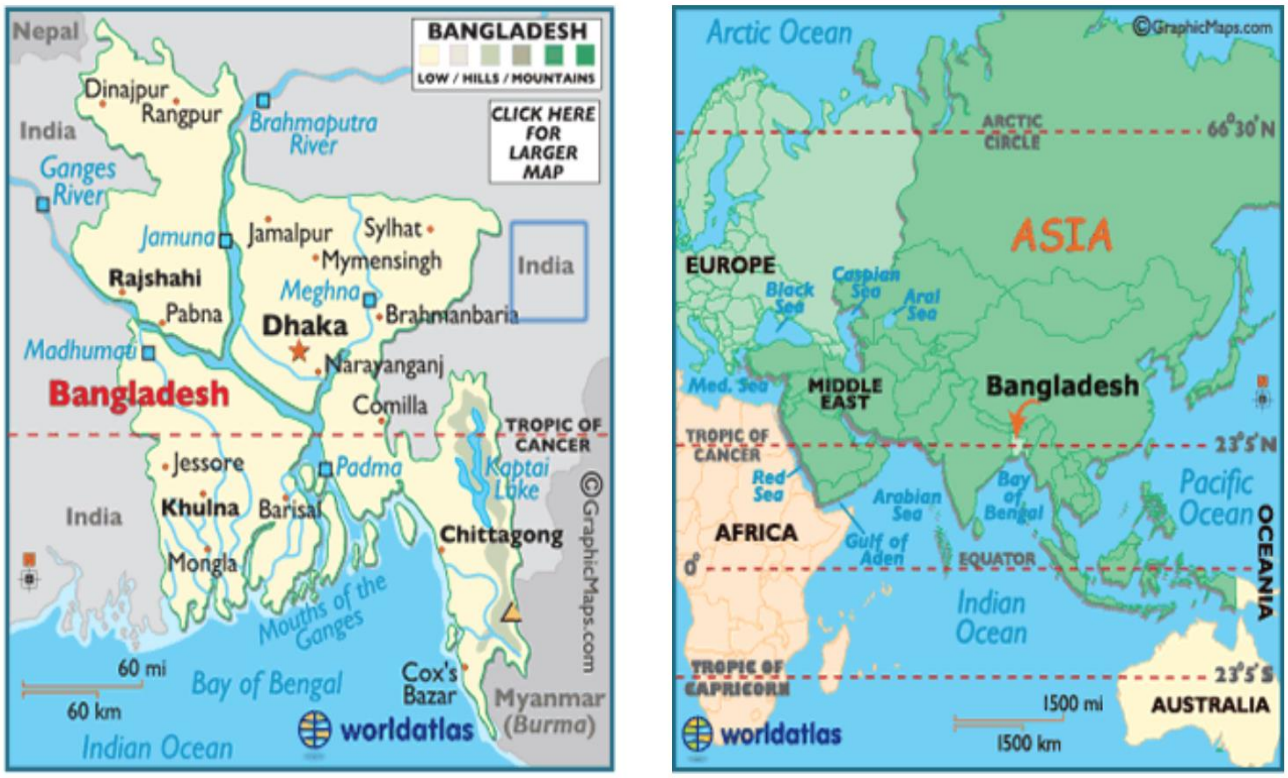
In terms of demographics, Bangladesh is one of the most densely populated countries in the world (see Figure 1 below) with an estimated population of 164.67 million in 2017. The countries that border Bangladesh are India (on the western side) and Myanmar (on the southeastern side). The Bay of Bengal is situated on the south of Bangladesh. Dhaka, the capital is a megacity with a population of 18 million in 2016. There are approximately 1,115.62 people per square kilometer, which makes it rank the tenth highest in the world, in terms of its population density (World Population Review, 2017). The total landmass of Bangladesh is 144,000 km^2 with nearly 230 rivers, and their tributaries have a total length of approximately 24,140 km (Nakamura, 2002). The three major rivers that flow through Bangladesh are the Ganges, the Brahmaputra and the Meghna Rivers. The rivers flow into the Bay of Bengal. As a low-lying country, in which

about 80% of the land is floodplains, it is considered to be one of the most susceptible nations to climate change and sea level rise (Impacts, Adaptation & Vulnerability, IPCC, 2007; Salehin et al, 1997).

The GDP per capita of Bangladesh was 1029.60 US dollars in 2016, which is equivalent to only 8% of the world's average (Trading Economics, 2016). According to the 'Country Programme Document' created by UNICEF, poverty levels have gradually improved over the past few decades, however there are still "twenty-six million children who live below the national poverty line, typically deprived of four out of seven of the following basic services: water, sanitation, nutrition, education, health, information and shelter" in Bangladesh (CPD, UNICEF).

Due to exacerbating weather events combined with human stress factors such as population growth and migration, the people of Bangladesh, who are already struggling to mitigate and adapt to such changes, will face heavy impacts of climate change. However, over the past few decades there have been some incredible grassroots level adaptation measures that the Bengali people have established in order to adapt to the negative impacts of climate change. Examples of such adaptive measures include floating schools which are solar powered, farming vegetables such as pumpkins on sand bars known as 'chars' and importantly the notable 'floating gardens' which are known as 'baira', which are "built using aquatic weeds as a base on which vegetables can be grown" (Practical Action, FAO). Several adaptive measures will be described thoroughly in this Major Paper to understand the extent of how helpful they are to the Bengali people and whether they help reduce their vulnerability to some extent.

Figure 1. Map of Bangladesh, showcasing the major rivers (Source: World Atlas)



1.2.1 Research questions and Methodology

The overall objective of my research paper is to explore the socioeconomic implications of climate change, with a specific focus on climate change induced flooding on Bangladesh's food security. Another important objective for my study is to identify the adaptation measures that have been established in the agriculture sector, and assess their effectiveness in reducing poverty and vulnerability. The core questions that I address in this research paper are the following;

1. What are the observed climate change patterns in Bangladesh including flooding?
2. Can education and use of modern high yielding seed technology for rural and vulnerable low-income farmers play a certain role in minimizing poverty and the devastating impacts of flooding on rice crops and production?
3. What are some local grassroots level flood adaptation schemes that are in place in Bangladesh? To what extent are these adaptation strategies beneficial to the local people?

In order to address the core questions listed above, my research paper contains both primary and secondary data. My primary data collection consisted of conducting long distance telephone interviews in a small rural town located in North-western Bangladesh, with flood victims that work on a rice farm. However, the main research method that falls under secondary data collection for my paper is that it takes a literature review approach. The peer-reviewed articles from various journals that mainly relate to climate change science that I used were found using academic databases such as Google Scholar and York University's online library databases. Several books on climate change such as 'Climate Change risks and food security in Bangladesh' by Yu et al (2010), 'Climate Change adaptation through indigenous technology knowledge' by Pajajuli (2015) and 'Climate Change and Food Security in Bangladesh' by Winston et al (2010) which I also used are all listed in the bibliography section. Another important component of my secondary data collection was examining two case studies on adaptive approaches in the agriculture sector that have been introduced and reviewed by the NGO Practical Action.

I used the following criteria when choosing peer-reviewed articles, books and the two case studies. I sought studies that addressed these issues:

- The correlation between climate change science and Bangladesh, showcasing future scenarios as well
- The effects of climate change on Bangladesh's rice production
- Included arguments about whether Bangladesh should lean towards adaptation or mitigation measures
- Discussed in detail the adaptation schemes established in Northern Bangladesh

The next chapter builds on these ideas to explore observed climate change in Bangladesh, climate change impacts on crop productivity including the impacts of flooding on vulnerable groups of people and the government's policies on climate change.

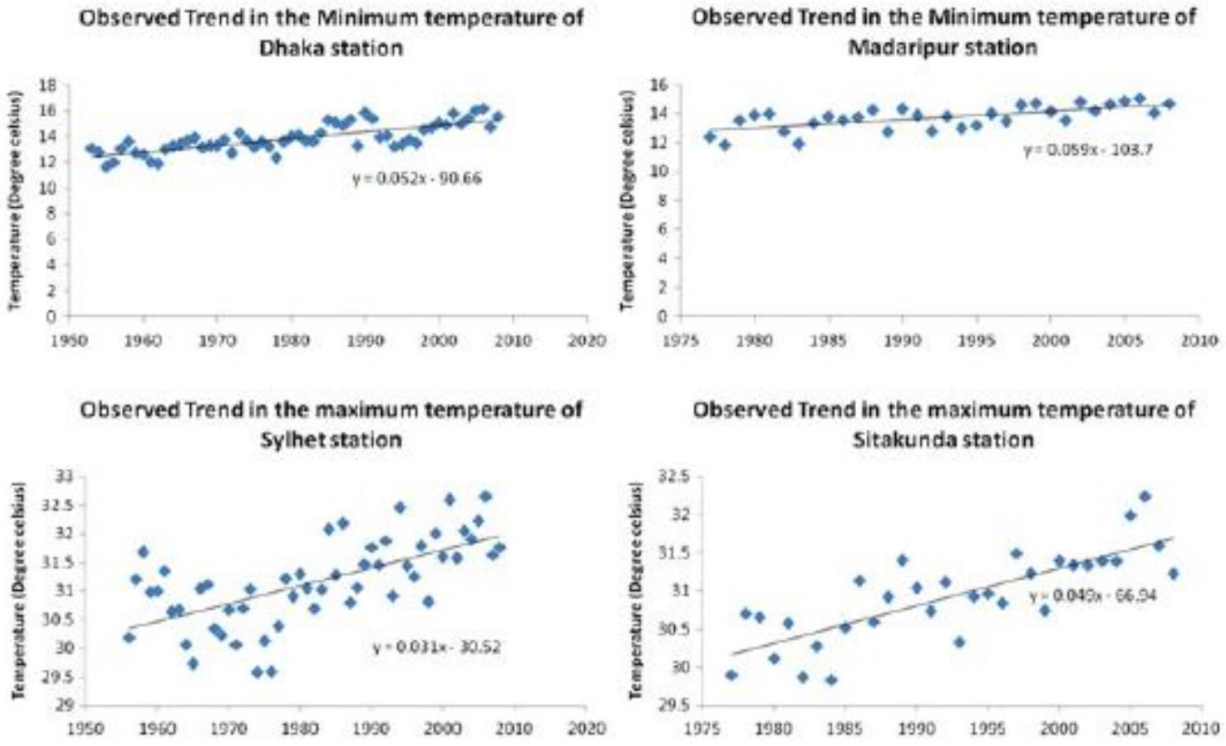
CHAPTER 2: LITERATURE REVIEW

2.1 Observed Climate Change in Bangladesh

Authors Kreft et al, in their recent report 'Who Suffers Most From Extreme Weather Events? Global Climate Risk Index 2017', evaluate to what extent countries are affected by the effects of weather-related loss events including floods, storms, heat waves and others. One of the key findings from their report is that Bangladesh was one of the top ten most affected countries in the world by such events, between 1996 and 2015 (CRI, 2017). However, such findings are no longer a surprise since Bangladesh is now known as the 'ground zero of climate change' (Niazi, 2015). Furthermore, the National Center for Atmospheric Research has estimated that "overall precipitation should rise by about 7% for every 1 degree Celsius of warming" (Henson, pg.69). This prediction would have severe impacts on flooding in Bangladesh, since rising temperatures lead to an increase in precipitation intensity. This occurs because as the oceans warm due to the increased temperatures, the water particles, which are nearer to the surface, gain more energy and evaporate quicker. Since a warmer atmosphere can hold more water vapour, this leads to an increase in precipitation.

There are four seasons in Bangladesh, which are winter (December-February), pre-monsoon (March-May), monsoon (June-early October) followed by post monsoon (late October- November). Researchers Nishat et al (2013) have observed and analyzed data from the Bangladesh Meteorological Department (BMD) over several decades (1970-2010). Overall, they have found that during the past 40 years, winters as well as monsoon seasons are experiencing fluctuating mean surface air temperatures. Specifically, during the winters there is an increase in the minimum temperature by 0.4-0.65 degrees Celsius. There has also been a rise in the maximum temperature during the hot summer months of June, July and August, within ranges of 0.03-0.05 degrees Celsius in Northern regions such as Sylhet, Tangail and Saydpur (Figure 2 below demonstrates these findings in the selected areas). Likewise, during the pre-monsoon and monsoon seasons there have been increases in the maximum and minimum temperatures.

Figure 2. Observed trends of increasing minimum and maximum temperatures in four selected regions of Bangladesh. Source: Nishat et al (2013, pg.17)



The increase in seasonal temperatures is expected to increase the seasonal rainfall. This is very important because Bangladesh already receives 80% of its mean annual rainfall during the monsoon season alone. Specifically, the mean annual rainfall in Bangladesh varies from 1640-2831 mm with an average of 2347 mm. Some of the other notable findings from Nishat et all (2013) are the following: they've found an increase in rainfall in the pre-monsoon season in 30 out of 32 meteorological stations, with a prominent increase in the coastal regions. During the monsoon season, they've found increased annual mean temperatures in 18 out of the 32 meteorological stations with a range of 21-42 mm/year. There has also been an increase in rainfall in the post-monsoon season, which was found in 24/32 meteorological stations, with a range of 12-24mm/year. Another significant finding from their research is that they have observed a decrease in the total number of 'non-rainy' days in more recent years, which indicates that there is an increase in the frequency of precipitation. This trend was found in 26 out of the 32 rainfall

stations. They've also found that along with an increase in seasonal temperatures and seasonal rainfall, there is also an increase in the intensity of daily rainfall; this trend was found in 25 out of the 32 rainfall stations. Overall, their results demonstrate that Bangladesh has been experiencing climate variability over the past few decades and these changes are very likely to get more extreme in the future.

2.1.1 Climate Model Predictions for future Climate Scenarios

There have been considerable numbers of studies, which focus and speculate on future climate scenarios and sea level rise projections for Bangladesh; most of these studies include the use of climate models. As defined by IPCC, a GCM (General Circulation Model) is defined as numerical models, which represent "physical processes in the atmosphere, ocean, cryosphere and land surface, and are the most advanced tools currently available for simulating the response of the global climate system to increasing greenhouse gas concentrations". In a study by Agrawala et al (2003), changes in precipitation and average temperatures in Bangladesh were studied using more than 12 GCMs. The main GCM that they used was the MAGICC/SCENGEN, which is a simple model that "computes the mean global surface air temperature and sea-level rise for particular emissions scenarios for greenhouse gases and sulphur dioxide" (pg.12). This is the principal model, which IPCC also uses to predict different climate change scenarios. The data obtained from MAGICC/SCENGEN for Bangladesh are displayed in Table 1 below. Overall, the results from all the climate models showed an estimated intensification in temperatures for Bangladesh. The results also predicted that there will be more warming over the winter months, compared to the summer months. Specifically, what was found from the simulations was that "the resulting mean annual temperature changes were 1.4 degrees Celsius by 2050 and 2.4 degrees Celsius by 2100" (Winston et al, pg.21).

Table 1. GCM estimates of temperature and precipitation changes

Year	Temperature change (°C) mean (standard deviation)			Precipitation change (%) mean (standard deviation)		
	Annual	DJF[4]	JJA[5]	Annual	DJF	JJA
Baseline average				*2278 mm*	*33.7 mm*	*1343.7 mm*
2030	1.0 (0.11)	1.1 (0.18)	0.8 (0.16)	+3.8 (2.30)	-1.2 (12.56)	+4.7 (3.17)
2050	1.4 (0.16)	1.6 (0.26)	1.1 (0.23)	+5.6 (3.33)	-1.7 (18.15)	+6.8 (4.58)
2100	2.4 (0.28)	2.7 (0.46)	1.9 (0.40)	+9.7 (5.80)	-3.0 (31.60)	+11.8 (7.97)

Source: Agrawala et al (2003, pg.13)

Another extremely important finding from these climate models, which is also demonstrated in Table 1, is the estimated increase in precipitation during the monsoon season, during which Bangladesh already receives 80% of its annual rainfall as previously stated in section 2.1. Specifically, the annual precipitation is expected to increase by 5.6% by 2050 and by 9.7% by 2100" (Winston et al, pg.21). This is predicted to occur because the "air over the land will warm more than the air over the oceans in summer" (Agrawala et al, 2003), which will enhance the low pressure system over land which takes place during the monsoon and as a result create more precipitation. Another distinguished finding from these results is that the increases in summer precipitation over the months of June, July and August are significant; in fact it is higher than the standard deviation across the models. In another study by Tanner et al (2007), they found similar results to that of Agrawala et al. They used similar GCMs to Agrawala et al and found that for the projected changes in temperature by 2050, there will be an increase in average temperatures by 1.6 degrees Celsius with an increase of 4% in the projected rainfall, which is slightly lower than what Agrawala et al had found (5.6%). Overall, "these projected seasonal changes are consistently found across many studies of the South Asian monsoon region" (Winston et al, pg.21).

2.1.2 Sea level rise and Flooding in Bangladesh

In a study by Frihy et al (2003), it has been reported that there is a rise in sea levels of 1.0cm per year in Bangladesh. Their study examined different scenarios and sea level projections for Bangladesh, in which it was estimated that if there is a 25cm rise in sea levels by the year 2050, 4% of the total landmass of Bangladesh will be affected and if there is a rise in sea levels by 1m by the year 2100, then 17.5% of the land mass will be affected which will affect millions of people, since Bangladesh has such a high population. In another study by Winston et al (2010), they used climate simulation models for three scenarios, which were a rise in sea levels by 15 cm, 27 cm and 62 cm for the coastal zones in Southern Bangladesh. They found that "of a total 33,000 km^2 in these coastal areas, over half is annually flooded" and "with an extreme rise of 62 cm, an increase in 10 percent of flooded area is anticipated" (Winston et al, pg.26).

The largest mega-delta region in the world is located in Bangladesh; it is formed by the Ganges-Brahmaputra-Meghna river systems. There are four main types of floods that occur in Bangladesh; river floods; rainwater floods, flash floods and storm induced coastal floods. Over the past decades, Bangladesh has been prone to many severe floods, however the floods of 1988 and 1998 were unique because the rate/occurrence interval of such floods happening was once in 100 years. The damages from floods are severe, for example it has been estimated that in the floods of 2007, there was damage of $1.1 billion USD in losses (Ikeuchi et al, 2016). More recently and according to government estimates, around 61,877 hectares of cropland, mostly rice which is the single most important agricultural product of Bangladesh, were "completely damaged," while 531 million hectares have been "partially damaged" in the floods of 2017 alone (George, 2017). Furthermore, the International Federation of Red Cross and Red Crescent Societies (IFRC) has estimated that more than 1200 people in South Asia (Bangladesh, India and Nepal) have lost their lives due to inundation; overall, it has been estimated that 40 million people were affected in the floods of 2017 (Siddique, 2017). Villagers described the floods of 2017 as the "worst in living memory" (George, 2017).

One of the ways that climate change affects floods, specifically river floods, is that the estimated increase in the intensity and the frequency of the rainfall during monsoon season (which has been discussed in previous sections) will intensify the floods. Rise in sea levels can also cause the water in rivers to rise due to the backwater effect. In the article 'Modeling complex flow dynamics of fluvial floods exacerbated by sea level rise in the Ganges‐Brahmaputra‐Meghna Delta' (2016), researchers define backwater effect as "the propagation of the effect of sea level rise upstream and can be expressed as changes in water levels in the river flow calculation" (pg.2). Other effects of climate change which may occur due to the possible changes in precipitation, temperature and evapo-transpiration are that there will be changes in soil moisture, for example if there is an increase in soil moisture this will eventually lead to an increase in overland flow as well as in physical runoff, which will once again only help to exacerbate the floods (Nishat et al 2013).

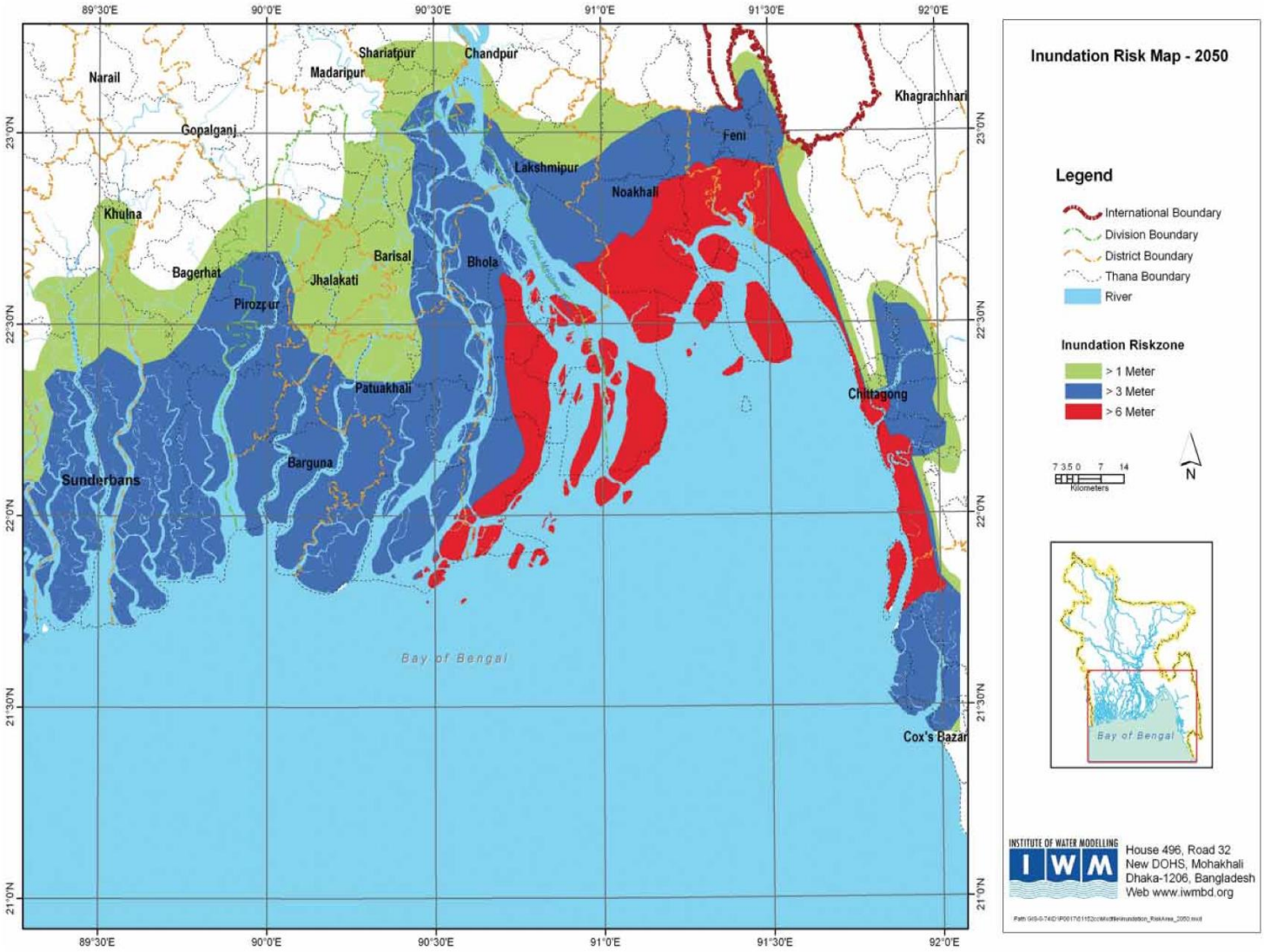
2.1.3 Climate Change induced Cyclones/Storm Surges

Research indicates that there will be a change in the intensity and frequency of cyclones due to climate change in the future. Unfortunately, Bangladesh is already vulnerable to tropical cyclones due to several reasons but mainly because of the country's extreme low topography, which creates an inverted funnel effect. Cyclones usually begin in the Indian Ocean and make their way to the Bay of Bengal. Although the coastal communities are affected very heavily by the Bay of Bengal, it is also important to understand that two-thirds of the whole country is only 5 m above sea level, therefore non-coastal zones will also be affected such as Northern Bangladesh. Storm surge height can range from 1.5 m to an astonishing 15 m in height (Agrawala et al, 2013).

In a study by Dasgupta et al, they discuss scientific evidence that suggests that the increase in sea surface temperatures due to climate change will "intensify cyclone activity and heighten storm surges" (pg.96). As discussed previously in Chapter 1, one of the reasons sea levels are rising is due to thermal expansion as well as due to melting ice caps, which explains why storm surges are expected to increase in height and intensify inundation. In their study, they used simulations of climate change induced storm surges to

get an approximate idea of how much land will be inundated by 2050 in the Southern region of Bangladesh. The methodology of their study was that they developed a climate change scenario using a set of simulations from the cyclones of 1974, 1988, 1991 and 2007. This was conducted because "future storm tracks cannot be predicted with any degree of precision" (pg.100). In order to understand the extent of inundation zones by the year 2050, a 27-cm rise in sea level was integrated into the storm-surge model, along with landfall of cyclones during high tide and a 10% upsurge in wind speed. What the simulation results showed was that "the vulnerable area in coastal Bangladesh with more than 3 m of inundation depth is likely to increase by 69% and that with a 1–3 m inundation depth is likely to increase by 14% due to climate change" (pg. 100). Figure 3 below demonstrates these findings.

Figure 3. High-risk inundation zones in a changing climate in Bangladesh (2050).



Source: Dasgupta et al, 2014

The areas in red are at most risk with inundations depths of > 6 meters, followed by blue zones with inundations depths of > 3 meters followed by the green zones with inundations depths of > 1 meter. Similarly, they also studied the impacts and expected damages of a single cyclone in 2050 in Bangladesh. The main factors, which they took into consideration to be able to assess potential damages, included the projected "annual growth in Bangladesh's coastal population by 1% and GDP by 6-8%" and the extensive damages caused by Cyclone Sidr, which wreaked extreme havoc with wind speeds of 223 km/hour. After studying cyclones that have affected Bangladesh between the years of 1876 and 2009, Dasgupta et al have estimated that a cyclone like Sidr occurs once within 10

years. At the present moment, 26% of vulnerable area is flooded by a 10-year return interval cyclone; this number is expected to nearly double to 43% in 2050 under a climate change scenario. They've also found that the total "additional potential damage from a 10-year return period cyclone in a changing climate is estimated at US $2.437 billion, with US$2.123 billion in added potential losses" in which "damages refer to the potential complete or partial destruction inflicted on assets, while losses refer to the potential flow of goods and services not provided and increased costs of continuing essential services" (pg.101). The GDP per capita of Bangladesh was 1029.60 US Dollars in 2016 (Trading Economics, 2016); therefore, this demonstrates how significant the estimated potential damage sand losses are from a 10-year return period cyclone.

Infrastructure/sector asset	Damage estimate (million US$)	Loss estimate (million US$)
Housing	1947.3	0.8
Education	9.0	835.4
Agriculture	75.4	1084.0
Non-agricultural productivity	87.9	52.7
Roads	239.5	150.0
Power	60.2	
Coastal protection	17.3	
Total	2436.6	2122.9

Table 2. Potential damage and loss from a cyclone-induced inundation in a climate change scenario in 2050. Source: Dasgupta et al, 2014

2.1.3.1.Cyclone Sidr: Case Study

Bangladesh has faced and continues to face some of the most powerful cyclones in the world. During the 1970 cyclone, approximately 500,000 people were killed. More recently on 15th November 2007 Cyclone Sidr, which was a category 4 Cyclone, struck Southwest Bangladesh, causing extensive damage and loss. What was particularly tough for the country as a whole was that in 2007 this was the second natural disaster to strike them. In 2007, they had already faced monsoon floods, which led to "extensive agricultural

production losses and destruction of physical assets, totalling near US$ 1.1 billion" (pg.14, Cyclone Sidr in Bangladesh Executive Summary Report, 2008).

This report found that approximately, 2.3 million households were affected, with a death toll of 3406 people with 55,000 people sustaining severe injures and 1000 people missing. This report, which was created as a joint effort by the Government of Bangladesh and international researchers named The Joint Damage, Loss, and Needs Assessment (JDNLA) calculated that there was a total loss of US$ 1.7 billion, which is around Bangladesh Taka (BDT) 115.6 billion. Table 3 below demonstrates these findings. What is particularly alarming about these findings is that there was a total damage of US$ 437.6 million for the agriculture sector alone. This is very important because agriculture is a huge part of Bangladesh's economy particularly the rice industry, which will be looked on in more detail in Section 2.2.1.

Sector	Sub-Sector	Disaster Effects (BDT Million)			Disaster Effects (US$ Million)		
		Damage	Losses	Total	Damage	Losses	Total
Social Sectors		**4,482**	**1,453**	**5,934**	**65.0**	**21.1**	**86.0**
	Health and Nutrition	169	1,038	1,206	2.4	15.0	17.5
	Education	4,313	415	4,728	62.5	6.0	68.5
Infrastructure		**71,064**	**2,130**	**73,194**	**1,029.9**	**30.9**	**1,060.8**
	Housing	57,915	—	57,915	839.3	—	839.3
	Transport	8,006	1,725	9,731	116.0	25.0	141.0
	Electricity	576	359	935	8.3	5.2	13.6
	Water and Sanitation	157	46	203	2.3	0.7	2.9
	Urban and Municipal	1,696	—	1,696	24.6	—	24.6
	Water Resource Control	4,918	—	4,918	71.3	—	71.3
Productive Sectors		**1,734**	**32,083**	**33,817**	**25.1**	**465.0**	**490.1**
	Agriculture	1,472	28,725	30,197	21.3	416.3	437.6
	Industry	262	2,035	2,297	3.8	29.5	33.3
	Commerce	—	1,258	1,258	—	18.2	18.2
	Tourism	—	65	65	—	0.9	0.9
Cross-Cutting Issues		**420**	**0**	**420**	**6.1**	**0.0**	**6.1**
	Environment	420	—	420	6.1	—	6.1
Total		**79,904**	**35,665**	**115,569**	**1,158.0**	**516.9**	**1,674.9**

Source: Estimates by JDNLA Team.

Table 3. Summary of the damages and losses caused by Cyclone Sidr across sectors. Source: Cyclone Sidr in Bangladesh Executive Summary Report (2008, pg. 15)

2.2 Climate Change impacts on crop productivity

2.2.1 Impacts of flooding on vulnerable groups of people

Authors O'Hare et al define vulnerability as "the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard" (pg.352). One of the most vulnerable groups of people who are affected by floods are the rural farmers of Bangladesh, especially the landless labourers who work on the farms and depend on a small daily wage. Many of these poor labourers migrate from place to place looking for work; this seasonal migration pattern is a way for them to diversify their sources of income and this is also a coping strategy adopted by them, especially after natural disasters strike. These workers often do not own land; they live in small mud houses often in crowded and unhealthy conditions. Many of them live in slums, which are known as '*bosti*' in Bengali.

Similarly, many of these farm workers are women, which makes them more vulnerable in a male dominant society. In the UNEP (United Nations Environmental Program) report 'Women at the frontline of climate change Gender risks and hope', authors Nellemann et al (2011) discuss how women are usually in the frontline in respect to the impacts of climate change. This report states that women are essential for developing sustainable adaptation options "due to their critical knowledge, multiple and simultaneous responsibilities and roles in productive areas" (pg.6), including in the highly important agriculture sector of Bangladesh. During and after natural disasters such as floods, women face greater gender-based violence such as in the forms of sexual harassment. This occurs as many woman and children become separated from their families or orphaned. Also, when the unaccompanied women seek temporary shelter from the floods in either a school (often in rural Bangladesh this occurs) or in cyclone shelters, they may be subjugated to sexual harassment in these insecure places. This report further states that "women experience acute and differential impacts given the accelerated pace of climate change. These impacts exacerbate existing inequalities in socially constructed gender roles, responsibilities, perceptions and skewed power relations that tend to disadvantage women" (pg.7).

2.2.2 Agriculture Sector of Bangladesh

According to the 'Country Programme Document' created by UNICEF, poverty levels have gradually improved in Bangladesh and the growth in rice production has been substantial over the past few decades, mostly due to an increase in rice yields, which have increased from 26 million tonnes in 1995 to 50 million tonnes in 2010. Bangladesh is the fourth largest rice producer in the world with a total landmass of 144,000 $km^{2,}$ out of which rice is harvested on approximately 10.5 million hectares of land. Agriculture is one of the most important sectors in the economy, contributing 19.6% to the GDP (Winston et al, 2010). This sector comprises approximately 65% of the country's labour force with 48% of rural employment (Nishat et al). These facts demonstrate that the economy of Bangladesh is highly sensitive to climate variability, since it can be directly affected by the changes in precipitation, temperature and importantly by carbon dioxide emissions (Lotze-Campen et al).

There is no substantial scale commercial farming in Bangladesh; the majority of the farms follow subsistence farming methods. The majority of the farms are small with approximately 70% of the farms being 2.5 acres or less in size with around 80.3% of the farms being less than 5.0 acres in size (Nishat et al, pg.34). The majority of the farms are undercapitalized and the farmers do not own/have access to mechanized agricultural tools. Overall, there is also a lack of fertilizer, quality seeds and pest control (O'Hare et al). The farmers tend to base their farming decisions on "traditional predictive factors related to flooding characteristics". Therefore, if "their decisions are in accord with natural phenomena, that is if the predictions for the degree and nature of flooding prove to be correct, then there is usually sufficient production for their needs" (Younus, Pg.4).

2.2.3 The uncertain effects of elevated carbon dioxide emissions on crop productivity

There has been a lot of research conducted on how changes in the climate will affect crop productivity because the yield of crops can be both positively as well as negatively affected by climate change. Researchers Lotze-Campen et al (2011) state that yields of most crops increase with increased carbon dioxide emissions. They have found that productivity increases from 15-25% when experiments were conducted using a free air carbon enrichment (FACE) approach for crops such as rice, wheat and soybeans. They have also stated that elevated levels of carbon dioxide improve the water-use efficiency for these crops, known as C3 plants. Furthermore, they state that while many studies agree with such findings using the FACE methodology, other studies have found "much less favourable crop response to elevated carbon dioxide in practice than that asserted on experimental sites" (pg.4). Similarly, researchers Karim et al (1996) calculated that with an increase in temperatures by 2 degrees Celsius there will be a small positive change in rice yields for the year 2050. His study assumed that there was no moisture stress, so the crops would have sufficient water levels along with high levels of carbon dioxide as well, which is similar to the studies conducted by Lotze-Campen. His study also found that an increase of 4 degrees Celsius in temperatures will result in mixed yield changes for rice. Overall, "the magnitude of the positive yield effect due to enhanced carbon dioxide emissions is still uncertain" as many of these experiments "do not address important co-limitations because of the water and nutrient availability" (Crop Adaptation to Climate Change, pg.4).

Another important impact of climate change on crop productivity is the expected droughts. As temperatures increase this can lead to less precipitation during the winter months in Bangladesh. What is likely to occur is moisture stress because the "moisture content of the topsoil would decrease substantially" (Nishat et al, pg.35). Therefore, an increase in temperatures will lead to higher rates of evapotranspiration, which would subsequently lead to 'phenological' drought conditions in the winter months. Such droughts during winter months with consequently affect cultivation of the Aman variety of rice, which grows specifically in November and December. The Aman variety of rice also accounts for more than half of annual rice productions, so it is very important. Earlier

droughts would also have adverse effects on the two other major types of rice grown in Bangladesh, which are namely Aus and Boro.

Another issue that should be highlighted in regards to the impacts of climate change to the agriculture sector is saltwater intrusion, especially in coastal areas such as in Southern Bangladesh. Furthermore, authors Nishat et al argue that more droughts will "increase capillary action and salinity buildup in the top soil" (pg.35). It has been found that annually there is a net reduction of approximately 0.2 Mmt of rice production due to increased salinity in the soil. It has been predicted that due to the increased salinity in soil, there would be massive reductions in Aman rice crops (two fold yield reductions). Another important concern is that due to prolonged periods of flooding and due to sea level rise, there is a reduction in rice cultivating lands for both Aman and Boro rice, this is expected to get much more worse in the future.

2.2.4 The Concept of Creative Destruction

In the article, 'Creative destruction: Analysing flood and flood control in Bangladesh' (2010), author Banerjee studies the notion of 'creative destruction' in "analyzing the effects of riverine floods on agricultural productivity in Bangladesh". She describes the theory of 'creative destruction' as a process "that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one" and also as a "permanently unsettled rhythm of creation and destruction" (pg.103). She argues that particularly in disaster studies, this idea is often used to address the direct effects of disasters on several economic variables for example on employment growth, total factor productivity and capital accumulation. What is rather thought-provoking is her main argument that while disasters destroy a lot of assets including entire industries, as well as physical capital stock in a country, which causes a fall in productivity in the short run, she claims that despite this decline, "they also provide an impetus for absorption of modern and more up-to-date technology, and/or an update in factor composition, thus creating the opportunity for greater efficiency in the long run" (pg.103).

In the agricultural context of Bangladesh, Banerjee bases her ideas using Schumpeter's (1961) research, that in the ensuing cycle of creation and destruction, individuals and families rise and fall economically and socially and the people affected by change face a lot of struggle as well as loss of tradition, since now they have to continually find new means of survival. However, it is also important to remember that the economic changes that occur after such changes, affect the communities unevenly. The author discusses how the concept of creative destruction is exercised to study the effects of floods on agricultural productivity in Bangladesh, especially on the rice cultivation. She studies this correlation by looking at it not only as a threat but also as a generating factor for output growth.

Her research methodology includes a quantitative as well as a qualitative approach. She began her research by identifying the rice productivity for each district in Bangladesh from the time periods of 1978-2000, which was measured in metric tons per hectare of land. She looked at the three main varieties of rice grown in Bangladesh: *aus, boro* and *aman, which* have been discussed in the section above. Over this timeframe of twenty-two years, she identified three 'disaster years', which were 1987, 1988 and 1998. A disaster year is defined as when "35 percent or more of the total area of Bangladesh is submerged under standing water of a depth of 180 cm or more for a continuous period of three weeks or more" (pg. 105). The author used this definition from the Bangladesh National Water Plan, which was founded in 1986. After graphing her collected data of the annual rice productivity using a linear trend (Figure 4 below), the results show that between 1978-2000, the average annual productivity of rice has risen, but in the disaster years of 1987 and 1988 major shortfalls occurred and productivity levels fell. However, what is interesting to note is that in the disaster year of 1998 productivity was comparatively high.

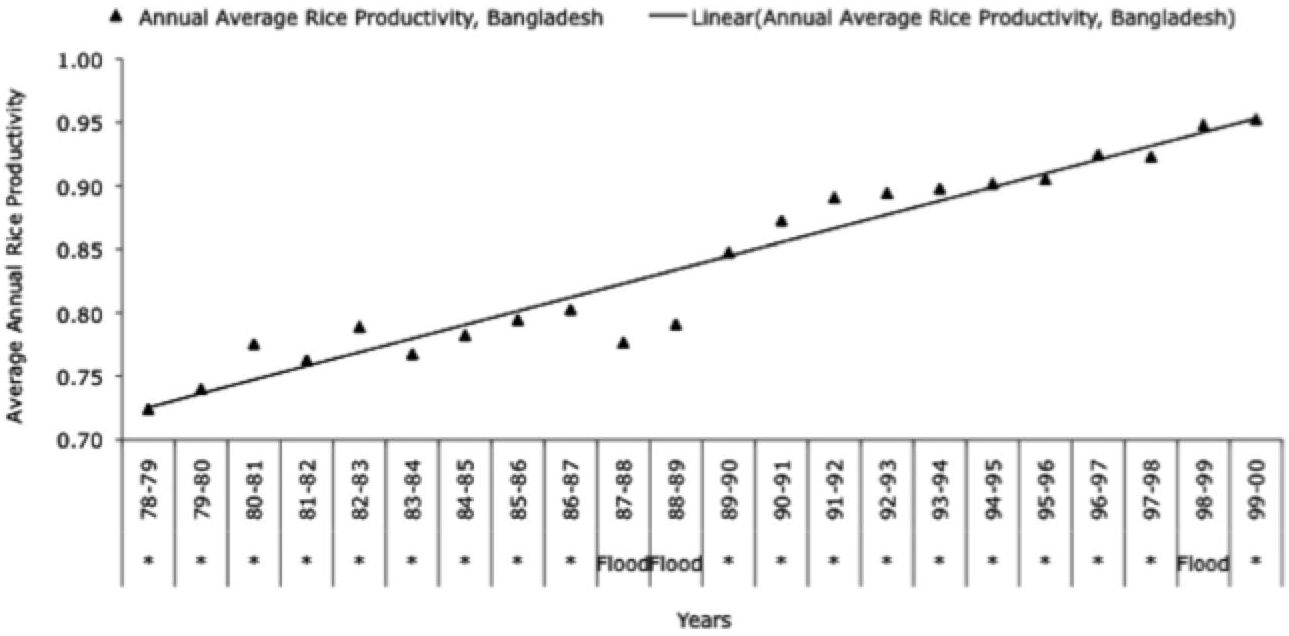


Figure 4. Annual average rice productivity, Bangladesh: trend (linear) (1979-2000), and fluctuations in disaster years (1987, 1988 and 1998)

Source: Banerjee (Creative destruction: Analyzing flood and flood control in Bangladesh, 2010)

One shortcoming of this article is that the author did not explicitly state why productivity levels of rice were higher in 1998. Similarly, in the article 'Averting a food crisis: private imports and public targeted distribution in Bangladesh after the 1998 flood' (2001), authors Nino and Dorosh state that there was a peak in the harvest of *boro* rice in mid-1998, however the devastating floods ultimately resulted in a loss of 2.2 million tons in rice production, which threatened the food security of tens of thousands of households. The authors also discuss that even though this flood did not lead to famine, it still resulted in crop shortages and a sharp hike in rice prices.

Another noteworthy finding from Banerjee's research is that despite the fact that *boro* rice has a high yield rate, only 34% of land under rice cultivation is devoted to it, whereas 54% of the land is devoted to the *aman* variety. Therefore, she argues that there should be much greater emphasis placed on growing *boro* rice for overall agricultural growth in Bangladesh. This makes one question how come the farmers are not doing so already? The answer lies in the fact that costs of production are higher for *boro* crops as they require

additional and therefore costly inputs such as fertilizers, pesticides as well as a much higher amounts of irrigational water, since *boro* rice grows in the post-monsoon dry season compared to the *aman* crop, which grows in the wet-monsoon season. Therefore, for a poor farmer, growing *boro* rice is not a feasible option, as it is "closely tied to his purchasing power" (pg.109). Consequently, the poor farmers suffer much more and are also much more at risk compared to rich farmers because they invest in cheaper wet-season rice. Such types of rice are much more easily destroyed leaving the poor farmers with greater losses and facing greater disparity.

2.2.5 Agricultural technology Adoption

Author Mendola (2007) in her article 'Agricultural technology adoption and poverty reduction: A propensity-score matching analysis for rural Bangladesh' investigates how enhancing agricultural technology in the form of adopting high yielding varieties (HYVs) of rice can directly alleviate poverty levels in Bangladesh. This is a notable study in comparison with Banerjee's work, because in her research she has highlighted how poor and vulnerable farmers face more risks and subsequent loss from flooding, whereas this study focuses more on a detailed examination of the situation "through an empirical investigation of the relationship between technological change, of the Green Revolution type, and wellbeing of smallholder farm households in two rural Bangladeshi regions" (pg. 372).

Mendola states that on a global scale, agricultural growth using methods such as irrigation and area expansion has already become a 'minimal source of output growth'. Therefore, she argues that high-yielding technological change is the way to go for enhancing agricultural growth. Her study took more of a quantitative approach in which she used data from eight villages from two rural areas of Bangladesh. She wants to see if yield-increasing technological change can directly contribute to poverty reduction. This makes her research stronger as she is filling in a gap, since there has already been much attention to the indirect effects "given high levels of functional landlessness in South Asia" but "they do not explicitly point to a causal effect of agricultural technology adoption on

farm household well-being, or, in other words, they fail to establish an adequate counterfactual situation and identify the true causality of change" (pg. 373). So, she argues that a researcher should certainly take into consideration a counterfactual situation, which is to assess what would have occurred in the situation if the technology had not been applied. Besides her research taking a counterfactual framework approach, one of her main questions leading her research was 'does technological adaptation increase household income?'

The eight villages were chosen specifically "to provide a representation of the six main rice-cropping patterns in Bangladesh" (pg.380). Half of the households selected were small and medium-scale farmers. Out of the 2562 surveyed households, she found that 1113 were adopters of HYVs (High yielding varieties) of rice and 1449 were non-adopters. What is a very interesting finding from her research is that the educational level of the head of the household did not differ between the two groups. The percentage of households with the family head's educational level equal to the primary level or more was 9.4% for non-adopters and 9.8% for adopters (see Table 4 below). Therefore indicating that education did not play a large role in the decision to adopt or not adapt to the HYVs.

Another noteworthy finding is that households who had access to the new technology and adopted it had more 'institutional assets', which included whether they were members of an NGO and/or 'average number of loans ever taken from an NGO' (see Table 4 below). Similar, to Banerjee's findings, Mendola found that adopters of HPVs seemed to have much higher income. She found that an average income is 30% higher for adopters than non-adapters and the average annual gross crop-income (per consumption unit in USD) was 112.1 for adopters, whereas it was only 52.8 for non-adopters. Banerjee explains in further "Broad-based spread of the technology could not be achieved in the presence of pre-existing inequalities in income distribution of the potential beneficiaries. As a result, the creative effects of technologies and resources were unequally distributed" (pg.113).

Table 4. Characteristics of adopters and non-adopters: summary statistics

	Non-adopters	Adopters	Difference (%)
Number of observations	1449	1113	
Human assets			
Adults male (above 14 years old)	1.9	1.7	−11*
Adult female (above 14 years old)	1.6	1.4	−13*
Children (below 14 years old)	2.7	2.06	−24*
Average family size	6.4	5.1	−20*
Relative subsistence pressure (amount of land owned per adult male equivalents)	0.26	0.29	12
Labour availability (number of adults male equivalents)	3.3	2.8	−15*
Labour abundance (labour availability per acres cultivated)	3.9	2.6	−33*
Average age of household head	46.1	42.2	−8*
Education (percentage of households with the head's educational level equal to the primary level or more)	9.4	9.8	4
Land assets			
Average land productivity (gross value of output (Tk) per acre operated)	6016	8817	47*
Average owned land (acre)	0.884	0.887	0
Average cultivated land (acre)	1.8	2.3	28*
Percentage of area irrigated	26.7	65.9	147*
Percentage of temple land – *sharecropping*	5.8	16.1	178*
Percentage of rented-in land – *pure tenants*	1.6	1.8	13
Percentage of mortgaged-out land	11.1	7.5	−32*
Tenure security (percentage of own land over total cultivated land)	52.6	33.6	−36*
Average number of farm equipments	0.3	0.5	67*
Percentage applying modern irrigation	5	44.6	792*
Institutional assets			
Percentage ever member of an NGO	11.9	41	245*
Average number of loans ever taken from NGO	0.3	1.7	467*
Percentage of households self-assessed in food deficit (occasionally or chronically)	46.6	37.8	−19*

* Indicates that difference between adopters and non-adopters is statistically significant at 95% level (*t*-test are used for differences in means).

Source: Mendola (2007, pg.382)

Overall, both scholars agree that due to the low income and therefore a low purchasing power of rural farmers, they are at a higher risk and face more damages due to flooding in Bangladesh every year. However, there is evidence that the use of modern high-yielding seed technology increases rural incomes, and therefore alleviates poverty levels. In Mendola's research, she explicitly claims that there is substantial potential for "increasing rural incomes through the diffusion of modern farming technology" (pg. 390) since she has found a positive correlation between adopting modern high-yielding seed technology and a reduction in poverty for rural farmer households. Therefore, the government needs to enhance the role of agricultural technology in not only anti-poverty but importantly in climate change adaptation policies in rural areas. Moreover, Banerjee discusses that if poverty levels can be reduced then such farmers can shift to using high yielding varieties of rice such as *boro,* which can lead to a bumper harvest in the post-monsoon dry season.

Overall, this can lead to more stakeholders benefitting from the “creative impetus” (pg. 113).

2.3 Government Policies on Climate Change

2.3.1 Adaptation vs. Mitigation: A divisive approach to handling Climate Change

As previously mentioned, O’Hare et al (2005) argue that sustainable development along with raising adaptive capacity is the key to reducing vulnerability. There are two contrasting views on how this can be done. The first viewpoint is a top-down approach known as mitigation, which incorporates the use of structural and large engineering works. The second and more modern viewpoint, which started gaining popularity in the mid-1980s, is adaptation, which is a bottom-up approach that considers community action, participation and self-empowerment.

Authors Alam et al discuss these two extensive response strategies to climate change (Adaptation to Climate Change in Bangladesh: Future Outlook) in detail. They define mitigation as “actions that are aimed at preventing or retarding greenhouse gas (GHG) emissions” and adaptation as “any adjustment - passive, reactive, or anticipatory - that can respond to anticipated or actual consequences associated with climate change" (pg.125). They explore the notion that mitigation can reduce the rate of climate change but this does not imply that it can stop it from occurring at all. Furthermore, they state that adaptation options especially for a developing country like Bangladesh help to reduce “vulnerability to some extent” (pg.125) and also by implementing adaptation measures there is an increase in resilience capacity, which can be defined as the ability of a community to withstand disasters (Chen et al, 2008).

What is interesting to note is that there is some confusion around the term ‘adaptation’, which must be addressed. Authors Shaw et al (2013) in their book ‘Climate Change Adaptation actions in Bangladesh’ argue that the reason that this term is not so well understood by the general public is because the same word refers to “the process by which organisms naturally adapt over time to survive in a new environment” (pg.7). Furthermore, they argue that research shows that “the rapid rate of climate change is expected to

outpace the capacity of many organisms in this classical sense" (pg.7). Moreover, there are two ways that adaptation is vital to climate change. Firstly, it assesses the vulnerabilities and impacts of climate change and secondly it is highly related to the development of response options.

Shaw et al state that adaptation to climate change will go a longer way than just mitigation because when communities learn to adapt to climate change, they become resilient societies. Another reason that adaptation to climate change is highly important is because despite cutting down on green house gases via mitigation measures, there is still an expected increase in not only global temperatures but also in extreme climate events. This is something that authors Alam et al have regarded and taken into consideration as well. Thus, as a result and despite mitigation measures sea levels may keep rising. Therefore, it is very important that there is a continuous effort especially in developing countries such as in Bangladesh to enhance and build adaptation strategies.

Author Erickson, in his article 'Socio-economic implications of Climate Change for Bangladesh', discusses these two principal yet opposing approaches for dealing specifically with flooding in Bangladesh as well. He studied six flood-control and irrigation projects and found that despite the benefits some of these mitigation projects have brought forward, mainly by protecting infrastructure and property against flooding, they have also created nuisance and trouble amidst the different stakeholders in the local Bengali communities where they were established. Furthermore, some of these projects became unsuccessful due to embankment cuts, failures or due to "greater than standard levels of flooding" (pg.13). Therefore, similar to the ideas of authors Alam et al and Shaw et al (2013), Erickson too claims that "a better approach is to build on the ability of Bangladeshis to cope with, and recover from flooding" since "it is technically and economically infeasible to prevent abnormal flooding, and embankments would create as many problems as they solve" (pg. 13), thereby supporting adaptation as well.

Author Brammer (2010) in his article 'After the Bangladesh Flood Action Plan: Looking to the future' discusses how mitigation measures especially in the form of building embankments along the main rivers in Bangladesh was one of the key objectives of the Flood Action Plan (FAP) that the government of Bangladesh proposed nearly 27 years ago.

The multi-dimensional 'Flood Action Plan' was developed after the catastrophic floods of 1987 and 1988 in Bangladesh; it was based on prior projects by UNDP, USAID and JICA (Japan International Cooperation Agency). The main objective of the FAP was to establish a long-term protection plan and find solutions for all the flood related issues and create effective management of land and water control in Bangladesh. Some of the specific goals out of the eleven guiding principles of the FAP were the following; to protect rural infrastructure, to build structures such as embankments to protect areas from flooding, to increase flood awareness and to improve flood preparedness by establishing early warning and flood forecasting systems, "reduction of flood flows in the major rivers by diversion into major distributaries and flood relief channels" (FAP, Banglapedia), to create floodplain zoning in appropriate areas and to synchronize effective planning of roads as well as railroads with the embankments, this was planned to ensure well drainage of floodwaters. Another important principle of the FAP was that it proposed to include as much participation as possible from the local people and to specifically include them in the "planning, design and operation of flood control and drainage works" (FAP, Banglapedia). This was done as an attempt to gain their support, since they would be the beneficiaries.

Funding was provided for the FAP by a total of 15 donor countries, in which the World Bank acted as the coordinator of funds. Since the estimated cost of the FAP was high, at around $155 billion USD in construction costs and $5-$10 billion USD in maintenance costs, the plan was heavily criticised by not just the foreign donors but by the Bangladeshis as well. One of the major critiques of this financial plan was that Bangladesh was not wealthy enough to keep up with the maintenance costs of the embankments, which would include many additional costs such as workers wages.

Ultimately, the FAP, along with its mitigation measures, was not successful and its objectives were not met. It had continued to face much criticism due to its extensive floodplain intervention and lack of public participation (Khan, 2008). Unlike the previous authors mentioned and despite the failure of the FAP, Brammer argues for mitigation especially in the form of structural methods to control floods in Bangladesh. He states that even though large-scale projects that were proposed (such as those by FAP) did not work in the past, this does not imply that mitigation measures should not be considered at all. He

argues that flood proofing of both urban and rural areas are needed to reduce the impacts of floods. For example, embankment levels should be raised because by doing so major road and rail communications would become flood proof. He also states that the government should provide sufficient funds for the upkeep of these structures (pg.128).

2.3.1.1 An Integrated Approach

Ayers et al (The Value of Linking Mitigation and Adaptation: A Case Study of Bangladesh, 2008) provide a different approach to this issue. They discuss how until very recently mitigation and adaptation have been studied separately in both climate change policy and science. They argue that adaptation is given more importance in the global South since their vulnerability is high and mitigative capacity is lower then that of developed nations. They also discuss how mitigation is usually seen as a better option for such developed nations. However, they debate that this view has "hindered progress against the achievement of the fundamental sustainable development challenges of climate change" (pg.753). They further explain that an integrated approach of both methods could be beneficial because by doing so this has the potential to bridge the gap "between the development and adaptation priorities of the South and the need to achieve global engagement in mitigation" (pg.753). They investigate this concept through a case study analysis of climate change policy in Bangladesh.

Moreover, they discuss that one of the ways to break down the conceptual divide between mitigation and adaptation is by understanding the synergies between them. They state that there are benefits to linking these two approaches. For example, by doing so the short-term benefit would be that some fiscal and corporate support could be directed towards adaptation (which is currently administered for mitigation). Ayers et al claim that this would be a 'win-win' solution, because both approaches would be given attention. The other benefit they discuss is that by connecting these two approaches it would "empower the adaptation agenda within the international climate change frameworks. In addition, this will increase the relevance of mitigation for the most vulnerable developing countries, moving beyond the perception of mitigation as an issue only for the North" (pg. 757). Overall, the ultimate goal of both mitigation and adaptation are the same, which is to

reduce the impacts of climate change. Furthermore, both of these approaches are connected in the climate system, and this is a very important concept, because the more effective mitigation methods that are established now, the less the need there will be in the future for adaptation (Ayers, 2008).

2.3.2 Implementation of The National Adaptation Program of Action (NAPA) and Bangladesh Climate Change Strategy Action Plan (BCCSAP)

Overall, all the authors debating whether Bangladesh should lean towards adaptation, mitigation or both of these approaches to combat climate change have made reasonable and valid points. However, it must be kept in mind that Bangladesh is one of the poorest countries in the world and the government does not have sufficient resources to build and maintain large structural engineering works, which are part of mitigation. As shown in the past, the massive Flood Action Plan was a disaster and eventually its objectives were not met. Ultimately, in 2005 Bangladesh was one of the first countries to submit a National Adaptation Programme of Action (NAPA) to UNFCCC, which was developed by the Ministry of Environment and Forest. The NAPA was prepared in consultation with a wide range of stakeholders ranging from local heads of government, scientific researchers, healthcare workers, NGOs and importantly local people including women. Participation from such a diverse group of individuals was possible due to several workshops that took place, which included one national and four sub-national workshops. Issues raised from these consultations revealed the impacts of climate change that the whole nation has been facing. These issues which included more frequent floods, storm surges, droughts, rise in temperature, salinity intrusion have been discussed in Section 2.1 of this research paper. In terms of crop productivity and climate change, the NAPA's final report placed great emphasis on the fact that climate change induced challenges will lead to significant yield reductions in the agriculture sector of Bangladesh (pg.15). Furthermore, the NAPA suggested fifteen future adaptation strategies; a few of them are mentioned in Figure 5 below.

Several Adaptation Strategies by NAPA

- "Capacity building for integrating climate change in planning, designing of infrastructure, conflict management and land-water zoning for water management institutions
- Climate change and adaptation information dissemination to vulnerable community for emergency preparedness measures and awareness raising on enhanced climatic disasters.
- Inclusion of climate change issues in curriculum at secondary and tertiary educational institution
- Development of eco-specific adaptive knowledge (including indigenous knowledge) on adaptation to climate variability to enhance adaptive capacity for future climate change.
- Promotion of research on drought, flood and saline tolerant varieties of crops to facilitate adaptation in future
- Adaptation to agriculture systems in areas prone to enhanced flash flooding in North and Central Region"

Figure 5. Adaptation Strategies. Source: NAPA Final Report (2005, pg.16)

The Bangladesh Climate Change Strategy Action Plan (BCCSAP)

More recently, in 2009 the Bangladesh Climate Change and Action Plan (BCCSAP) was developed. This plan was unique because the Government of Bangladesh itself funded it using the Bangladesh Climate Change Trust Fund (BCCTF), while Bengali scientists undertook the research. The International Monetary Fund Report on Bangladesh (2016) states that it was the first developing country to establish its own trust fund. Similar to the NAPA, this plan was also developed through a consultation process with a diverse array of individuals and stakeholders. In 2010, there was another fund established in Bangladesh known as The Bangladesh Climate Change Resilience Fund (BCCRF) to support NGOs "in the implementation of community-based adaptation, enhancing local innovation and the capacity of vulnerable people and local government institutions" (IMF report, pg. 11). The difference between BCCTF AND BCCRF is that donor countries funded the latter. Since, the implementation of the plan nearly a decade ago the government has "invested well over half a billion dollars of its own money in literally hundreds of actions to tackle climate change by both the government and civil society" (Huq, 2018). This demonstrates that

despite being one of the poorest countries in the world, climate change is being taken very seriously by the people of Bangladesh as well as by the government. Overall, this plan was based on six key pillars, which are listed below:

Key Pillars of BCCSAP

1. Food security, social protection and health
2. Comprehensive Disaster Management
3. Infrastructure
4. Research and Knowledge Management
5. Mitigation and low carbon development
6. Capacity Building and Institutional

Figure 6. Six Key Pillars of BCCSAP. Source: BCCSAP Final Report (2009, pg. 17)

Although adaptation was the key focus of this plan, lowering carbon emissions, which would fall under mitigation measures, was also added to this action plan after some debates. Saleemul Huq (director of ICCCAD) argues that it was not necessary to include mitigation measures in this plan because as a developing country Bangladesh emits low levels of greenhouse gases. He further states that albeit unnecessary, this was still a "remarkable feature of the BCCAP" and that "we felt it was our moral obligation to reduce emissions if we can" (Updating BCCSAP, 2018). Huq discusses how over the past decade, since the development of the BCCSAP, this plan has "achieved the purpose of mainstreaming climate change into national and sectoral development planning" (Huq, 2018). He argues that after a decade it is now time to revise this plan as it was "always envisioned to be a living plan" (Updating BCCSAP, 2018). His four key recommendations are listed in Figure 7 below.

Four Key Recommendations to revise the BCCSAP

- "Include climate change as an element in all relevant development plans, projects and investments" in the future in national and sectoral planning
- "We need to enhance the emphasis and investments in developing good Monitoring, Evaluation and Learning (MEL) systems to be able to demonstrate what we are doing and learn lessons while also be able to measure the outcomes more systematically than we have done so far"
- "We need to recognize the reality of a warming world that is already causing loss and damage due to anthropogenic climate change and hence mitigation and adaptation are no longer sufficient strategies by themselves. We now need to find ways to compensate the victims of anthropogenic climate change"
- "The revised BCCSAP should also focus on international diplomacy which goes well beyond merely sending a delegation to the annual conference of parties of the United Nations Framework Convention on Climate Change (UNFCCC). We should embed climate change in our normal diplomacy both at bilateral and multilateral levels."

Figure 7. Four Key Recommendations to revise the BCCSAP. Source: (Updating BCCSAP, 2018)

2.3.2.1 Adaptive Capacity

As discussed above, one of the adaptation strategies by BCCSAP was to build capacity. There are several ways in which the vulnerability of a group of people prone to climate change can be reduced, thus increasing their adaptive capacity, which can be defined as "the potential or ability of a system, region or community to adapt to the effects or impacts of climate change" (Shaw et al, page.9). There are several socioeconomic determinants that affect how high or low adaptive capacity can be for a certain group of people in a region, factors such as technological conditions that will either hinder or facilitate the placement of adaptive measures in a specific region. Authors O'Hare at al (2005) have discussed some other important factors that adaptive capacity of a system depends on, which are the "severity of the climate change in relation to the mean and the extremes and the vulnerability of the system" which is also "a reflection of the inherent ability of the system to cope with the climate hazards" (pg.352). Similar to the ideas of Shaw et al, authors O'Hare et al have also discussed how adaptive capacity depends heavily on the technical resources. Authors O'Hare et al (2005) state that increasing adaptive

capacity of a community is equal to “those promoting sustainable development” which he defines as “the wise or optimal use of local resources by a community so that its long term standard of living can be raised and sustained” (pg.353) for poor communities such as the rural farmers living in North-western Bangladesh.

The next chapter builds on these ideas to explore local grassroots level adaptation measures in the agriculture sector in Bangladesh, with an in-depth focus on two adaptation case studies.

CHAPTER 3: Local grassroots level adaptation measures in the Agriculture sector and Case Studies

3.1 Autonomous Adaptation

Given the risks and impacts of climate change that have been discussed in the previous sections, the dire need to adapt to these risks in order to steady economic growth and lower poverty rates is strong. The NAPA also highlights the urgent need to implement adaptation schemes immediately because "delay to start adaptation measures could increase vulnerability, or lead to increase cost of adaptation at a later stage" (pg.19). Households in Bangladesh have already had to adapt to such risks for many years in order to save themselves. Author Younis in his book 'Vulnerability and Adaptation to Climate Change in Bangladesh' (2014) describes such adaptation as 'autonomous adaptation' which is defined as when "crop cultivation is automatically carried out by farmers and mostly depends on nature" and that "farmers with land prone to annual inundation have developed strategies for dealing with floods which exceed the tolerance levels of their crops" (pg.3). He further discusses how the concept of autonomous adaptation is the opposite of 'planned adaptation' since they are not planned by the government but rather by individual farmer households. As discussed in the book 'Climate Change risks and Food security in Bangladesh' by Winston et al (2010), "the nature of these adaptations and the determinants of success depend on the availability of assets, labour, skills, education and social capital". It is further stated that the "relative severity of disasters has decreased substantially since the 1970s, as a result of improved macro-economic management, increased resilience of the poor and significant progress in disaster management" (pg.1).

Authors Winston et al state that diversifying household income sources is an important component of adaptation, which is possible because adaptations can focus not just on increasing crop productivity but also on other factors like such as "improving irrigation efficiency of expanding water supply, crop diversification and intensification" (pg.89). One great aspect regarding the agriculture sector in Bangladesh is that there is constant and active research in developing technology and innovating flood resistant rice varieties. Some of the main bodies of research stem from the Bangladesh Agriculture

Research Institute (BARI), Bangladesh Rice Research institute (BRRI) and from the Bangladesh Agriculture University (BAU). The Bangladesh Disaster Management Bureau along with the Department of Agriculture Extension (DAE) carry very ardent roles in such research. There is also another important department known as the Department of Agricultural Information Service (AIS), which is instrumental in preparing materials on specific technologies (pg.83).

Some of the flood-proof varieties of rice that BRRI has developed are the following: BR 11, 20, 21, 22, 23 and 24. What is special about these flood-proof varieties of rice is that they are not damaged by the floodwaters, because they can survive after being submerged by floodwaters for more than ten days. More specifically, some of these flood-proof varieties of rice have been crossbred with a gene known as SUB1, this helps preserve the rice because it prevents it from growing while it is submerged underwater. Not only is it important for these institutes to innovate such flood-resistant varieties of rice, but it is also important to develop saline-resistant varieties of rice, especially for Southern Bangladesh around the Bay of Bengal where after floods the saline water from the Indian Ocean mixes with freshwater. Saline water intrusion is also a key concern for Southern Bangladesh due to rising sea levels. However, notwithstanding such inventions, authors Winston et al state, "poor adoption of technologies and innovations can be common. The current large gap between actual and potential yields suggests substantial on-farm opportunities to increase incomes and production" (Winston et al, pg.83). Table 5 below demonstrates adaptation options in the agriculture sector in Bangladesh.

	Adaptation Option
1	Zero or minimum tillage to cultivate potato, aroid and groundnut with water hyacinth and straw mulch
2	Zero-tillage cultivation of mashkalai, khesari, lentil and mustard
3	Modified sorjan system (zuzubi garden) with vegetable cultivation in char land
4	Floating bed vegetable cultivation
5	Cultivating foxtail millet (kaon) in char land
6	Parenga practice of t. aman cultivation system
7	Relay cropping of sprouted seeds of aman rice in jute fields
8	Raising vegetables seedlings in polythene bags homestead trellises
9	Zero-tillage maize cultivation
10	Chickpea cultivation using a priming technique
11	Supplementary irrigation of t. aman from mini ponds
12	Year-round homestead vegetable cultivation
13	Pond-water harvesting for irrigation to cultivate rabi vegetables
14	Sorjan system for cultivating seasonal vegetables, fruits and fish

Table 5. An overview of adaptation options available in the agriculture sector in Bangladesh. Source: Winston et al (2016, pg.84)

3.2 Introduction of Floating Gardens in Gaibandha District of Northern Bangladesh by Practical Action (NGO)

Practical Action (PA) is a well-known international NGO that has been working in Bangladesh for many years; they are based out of the UK. PA was one of the pioneer NGOs to introduce the concept of floating gardens in the Gaibandha District in Northern Bangladesh. They have been working with local communities "to develop ways of allowing farmers to grow food on flooded land, using a process of community-led identification and prioritization of natural resource management options and technologies" (Ayers et al, pg.6). However, *baira* cultivation, (floating gardens) is not a new adaptation technique against flooding to improve food security as well as to provide much needed income for the poor farmers in Bangladesh. Typically, *baira* cultivation has been an age-old technique used primarily in the Southern coastal regions of Bangladesh. But, as flooding has become much more intense over the past few decades and land is being submerged for about 7-8 months (Pavel et al, 2014), it impossible to cultivate crops using usual methods. Therefore, this form of hydroponics has been introduced to the Northern regions of Bangladesh as well,

such as in the Gaibandha and Sunamganj districts. Many of the Northern districts are comprised of wetlands, known as *haor* in Bengali. The Gaibandha region is approximately two hours away from the Bogra District in which I have conducted my telephone interviews; this will be described further in Chapter 4.

Hydroponics can be defined as "a method of growing plants without using soil (i.e., soil less). This technique uses a mineral nutrient solution in a water solvent, allowing the nutrient uptake process to be more efficient than when using soil. There are several types or variations of hydroponics" (Maximum Yield). Authors Pavel et al (2014), state that there are many socio-economic and ecological benefits that stem from this method all year around, not just during the monsoon season. Importantly, these floating gardens are inexpensive to build and to maintain, as they require little investments, only in terms of seeds and fertilizer. Additionally, the aquatic weeds (known as water hyacinth) that are a vital component in building these gardens can be obtained for free, since they grow abundantly in the flood prone areas. Other substitutions for building the base of the raft are paddy straw, coconut straw and bamboo (Floating Gardens Technique, Practical Action). Another advantage of using baira is that after a year, which is how long they typically last, they are decomposed and used as fertilizer to boost crop productivity during the dry season (Ayers et al, 2009). Another advantage of using baira, is that tree saplings can be grown on them and later sold to generate supplementary income. Additionally, the baira rafts are flexible because they can be floated from place to place. The most suitable areas to build the rafts are ponds, flooded land and wetlands. Any water body that has tides and currents can damage baira therefore it is not a feasible option. However, a disadvantage to this hydroponics method is that heavy rainfalls can wash away the seeds before they get a chance to germinate. Also, if substantial rainfall occurs after germination, there is potential to damage the vegetables being harvested.

Nevertheless, despite the rainfall more than 20 varieties of vegetables are grown on baira, such as spinach, cucumber, onions, garlic, okra, and different types of gourd (bottle, sweet and bitter), chillies and aubergine. Spices such as turmeric, which is a key ingredient in the majority of Bengali dishes, can also be grown. The produce is sold in open-air local markets known at *hut*. The following figure from Winston et al (pg.90) explains how a floating garden is built.

Steps in building a Floating Garden

- Make a bamboo frame of 10m long and 1m wide on water near the land and fix the location with a bamboo pole;
- Add floating piles of water hyacinth within the bamboo frame and repeat several times at five to seven day intervals on the same piles until a heavy floating bed (about 60cm thick) is made;
- Mix seeds of the vegetables to be planted in a proportionate quantity, mix with soil and broadcast on the floating bed after five to seven days of application of fertilizers;
- Single crop vegetable seeds with recommended spacing may be sown on the floating bed;
- In a few days the seeds will germinate and grow;
- Apply a little urea depending on the growth of the vegetables;
- Continue to harvest the vegetables by thinning to allow the remaining seedlings to grow.
- When the water recedes the bed will touch the ground and the gourd plants will take root on the field and start fruiting.
- When the bed is about to touch the ground other winter vegetables like cabbage, cauliflower etc. can also be planted on the bed ahead of the scheduled planting date and can be grown as a field crop with some fertilizer as needed.

Figure 8. Steps in building a Floating Garden
Source: Climate Change risks and food security in Bangladesh (Winston et al, pg.90)

3.2.1 Case Study: An Economic Evaluation of Baira in Northern Bangladesh

Researchers Pavel et al have conducted a cost-benefit analysis study of baira cultivation in 2014, which was carried out in the Sunamganj district in Northern Bangladesh. Large sections of this region are wetlands, with annual precipitation being as high as 3334 mm. Approximately 73% of the residents living in Sunamganj work in agriculture with 92.47% of the arable land being used to produce single crops. The majority of the crops harvested are vegetables and paddy. For their research, 30 farmers were randomly chosen with 27 male and 3 females. The chosen participants cultivated vegetables on baira and they were interviewed using a semi-structured questionnaire. Direct observation was also utilized as another research method. For one week a month, for a total period of four months data was collected on the following issues: “details of

preparation of the floating garden, materials used to construct it, time taken for each activity, labour, seed, other cost of preparation, type of vegetable produced, crop harvested, amount of production, gender roles and final use of crop (subsistence or sale)" (pg.263). Other participants represented different stakeholders such as agriculture officers from the Ministry of Agriculture. In this study a cost-benefit analysis was used, gathering the unit price per kg of the vegetables that were produced on the baira. Approximately, once a week, a survey was conducted at the local market to collect data on vegetable prices. The statistical software, which was used to analyse these data, was Excel and SPSS.

3.2.1.1 Case Study Findings

The demographics from their study is the following: that out of the 30 participants, 33% of them were between the ages of 20-30, followed by the second largest age group which was 30-40 years for 27% of the participants. This is an important statistic because building and maintain baira are both labour intensive work, therefore younger and stronger people would be better suited for this adaptive technique. Out of all the participants, 60% were literate and 40% were illiterate. One shortcoming of this article is that the authors did not discuss in detail what they meant specifically about 60% of the participants being 'literate', they just stated that "education was provided by NGOs to some satisfaction level" (pg. 265). In terms of male to female ratio, they found that only three women were 'directly involved with the floating garden 'which displayed the "typical gender discrimination in rural society" (pg.266).

In terms of that occupational status of the selected farmers, 57% were in agriculture and 23% were landless. This is an interesting statistic, because once again it reinforces how important this type of adaptation is to the poorest of the poor, who own no land and therefore baira is a great means of subsistence agriculture and a source for them to generate income. Figure 9 below displays the monthly income of the farmers. On average it was found that majority of the farmers were very poor, with a monthly income of 15.76 – 31.51 CAD. This helps us understand just how vulnerable the people who are affected by climate change are in Northern Bangladesh.

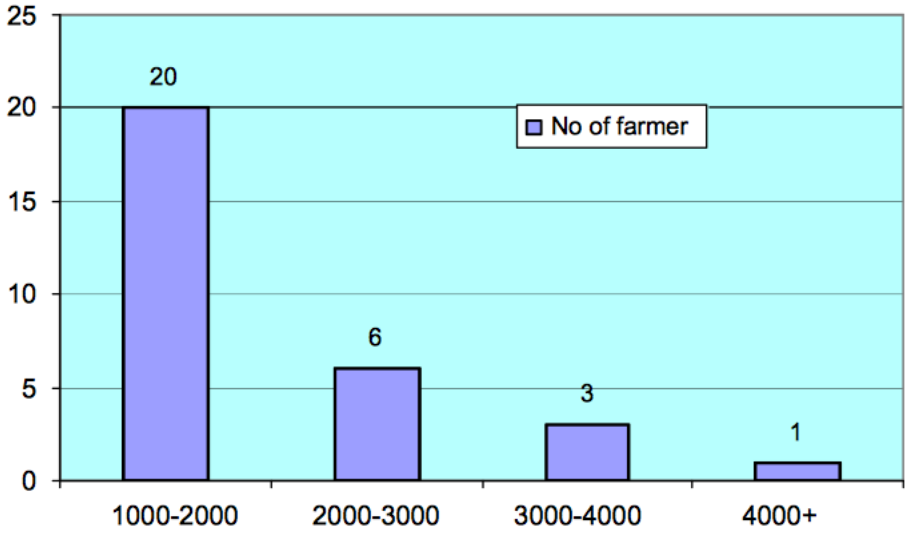


Figure 9. Average monthly income of the 30 farmers in Bangladeshi Taka (1 CAD=63 Taka)

Source: Pavel et al (2014, pg.5)

Parameter	Expenditure				Total expenditure	Revenue		Total revenue
	Labor	Seed	Making	Other		Sales	Consumption	
Mean	586.67	103.34	220	183.33	1093.34	2366.5	1650.57	4017.07
Mode	320	50	120	100	590	630	1680	2100
Median	320	80	120	100	620	1584	1573.50	2712.50
SD	357.36	71.31	134.01	111.68	671.37	2079.16	786.67	2717.62

Note: Making expenditure (bamboo, rope), Other expenditure (maintenance cost, fencing), Standard Deviation (SD), all values are given in BDT.

No of FGF	Size (ft) L × W × H	NR	NPV	CBA
1	12 × 4 × 3	1650	1034.05	2.80
2	12 × 4 × 2.5	3100	1872.99	2.63
3	11 × 4 × 2.5	1520	916.98	2.62
4	12 × 3 × 2	1515	907.23	2.59
5	15 × 4 × 3	6073	4168.38	3.37
6	12 × 4 × 3	3300	2068.09	2.80
7	16 × 3 × 2.5	2020	1380.35	3.34
8	12 × 4 × 3	1482	870.16	2.51
9	14 × 4 × 3	*9275*	*6145.74*	3.12
10	16 × 3 × 3	8080	5521.41	3.34
11	10 × 4 × 2	1480	877.96	2.55
12	12 × 4 × 3	1445	834.07	2.45
13	12 × 4 × 2	5500	3589.90	3.02
14	10 × 5 × 4	4615	2175.40	1.94
15	13 × 4 × 3	5070	3131.40	2.73
16	20 × 5 × 3	2170	1502.29	3.45
17	18 × 4 × 3	1540	907.23	2.53
18	17 × 4 × 3	1230	9.76	1.01
19	12 × 4 × 3	1650	1034.05	2.80
20	10 × 4 × 2	3929	2135.40	2.26
21	12 × 4 × 3	2920	1697.40	2.48
22	15 × 4 × 3	2200	1560.82	*3.67*
23	12 × 4 × 3	1510	897.47	2.56
24	10 × 5 × 4	1500	897.47	2.59
25	12 × 4 × 3	2890	1668.13	2.45
26	15 × 4 × 3	2200	1560.82	*3.67*
27	14 × 3 × 3	4060	2799.73	3.42
28	10 × 4 × 3	1400	799.92	2.41
29	12 × 4 × 3	*1050*	*−126.82*	*0.89*
30	12 × 4 × 3	1338	729.67	2.27

Note: All values are given in BDT and calculated values are valid only per bed in 0.26 years. Floating garden farmer (FGF), Net revenue (NR), Net present values (NPV) and Benefit cost ratio (BCR). 01 US$ = 83.1910 BDT as of 28 April 2012.

Figure 10. Total expenditure and total revenue costs of 30 floating gardens

Figure 11. Calculation of NPV and CBA of 30 floating gardens

Sources: Pavel et al (2014, pg.6)

According to the calculations, it was found that the benefits from the gardens varied according to their different sizes. Since, more vegetables can be cultivated on a larger garden (standard size of floating farm was 15 x 4 x 3 ft), it yields more benefits as the vegetables can either be sold or be consumed by the farmer's household or both. Specifically, it was found that net revenue (NR) of "US$111.55 was received by standard bed size areas (15 × 4 × 3 ft), while the lowest US$12.63 was received by small bed size" (pg. 267). If the value of cost benefit analysis (CBA) is less than one then the "project is not possible", only one very poor farmer was found to have a CBA of US$ 0.89.

3.3 Pumpkin Cultivation on Sand Bars/*Chars*

One of the impacts of flooding is frequent river erosion, which ultimately creates sand bars in the rivers. These sand bars are known as *Chars* in Bengali. They are "an integral part of the fluvial process of the river and its tributaries" and "suspended particles and the bed load combine during floods to create these almond-shaped formations" (Talukdar, 2017). In 2011, the number of people living on chars in all three major rivers namely Jamuna, Padma and Meghna had reached 12 million. Living on char certainly imposes its fair share of risks to the extremely poor and often landless inhabitants because char land is highly prone to river erosion. Since the year 2009 the NGO Practical Action has introduced sand-bar cropping to the char dwellers to cultivate vegetables but mainly to cultivate pumpkins in the Gaibandha district. Sandbar cropping is a very unique method of cultivating vegetables, just like the floating gardens, which have been discussed in the sections above. PA plays a very important role because they provide all the material to assist the farmers. Additionally, PA has created facilities that store the pumpkin, so that they can be sold for higher prices when they are no longer in season, such as during the monsoon season. When water levels recede after the monsoon season around mid-November, the sand bars rise to the surface and cultivation of pumpkins begins. Firstly, farmers dig many pits in the sandbars, which are approximately 1m3 in size. Then, they are filled with compost and manure (10-15 kg). Then seeds are placed (4-6) in each pit which are observed "with periodic irrigation and nurturing as required" (pg.649).

3.3.1 Case Study Evaluation of Sand bar Cropping in Gaibandha District

Khatun et al (2017) have conducted a study to understand whether sand bar cropping practices is helping to alleviate poverty and living conditions for the extremely vulnerable char dwellers. The main objectives of their study were the following; "to know the socio-economic and livelihood status of the farmers; to assess the cultivation practices of pumpkin by using sandbar cropping method and to estimate the profitability level of pumpkin cultivation by using sandbar cropping method" (pg. 649). The method of data collection was primary data collection via direct interviews. Over a period of four months (April to December), farmers who grew pumpkin using the sand bar cropping method were selected from Sundarganj in Gaibandha district.

3.3.1.1 Case Study Findings

An important socioeconomic factor for the success of this method is once again the age of the farmers. Similar to the floating gardens, this is an important factor because there is a lot of vigorous hard work that is required. It was found that 65% of the selected participants were aged between 35-49. Therefore, the majority of them were middle-aged and generally considered not too old to be able to carry out the necessary manual work. In terms of other socio-economic factors, such as the literacy rate, the national statistics literacy rate (2015) classified 42.81 % of the population in Gaibandha as literate. Amongst the participants, it was found that only 7% of them had attended elementary school and over 90% of them were able to sign their names only. Therefore, the vast majority of the farmers were not literate. As previously discussed in section 2.2.5 and displayed in Table 4 literacy rate is an important factor because "education is likely to influence the farmers to adopt the modern technology and it makes them more capable to manage scarce resources efficiently so that they can earn higher profit" (pg.653). Therefore, it is an important factor in overall farming productivity, and as a result, output.

Similar to the first case study, the occupational statuses as well as the household income of the participants have been discussed in this study. 93% of the farmer's primary occupation was agriculture. In terms of household size, 75 % of the selected farmers had a 'small' family, which is considered to have four or less members. Only 4% of the

participants had a 'large' family which is equal to or more than 6 people. This is interesting because there is a general understanding that most rural people have many children. However, this was not the case in this particular study and with less family members more produce can be sold. Furthermore, the Domestic Resource Cost (DRC) which is defined as "the ratio of the cost in domestic resources and non-traded inputs (valued at their shadow prices) of producing the commodity domestically to the net foreign exchange earned or saved by producing the good domestically" (pg.652) was calculated using the following equation to understand whether this type of adaptation was beneficial to Bangladesh's agriculture sector. After calculating the DRC of pumpkin cultivation for this study, it was found to be 0.074. Since, this value was found to be lower than 1, it indicates that Bangladesh "had comparative advantage in pumpkin production for export promotion" (pg. 660). This is important because export promotion "drives the international flow of goods and services and is one of the primary measures that governments utilize to sway the quantities and kinds of goods and services exported from their areas of jurisdiction" (Alliance Experts).

$$DRC = \frac{\text{Cost of domestic resource and non-traded inputs for producing per unit of output}}{\text{Value of tradable output} - \text{Value of tradable inputs}}$$

$$DRC = \frac{\sum F_{ij} P_j^d}{U_t - \sum a_{ik} P_k^b}$$

Where,

f_{ij} = Domestic resource and non-traded inputs j used for producing per unit commodity i

P^d_j = Price of non-traded intermediate inputs and domestic resource

U_i = Border price of output i

a_{ik}= Amount of traded intermediate inputs for unit production of i

P^b_k = Border price of traded intermediate input

Figure 12 (a) Calculating Domestic Resource Cost (DRC) of Pumpkin Cultivation

Items	Pumpkin
A. Traded input (Tk/MT)	379
B. Non-Traded inputs and domestic resources (Tk/MT)	2083
Human labour	1028
Mechanical power	51
Seed	51
Manure	210
Pesticides	153
Irrigation	350
Int. on operating capital	42
Land rent	203
C. Output price (Tk/MT)	28390
D. Value added (Tradable) (Tk/MT) (C-A)	28011
E**. DRC** (B/D)	**0.074**

Source: Author's calculation

Figure 12 (b)

Source: Khatun et al, 2018 (pg.651 & pg.660)

Given the case studies explored in this chapter and literature review explored in Chapter 2, the next chapter builds on these ideas and further explores adaptation measures in Northern Bangladesh against climate change. I wanted to understand how wide spread and prevalent adaptation measures such as baira are or not. Therefore, I decided to conduct long distance telephone interviews with farmers who have been affected by flooding in the Bogra District in Northern Bangladesh, which is very close to Gaibandha District, therefore the situation in the two districts are very similar. More specifically, I wanted to learn how they have been coping with annual floods and whether they have been using high yielding varieties of rice and floating gardens/*baira*. I also wanted to learn from the participants their thoughts on whether there were any positive impacts of the floods on rice productivity, a concept known as 'creative destruction', which has been discussed in Section 2.2.4.

CHAPTER 4. Farmer's Comments

Figure 13. Geographical location of Bogra and Gaibandha District in BD

Source: Google Map Images

4.1 Objective of Primary Data Collection/Interviews

My primary data collection consisted of conducting long-distance telephone interviews to Bogra district in Northern Bangladesh, which is approximately two hours away from Gaibandha district. The reason that I have chosen to conduct interviews is because they possess much strength, which is why it is one of the most common ways of obtaining data in qualitative research (Gill et al, 2008). For example, a great strength of interviews is that it is a way to directly connect with the respondents, hence it is deemed to be more personal than just questionnaires or surveys. There is also a chance for probing the respondents with follow up questions, which is why I have conducted semi-structured interviews which "consist of several key questions that help to define the areas to be explored, but also allows the interviewer or interviewee to diverge in order to pursue an idea or response in more detail" (Gill et al, pg.291). The main objective was to understand how the livelihoods of the extremely poor and vulnerable farmers were affected after experiencing severe climate induced floods and whether they had adopted any adaptation measures such as the floating gardens for their agriculture. As previously discussed, such marginalized farmers are some of the most vulnerable groups of people that are affected by climate change and therefore their voices need to be heard and their stories be told.

4.2 Research set-up for Interviews

I received Human Participants Research (HPR) approval from York University and therefore was able to conduct the interviews. The risks involved in participating in this study were minimal to the participants involved (please see Appendices B and C). The total sample size for my interviews was five participants. The participants came from a very low-income background from the village of Shantahar in Bogra District. They are farm workers on my paternal grandparents farm. A few of them also owned cattle and small plots of farmland themselves. The interviews were conducted in Bengali; therefore I had to ensure that they were being recorded, which enabled me to translate them word for word in order to analyze the data collected.

As the interviewer, it was very important that I avoided bias in all ways possible. For example, I ensured whilst conducting the telephone interviews that I did not present them with my own opinions or use any words or phrases including anything that may give away my views, therefore not only did I avoid such phrases but I also ensured that my tone sounded neutral, not negative or overly excited. Each participant was paid 600 Taka (10$) for their time by my uncle, whom my parents paid back.

4.3 Interview Results

A list of all the questions that were asked to each participant is attached in Appendix C. Participant 1 was interviewed along with Participant 2 on the same day. Participant 3 and 4 were interviewed on the same day as well. On the last day of interviews, Participant 5 was interviewed. All five participants were male and their ages ranged from 38-45 years. I had asked them which was the most severe flood they had ever faced because I wanted them to focus on a particular flood, since they have each faced numerous floods. Participants 1 and 2 stated that they remember the floods of 1988 (October) the most, because it was the most devastating flood they have ever encountered. The floods of 1988 had ravaged 60% of all of Bangladesh and affected around 32 million people (Nakamura, 2002). Participants 3, 4 and 5 discussed the recent floods of 2017.

Participant 2 described in detail that he remembers that the flood of 1988 "*came along with a cyclone and blew away the roof of my house and it also destroyed the water tube well*". In the article 'Tubewell water quality and predictors of contamination in three flood-prone areas in Bangladesh' by Gupta et al (2008), it is mentioned that "Hand-pumped tubewells are the dominant water supply technology in Bangladesh. A tubewell (also called a borehole) consists of a polyvinyl chloride pipe, typically 37mm in diameter, attached to a polyvinyl chloride screen placed in fine to coarse sands generally between 20 and 300m below the ground. As the static water level in much of Bangladesh is within 7m of the ground surface year-round, simple suction hand pumps are typically used to lift the water" (pg. 1002).

Figure 14. A woman and her child in rural Bangladesh collecting water from a Tube Well. Source: OCA News (2012)

When I had asked each participant whether he had any time to prepare for the floods they said no and that the floods came on very suddenly, this was unfortunately the case for both the 1988 and the 2017 floods. However, there was some time for participants to move their cattle to higher ground. Participant 1 stated that his house was situated at a higher ground and therefore was not submerged by the floods, however the floodwaters surrounding his house were still approximately 1-2 feet in height. He stated that some of his neighbors became homeless because their houses were completely destroyed. It is important to note that most houses in rural Bangladesh, still to this day are made of clay, in Bengali they are called '*matir basha'* which translates to 'Clay houses' (Figure 15).

Figure 15. Mud house in rural Bangladesh with tin roof.

Source: World housing Encyclopedia, 2014

Participants 1 and 2 stated that the duration of the 1988 floods was around two weeks, therefore there was a lot of damage done. Similar to Participant 1, Participant two's house did not have a lot of water inside the house, however the land around his house was fully flooded. He further stated, "*Luckily the pond in our house was saved*". This is of importance because many rural households in Bangladesh contain freshwater ponds, known as '*pukur*' in which fish is cultivated for the family and for selling; therefore it is a means of sustenance and income. Furthermore, Huq (2017) in his paper, 'Small scale freshwater ponds in rural Bangladesh: Navigating roles and services' describes that these "ponds serve multiple purposes for the rural household, used not only for fish culture but also to supply water for washing, bathing and other household needs" (pg.74). He further states that these small water bodies can be "classified into four types, firstly, human-made ditch known as *Doba* which is approximately 25–400 square metres in extent retain water seasonally, larger *Pukur*, which at 150–1000 square metres is a perennial water source third, a *dighi* is a small tank or reservoir, of over 750 square metres, and a fourth, *jola* or *khal* is a linear watercourse made for transport or irrigation purposes and to provide

means for excess water to drain away during floods" (pg.75). *Pukurs* are also important because they can be used for *baira* cultivation.

When I asked each participant "How did the flood affect the rice crops and the farms? What was destroyed?" Participant 1 answered that "*there was extreme damage to rice crops, as well as to canola crops and we were not able to harvest any crops especially rice. In addition to rice crops, the cattle also suffered and lot of them died".* Similar to Participant 1, the second participant also stated that all the crops in his family farm were lost, however his cattle were saved because he had moved them to higher ground. Participant 3 did not own any cattle however his vegetable and rice crops were destroyed in the floods. Participant 4 stated that his rice crops were destroyed and he was forced to move his cattle to a local primary school, where he and his family members took shelter. Participant 5 stated that he too was able to take his cattle to a save shelter but his smaller farm animals like chicken and roosters had been killed. For a very poor farmer working family in Bangladesh, such impacts are devastating on their livelihoods.

When participants were asked, "*Are there any positive impacts on the rice production and cultivation even after being damaged by the floods?"* the first participant answered that *"Yes, a very positive impact of flooding is that it leaves behind a lot of silt, which creates good soil. The year after the flood the production of the crops is at least two times higher, so it makes up damage for the past year".* All participants shared similar ideas regarding the positive effects of flooding except for Participant 5. He stated that during the floods of 2017, he was in his hometown of Chittagong, which is located in the Southeast region of Bangladesh. He stated that his village is very close to the sea, so they are also prone to coastal flooding. He said that there are not positive impacts of flooding in his region because the seawater combines with the freshwater, so fertility of the soil does not increase.

Then, I asked the participants a very important question, which was if there are any methods that that they use to adapt to such frequent flooding. I was very excited to hear their responses for this question because it is a central issue of my entire research. Participant 1 said that they used an indigenous adaptation method known as *'bhala'.* He stated that '*bhalas'* are little makeshift boats made out of banana trees, which are used to carry cattle, people as well as some of their belongings, since it can float for a while.

Participant 2 said that he also uses '*bhala'*, but mainly to transport cattle (please see Figure 16 below). Both participants stated that they don't use floating gardens.

Figure 16. A flood-affected girl with her goat and belongings sitting on a makeshift raft made of banana trees (used for transportation). Source: Getty Images

When each participant was asked 'What did your properties look like once the flood waters receded?' they said very similar things and mostly discussed the devastating impacts of the floods. Participant 1 said that "*it is much more difficult for poor and illiterate people like ourselves to recover from the floods and to reap the benefits of the floods".* When I asked them what were some of the impacts of the floods, most of them stated that there was shortage of food especially since rice is the staple food of Bangladesh but due to the floods, the rice crops were destroyed. Every participant discussed the health issues during and after a flood, especially Participant 3, who discussed how the floods lead to his family members getting severe diarrhea and skin diseases. A reason for this is that drinking water is contaminated by floodwaters as toilets and tube wells are washed away. When I asked the interviewees why they think floods occur and are much more frequent now, they had very interesting responses.

Participant 1 said that during his childhood, he did not witness such frequent flooding. When I asked him to elaborate a bit further, he stated that over the past twenty years he has noticed the climate changing and now they certainly receive more rain and flooding as a result. Other reasons given were more political, that during India's monsoon season they open the flood gates and Bangladesh gets flooded. Participant 3 said that "*floods are occurring because our country is really low lying and also because of the heavy rain that we get during monsoon season and also due to the water from India*". Participants 4 and 5 stated all the reasons mentioned above, however they also added that the government of Bangladesh is unable to properly create adequate flood protection structural measures such as embankments because the country is impoverished and for the embankments that are built they are not strong enough and "*sometimes they are just built temporarily*". Participant 5 stated something very interesting; he said "*floods and cyclones are occurring so frequently because it's the curse of God. These disasters are to warn people".*

When I asked participants how much help they received from the government as well as NGOs, Participants 1 and 2 stated that NGOs provided the flood victims with aid in the form of rescuing people who were stranded in flood waters, distributing clothes and importantly with non-perishable food items and fresh drinking water. This type of support is vital because as food and rice crops are destroyed, there is nothing to consume and as a result many people starve, which is something that Participant 4 mentioned when I asked him about the impacts of the floods. Furthermore, Participant 1 said, "*we received more help from the NGOs as compared to the government*". The government provided some land for those people who became homeless during the severe floods of 1988 and created some 'cluster villages' for the people to live in. However, this varies from individual to individual because Participant 2 stated that he received no help from the government to reconstruct his house whatsoever. Participant 3 stated that the government provided him and his neighbors with building materials (tin for roofs) and helped to reconstruct water tube wells. Participant 4 also stated that he did not receive any help from the government either, therefore in order to be able to reconstruct his house he took a loan from Grameen Bank (micro credit) and invested that amount to build his house. It was only Participant 5 who said "*the government provided a lot of help and built one room for us and also helped us by*

giving us other building materials". He also mentioned that the government has built many flood shelters around Chittagong where he is from, but now he works and resides in Bogra.

In terms of medical health due to the spread of diseases after and during a flood, Participant 1 stated, "*it depends on who you are, for a wealthy person they can afford to go see a doctor even if he is further away but poor people are badly affected".* One of the worst consequences of flooding is the spread of water and vector-borne diseases, which is defined as "human illnesses caused by parasites, viruses and bacteria that are transmitted by mosquitoes, sandflies, triatomine bugs, blackflies, ticks, tsetse flies, mites, snails and lice" (World Health Organization, Vector-borne Fact Sheet). There is also the potential risk of exposure to toxic waste after a flood. Alderman argues that floodwater may help to release chemicals such as agricultural chemicals, carbon monoxides, pesticides, and a number of heavy metals by acting as a trigger. Those who live near agricultural belts and flood-impacted industrial zones are at the highest risk to exposure. What is worrying is that it is known that exposure to such contaminants can eventually lead to cancer, kidney, gastrointestinal, neurological, cardiovascular diseases (Alderman et al, pg.39).

Participants 4 and 5 stated that children, elderly residents and especially woman are much more affected by the floods because they are more vulnerable. Participant 5 also stated that women have a much more difficult time after the flood waters have receded because they have traditional duties to fulfill such as clean, cook and help with every other chore. Participant 5 stated that health issues are of a large concern for his village especially during and after a flood because the nearest health center is many kilometers away in the next town.

During the more recent floods of 2017, Participants 3, 4 and 5 stated that the government and NGOs built some makeshift medical camps inside 'bazaars' where the land was more elevated. However, there was a pattern in the responses of each participant, which was that the government did not provide sufficient support after the flood. When I asked the Participants 1 and 2 if warnings were given prior to the cyclone and flooding they said no because back in the day most people did not have technology in the form of televisions and radios nor did the government have enough technology and resources to track and predict cyclones. Surprisingly, Participant 4 who discussed the 2017 floods said *"rural Bangladesh is deprived from modern day technologies such as TV and radio, so the*

warning systems prior to the flood did not reach poorer people who live deep in the villages". This finding was somewhat surprising because it shows us that even now, rural Bangladesh is still very poor and therefore majority of the people do have access to technology such as TVs and radios. Therefore, flood and hurricane warnings may not reach everyone in such locations, or may reach them but too late.

4.4 Discussion

Overall, there was a lot of damage caused by the floods for the livelihoods of the five rural farm workers that I had interviewed. Not only was there significant damage to rice crops, but also to other agriculture such as canola crops. In terms of evacuating prior to the more recent floods, the participants stated that they were able to evacuate to higher grounds and also had sufficient time to move their cattle. Needless to say, saving the cattle is vital since they are used for cultivating land for rice production and often times the poor farmers sell their milk for additional income. It was very important to ask the participants regarding the positive impacts of flooding on agriculture, mainly on rice production. The response given by Participant 1 was interesting as he stated that "After the flood, the production of crops is at least two times higher, so it makes up damage for the past year.". However, not everyone will agree, because often times the damages are far greater. Participant 5's response regarding this issue was an anomaly and does not correlate to my research because he spoke about Southern Bangladesh.

What was surprising about the interviews was that none of the five participants had adopted any methods of agricultural adaptation against climate change. My hypothesis was that at least a few of them would incorporate floating gardens in their agricultural practices. They are so widely used in the Gaibandha District, which is just two hours away from Bogra. However, it is important to understand the limitations of my study. For example, my participant selection was not as large as I had hoped for. This is because it was difficult to recruit many participants and whilst I was interviewing them, the telephone connection was giving some trouble. This could be considered as a weakness for long-distance telephone interviews. Another limitation of my study was that none of my

participants were women. As previously discussed, women and men do not experience the impacts of climate change equally in a developing country. Participant 5 was the only one who discussed this issue thoroughly because he understood that women were more vulnerable when disaster strikes. If I was able to interview women, from the same village, I might gain valuable knowledge about their suffering and coping skills through their perspectives. Another limitation of my study was that I had to reduce the number of questions from my initial questions list, which had approximately twenty-five questions. This was because due to the time difference between Canada and Bangladesh, as well as due to time constraints that the participants had, each interview lasted from 30-40 minutes.

The following chapter discusses the overall findings, limitations and recommendations of this paper. Furthermore, it summarizes the main findings to each of my core research questions, which were stated in Section 1.2.1 of this MRP.

CHAPTER 5: DISCUSSION

5.1 Overall findings

The first core question that I sought to address in this MRP was the following: i) what are the observed climate change patterns in Bangladesh including flooding? Based on my findings, changes in Bangladesh's climate have been observed over the past few decades. Furthermore, Bangladesh was found to be one of the top ten most affected countries in the world by the effects of weather-related loss events including severe floods and storms (Kreft et al, 2017). More specifically, researchers Nishat et al (2013) who have studied data from the Bangladesh Meteorological Department (BMD) over several decades (1970-2010) found that Bangladesh has been experiencing climate variability over the 40 years. Their studies conclude that winters as well as monsoon seasons are experiencing fluctuating mean surface air temperatures. Specifically, during the winters there is an increase in the minimum temperature by 0.4 - 0.65 degrees Celsius. There has also been a rise in the maximum temperature during the hot summer months of June, July and August, within ranges of 0.03-0.05 degrees Celsius in Northern regions such as Sylhet, Tangail and Saydpur.

Similarly, during the pre-monsoon and monsoon seasons there have been increases in the maximum and minimum temperatures. The increase in seasonal temperatures is expected to increase the seasonal rainfall, which will lead to flooding during monsoon season, in which Bangladesh already receives 80% of its mean annual rainfall. Some of the other notable findings from Nishat et al (2013) are the following: they've found an increase in rainfall in the pre-monsoon season in 30 out of 32 meteorological stations, with a prominent increase in the coastal regions. During the monsoon season, they've found increased annual mean temperatures in 18 out of the 32 meteorological stations with a range of 21-42 mm/year. There has also been an increase in rainfall in the post-monsoon season, which was found in 24/32 meteorological stations, with a range of 12-24mm/year. Another significant finding from their research is that they have observed a decrease in the total number of 'non-rainy' days in more recent years, which indicates that there is an increase in the frequency of precipitation. This trend was found in 26 out of the 32 rainfall

stations. They have also found that along with an increase in seasonal temperatures and seasonal rainfall, there is also an increase in the intensity of daily rainfall; this trend was found in 25 out of the 32 rainfall stations.

Global climate models also estimated increases in precipitation during the monsoon season. It was found in several studies by researchers who studied GCMs that showed an estimated intensification in temperatures for Bangladesh (Agrawala et al, Tanner et al, Winston et al). The results also predicted that there will be more warming over the winter months, compared to the summer months. Specifically, what was found from the simulations was that "the resulting mean annual temperature changes were 1.4 degrees Celsius by 2050 and 2.4 degrees Celsius by 2100" (Winston et al, pg.21). The annual precipitation is expected to increase by 5.6% by 2050 and by 9.7% by 2100" (Winston et al, pg.21). This is predicted to occur because the "air over the land will warm more than the air over the oceans in summer" (Agrawala et al, 2003), which will enhance the low pressure system over land which takes place during the monsoon and as a result creates more precipitation. In another study by Tanner et al (2007), they found similar results to that of Agrawala et al. They used similar GCMs to Agrawala et al and found that for the projected changes in temperature by 2050, there will be an increase in average temperatures by 1.6 degrees Celsius with an increase of 4% in the projected rainfall, which is slightly lower than what Agrawala et al had found (5.6%). Overall, "these projected seasonal changes are consistently found across many studies of the South Asian monsoon region" (Winston et al, pg.21).

Similarly, in regards to sea level rise, it was found in a study conducted by Frihy et al (2003), that there is already a rise in sea levels of 1.0 cm per year in Bangladesh. Additionally, it was estimated by him that if there is a 25 cm rise in sea levels by the year 2050, 4% of the total landmass of Bangladesh will be affected and if there is a rise in sea levels by 1m by the year 2100, then 17.5% of the land mass will be affected which will affect millions of people. However, a limitation of studies that predict sea level rise is that they are estimating approximate values; nobody knows for certain. For example, this MRP has found that studies have predicted different sea level rise scenarios for the same year. In the study by Frihy et al, they estimated a rise in sea levels of 1m by the year 2100, whereas IPCC 2014 predicted up to ~60cm for the same year. As stated in Sections 1.1 and 2.1.3, one

of the main reasons for this is due to thermal expansion. This finding by IPCC should be given a lot of importance and priority because we are less than a century away until this becomes a global reality. Overall, these findings demonstrate to us that Bangladesh has been experiencing climate variability over the past few decades in the forms of fluctuating annual temperatures, increased precipitation during several seasons (monsoon, post-monsoon) which leads to increased flooding, as well as increasing sea levels, which can also lead to climate-change induced flooding. Unfortunately and as previously discussed in Section 2.1.1, such observed changes in Bangladesh's climate are very likely to get extreme in the future.

The second core question that I sought to address in this research paper was the following: ii) Can education and use of modern high yielding seed technology for rural and vulnerable low-income farmers play a certain role in minimizing poverty and the devastating impacts of flooding on rice crops and production? Based on my findings in this MRP, education did not seem to play a significant role in reducing the devastating impacts of flooding on rice crops and production for rural and vulnerable low-income farmers. However, the adoption of high yielding seed technology did improve poverty levels of the rural farmers by generating income. This was discussed thoroughly in Section 2.2.5 of this MRP, where author Mendola (2007) argued that high-yielding technological change is the way to go for enhancing agricultural growth because on a global scale, other methods such as irrigation and area expansion has already become a 'minimal source of output growth'. Her research was very noteworthy because she conducted her study through a unique lens that took into account a 'counterfactual situation', which was to assess what would have occurred in the situation if the technology had not been applied. One of her key objectives was to comprehend whether technological adaptation (use of HYVs) increased household income or not. Her study found that out of the 2562 surveyed households, she found that 1113 were adopters of HYVs of rice and 1449 were non-adopters. It was found that the educational level of the head of the household did not differ between the two groups. The percentage of households with the family head's educational level equal to the primary level or more was 9.4% for non-adopters and 9.8% for adopters (see Table 4). This indicates once again that education did not play a large role in the decision to adopt or not

adopt to the HYVs. However, Mendola found that adopters of HPVs seemed to have much higher income, therefore adopting HPVs helped to alleviate poverty of the poor farmers. She found that an average income is 30% higher for adopters than non-adapters and the average annual gross crop-income (per consumption unit in USD) was 112.1 for adopters, whereas it was only 52.8 for non-adopters. Given these findings, adoption of new technology seems like it should be encouraged however as researchers Winston et al discuss that for "for many communities, adoption of new technologies can represent high downside risks unless options are well tested in the field" and that "potential for economic return will be a critical determinant of overall adoption" (pg.83, 85). Therefore, it is crucial that government agriculture officers make continued efforts to ensure that the farmers do not face too many risks. The government should also provide financial and technical support and reduce unit costs, which are defined as "costs that would be borne by the farmer to implement the adaptation option" (pg.85).

In Section 2.2.4 Banerjee (2010) highlighted how poor and vulnerable farmers face more risks and subsequent loss from flooding. This is because poor farmers cannot afford to grow HYV's of rice such as boro, which has only 34% of land under cultivation devoted to it. Therefore, she argues that there should be much greater emphasis placed on growing *boro* rice for overall agricultural growth in Bangladesh. This makes one question how come the farmers are not doing so already? The answer lies in the fact that costs of production are higher for *boro* crops as they require additional and therefore costly inputs such as fertilizers, pesticides as well as a much higher amounts of irrigational water, since *boro* rice grows in the post-monsoon dry season compared to the *aman* crop, which grows in the wet-monsoon season. Therefore, for a poor farmer, growing *boro* rice is not a feasible option, as it is "closely tied to his purchasing power" (pg.109). Consequently, the poor farmers suffer much more and are also much more at risk compared to rich farmers because they invest in cheaper wet-season rice. Such types of rice are much more easily destroyed leaving the vulnerable farmers with greater losses and facing greater disparity.

Overall, both scholars agree that due to the low income and therefore a low purchasing power of rural farmers, they are at a higher risk and face more damages due to flooding in Bangladesh every year. However, there is evidence that the use of modern high-

yielding seed technology increases rural incomes, and therefore alleviates poverty levels. In Mendola's research, she explicitly claims that there is substantial potential for "increasing rural incomes through the diffusion of modern farming technology" (pg. 390) since she has found a positive correlation between adopting modern high-yielding seed technology and a reduction in poverty for rural farmer households. Therefore, the government needs to enhance the role of agricultural technology in not only anti-poverty but importantly in climate change adaptation policies in rural areas. Moreover, Banerjee discusses that if poverty levels can be reduced then such farmers can shift to using high yielding varieties of rice such as *boro,* which can lead to a bumper harvest in the post-monsoon dry season. Overall, this can lead to more stakeholders benefitting from the "creative impetus" (pg. 113).

The third core question that I sought to address in this research paper is the following: iii) what are some local grassroots level flood adaptation schemes that are in place in Bangladesh? To what extent are these adaptation strategies beneficial to the local people? Based on my findings in this MRP, there are several grassroots level flood adaptation schemes that are in place in Bangladesh. Firstly, the Floating Garden Case Study in the Gaibandha District discussed in Section 3.2 demonstrated that it is a suitable adaptation measure for Northern Bangladesh, where a lot of land is wetlands and are submerged for months due to extensive flooding, especially during monsoon season. Depending on how many vegetables are cultivated and whether there is surplus production, it can really help the vulnerable farmers to generate income. Whether or not there will be enough produce to sell depends on the size of each garden. Another important factor to consider is how large each household is of each farmer. This was unfortunately not mentioned in the study.

Based on my findings I believe that these adaptation schemes are beneficial to the poor farmers to a good extent, because not only do they help generate much needed income but by doing so, it gives the men and the few women involved who have adapted this hydroponics system "a sense of economic satisfaction". Since floating gardens generate much needed income, this reduces the extreme vulnerability of such poor groups of people. As this study had found, the average monthly income of the farmers is approximately

15.76 – 31.51 CAD per month. Importantly, baira gardens help to raise adaptive capacity to some extent and the fact that local indigenous knowledge can be well used and integrated is certainly an advantage. Overall, the floating gardens provide a practical community level solution to the ever exacerbating impacts of climate change.

The second Case Study on Pumpkin Cultivation on Sand Bars/*Chars* discussed in Section 3.3 found that the farmers were very poor with little to no education and their lifestyle was based entirely around agriculture. However, this new method of sand bar cropping and pumpkin cultivation, which is an adaptation measure is improving their lifestyle by once again generating much needed income. The majority of pumpkin farmers earned an annual income of 50,000 to 100,000 Bangladeshi Taka, which is approximately 4166 to 8333 Taka per month (65 to 130 CAD). Therefore, the monthly income of pumpkin farmers was much higher than that of the floating garden farmers. Furthermore, it could be argued that for both adaptive farming techniques, productivity and income is likely to increase over the next few years as the farmers gain more experience, since this farming practice is relatively new in the Northern Districts of Bangladesh. Khatun et al state that experienced farmers "attain higher levels of technical efficiency. Technical inefficiency of the production is significantly related to farming experience of the farmers" (pg.655). Also, in contrast to floating gardens; one great factor of sand bar cropping is that women play a much larger role in it. Authors Khatun et al have found that out of a "total of 5,262 households, 50% of them were women farmers, who cultivated pumpkin on 774 hectares of sandy barren char lands and produced 17,790 tonnes of the crop and earned Taka 15.22 crore during two years period from 2012 to 2014" (pg. 648).

5.2 Recommendations and Limitations

Chapter 2 began by exploring the science behind climate change. Importantly, in Section 2.1.1 future climate scenarios and sea level projections using climate models were discussed. However, as useful as GCMs are to help us better comprehend what the future holds, a limitation of using them is that our climate is constantly evolving. This is specifically a limitation for Bangladesh, because it is part of the Ganges Delta, which is continuously evolving and changing in shape; this makes it difficult to predict climate change using such large climate models. Therefore, it can be recommended to develop regional and smaller scale climate model projections for Bangladesh in the near future. Authors Winston et al recommend that one of the ways to do this would be by "downscaling GCM simulations to the Bangladesh region using the IPCC four-factor method, which includes 1) sea level rise components for global thermal expansion; 2) local land processes including accretion, erosion and subsidence; 3) melt-water from glaciers, ice caps and ice sheets; and 4) coastal circulation patterns as affected by currents, tides and weather" (page.26). By integrating all of these four recommendations into a GCM, it would help the model become more specific and narrowed down because each one of these recommendations is a key issue for Bangladesh. However, this will certainly not be an easy task due to several reasons. For example, it might be difficult to estimate how much change Bangladesh's vast delta regions will go through due to the constant erosion and subsidence. However, in the near future researchers can look at the present rates of erosion and subsidence and incorporate the data into a GCM. Another potential area of research is how sea level rise impacts the local land processes; will it exacerbate rates of accretion, erosion and subsidence?

Sections 2.2.1-2.2.5 discuss climate change impacts on food security, specifically on rice production, technology adoption and how vulnerable groups of people are affected by changes in climate. Since, agriculture is Bangladesh's most important economic sector, it can be directly affected by climate variability. Rice production has been growing significantly. For example, in 1995 the rice-harvested area in Bangladesh was around 10 million ha, and this figure has nearly increased to 12 million ha in 2010. Also, of the total cropped area in Bangladesh, rice is planted on 75% of it and on 80% of the total irrigated

area (Bangladesh Rice Knowledge Bank). However, despite the growth there are significant damages in the agriculture sector when disaster strikes. For example, after Cyclone Sidr struck Bangladesh in 2007, studies found there was a total damage of US$ 437.6 million for the agriculture sector alone. Section 2.1.3 discussed scientific evidence, which suggested that the increase in sea surface temperature would strengthen cyclonic activity.

Section 2.2.1 discussed the rural and vulnerable farmers of Bangladesh. There are some individuals who are more susceptible within the vulnerable group itself; this includes marginalised groups, women, children, elderly people and importantly people who are the most isolated from infrastructures such as from health care services. As discussed, women are particularly vulnerable in a male dominant and high crime society. It is highly recommended to include women in adaptation measures when policy makers are making important decisions. Therefore, it is important that they get meaningful participation from women and include their priorities, which are often over looked due to unequal gender relations. Furthermore, adaptation measures should be developed in such a manner which will ensure that "women get access, control and ownership of resources such as land, livestock, property and income opportunities and access to development resources such as credit, information, training and outreach and culturally appropriate labour saving technology" (UNEP Report, pg.8). It is really vital that adaptation methods provide a source of income for the women, because it is an excellent way for self-empowerment. Overall, there is a great potential for future research to fill in the gaps of how men and women experience climate change differently in developing nations "in terms of adaptation, impacts, responses, vulnerabilities and opportunities provided by climate and other simultaneous drivers of change" (UNEP Report, pg.8).

Additionally, local participation by both men and women should be highly encouraged when adaptation measures are being developed during policy-making either by the government or by NGOs such as Practical Action. There should also be an emphasis on grassroots level/ bottom- up adaptation approaches because there are many benefits to this method. Local indigenous and ingenious knowledge should also be considered and integrated. A great example of this would be the floating gardens, which were originally an indigenous method used in Southern Bangladesh, and then Practical Action introduced it to the Northern regions such as in Gaibandha District, where it became a success.

In regards to agriculture, what is interesting to note which authors Lotze-Campen et al (Crop Adaptation to climate change, 2011) have discussed is that carbon dioxide is being released into the atmosphere from rice production, livestock, tropical deforestation as well as from nitrogen fertilization, all of these factors combined are adding approximately one-third to total and global greenhouse gas emissions. It could be assumed that since Bangladesh has a very large agriculture sector, they emit a lot of GHGs. However, this is not accurate because as a developing country Bangladesh emits low levels of greenhouse gas emissions, compared to other nations especially developed countries. According to a report by USAID (2012), Bangladesh produced a total of 190 MtCO2e* GHG emissions, which was only 0.40% of the world total (47,599 MtCO2e).

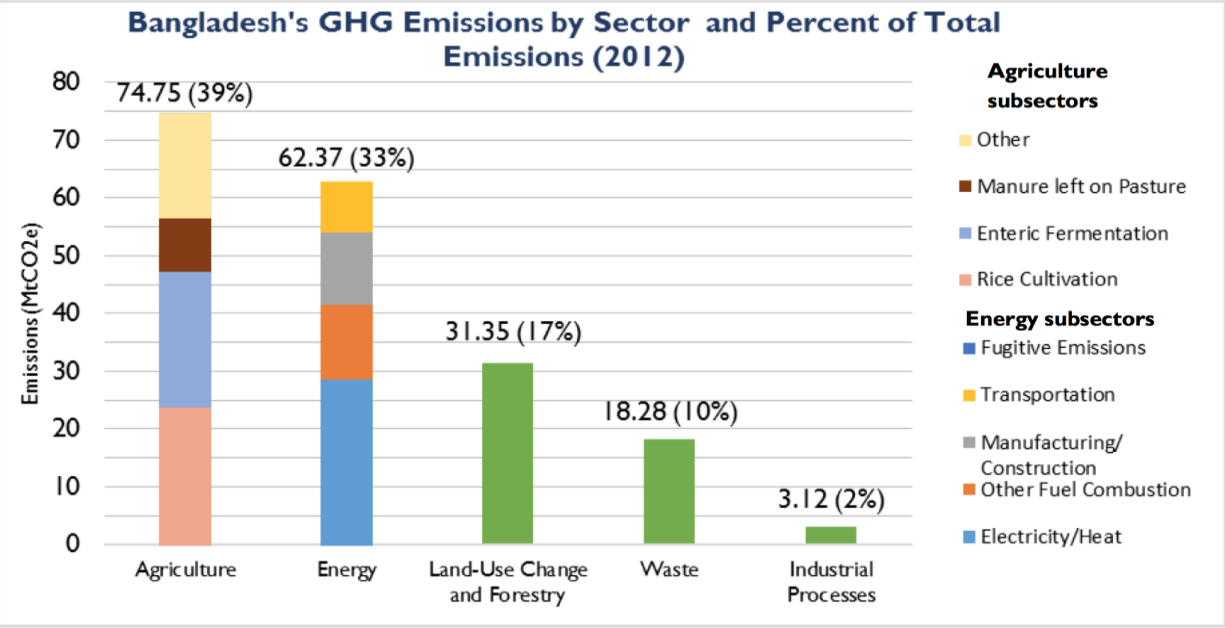


Figure 17. GHG Emissions by Sector (2012). Source: USAID Report, 2012

Figure 17 above, demonstrates that within that small amount of GHGs that Bangladesh produces, 39% of it came from the Agriculture sector. Section 2.2.3 discussed the uncertain effects of elevated carbon dioxide emissions on crop productivity. This is an area, which I wanted to explore and have previously mentioned in my research proposal. This is imperative to my research, because I wanted to find out if there were any positive impacts to climate change on crop productivity in Bangladesh. Would accelerated levels of carbon dioxide increase rice productivity? Would it help Bangladesh's economy since it relies heavily on its agriculture sector? However, what the studies found was somewhat

conflicting, because some research such as by Lotze-Campen et al (2011) and Karim et al (1996) stated that yields of most crops are expected to increase with elevated carbon dioxide emissions. Specifically, the latter study calculated that with an increase in temperatures by 2 degrees Celsius there would be a small positive change in rice yields for the year 2050. However, a limitation of both of these studies is that it was assumed that there was no moisture stress, so the crops would have sufficient water levels along with high levels of carbon dioxide as well.

Therefore, there is potential in the near future to conduct research, in which such factors (adequate moisture and carbon dioxide) as well as nutrient availability are taken into consideration, which would enable us to better understand the possible and different scenarios. Section 2.2.3 also discussed how droughts and saltwater intrusion impact rice cultivation and production. The Aman variety of rice which accounts for more than half of annual rice production is likely to be impacted by droughts because it is only cultivated during winter months when the droughts occur and are expected to become more severe. Therefore, investments in water infrastructure by the public sector are important to reduce such risks during winter months. It is important to give credit when it is due, such as for many research institutes in Bangladesh who have been very proactive in developing saline resistant varieties of rice and have been successful. However, there are no drought-tolerant varieties of rice yet. Therefore, further research in this specific area is needed.

Section 2.3 discusses the contrasting viewpoints of several researchers on whether Bangladesh should choose mitigation, adaption or both. Researchers Alam et al, Shaw et al and Erickson have all stated that Bangladesh should lean towards adaptation to fight against climate change, which is usually the norm for a developing country. Whereas, Brammer argues for mitigation especially in the form of structural methods to control floods in Bangladesh. He states that even though large-scale projects that were proposed such as those by Flood Action Plan did not succeed in the past does not imply that mitigation measures should not be considered at all. However, it is important to mention that large top-down approaches such as by FAP were not effective due to extreme high costs of building and maintenance. Ultimately, the FAP along with its mitigation measures were not successful and its objectives were not met. It had continued to face much more

criticism due to its extensive floodplain intervention and lack of public participation. Therefore, a recommendation for the Bangladeshi government is to include the general population in climate change planning; after all they are affected the most when disaster strikes. In Section 2.3.1.1, Ayers et al provided an interesting perspective; she argued that there are benefits to linking the two approaches. However, it must be considered that Bangladesh is one of the poorest countries in the world and the government does not have sufficient resources to build and maintain large structural engineering works, which are part of mitigation. As shown in the past, the massive Flood Action Plan was a disaster and eventually its objectives were not met. Section 2.3.2 discussed the implementation of The National Adaptation Program of Action (NAPA) and Bangladesh Climate Change Strategy Action Plan (BCCSAP). It is noteworthy to mention that Bangladesh was one of the first countries to submit a National Adaptation Programme of Action (NAPA) to UNFCCC. Considering all the different perspectives on this issue, I believe that Bangladesh should focus more on adaptation as opposed to mitigation measures.

CHAPTER 6: CONCLUSION

Global climate change is one of the foremost challenges of our current century. It was found by reports such as from the Climate Risk Index 2017 that overall there has been an increase in extreme weather events, with certain regions in the world facing them more frequently. Importantly, it was discussed that by the year 2100 global sea levels are expected to rise by up to ~60cm (IPCC, 2014). In Section 1.2, Bangladesh's demographics and geographical information were presented. As found in many studies, it is one of the countries most vulnerable to climate change especially in terms of rising sea levels, as 80% of the landmass considered to be floodplains. This was one of the primary reasons, as to why this paper focuses exclusively on Bangladesh. What is of high concern is Bangladesh's ever expanding and large population, the majority of whom work in the agriculture sector, still live below the poverty line, and hence are highly vulnerable to even the slightest changes in climate. By the year 2060, the UN World Populations Prospective databases estimates the population of Bangladesh will reach 202 million. Therefore, with rising sea levels and a booming population, amongst many other factors Bangladesh is in a very dire situation.

In conclusion, burning fossil fuels from the industrial revolution and onwards has released large amounts of greenhouse gases into our atmosphere. As these gases accumulate, they are altering the delicate balance of our global climate. It has taken over two decades just to establish the scientific footing of the climate change problem. Albeit, there is much more research to conduct regarding this sensitive issue, what is at least something to acknowledge is that at the present time there is a need, a want and an urgency to learn more about climate change and to find sustainable solutions for the future generations to come especially for developing nations such as Bangladesh. Even though these developing nations are the least responsible for climate change they are however, the most vulnerable to its effects, and this creates a lot of injustice (Adger et al, 2003). The developed nations are not only less vulnerable to the impacts of climate change, they also have higher adaptive and mitigative capabilities to combat and cope better with the changes due to enhanced financial and technological means.

As discussed thoroughly in this paper, Bangladesh is expected to be the country that will face the most impacts of climate change. At present times, it has already become evident that this small, poverty-stricken nation has been facing devastating climate change effects in just the past decade, in the form of more frequent cyclones, floods, salt-water intrusion as well as droughts. It is heartbreaking to see that as a developing country that produces a small percentage of global greenhouse gases, is in such a vulnerable situation. As Afsan Chowdhury as highlighted in his documentary, 'Does anyone care if Bangladesh drowns?' (2007) it is unfortunately as if no one cares and the poor continue to suffer and face the most risks. However, this is certainly not fair and this is a classic example of climate injustice.

Therefore, international policy makers must acknowledge this and along with the government of Bangladesh, help the Bengali people adapt to the upcoming and continuous challenges that climate change is imposing upon them because there is no more time left, the time to act is upon us now. It is very important that scientific researchers and international policy makers as well as the government of Bangladesh innovate more options for climate change adaptation and thus help improve the adaptive capacity of the Bengali people especially for the vulnerable and poor farmers, whose livelihoods heavily depend on their agricultural practices and production. More specifically, it is vital to improve the adaptive capacity and to increase resilience in the agriculture sector, which is one of the most instrumental sectors in the economy of Bangladesh. With an ever-increasing population, Bangladesh has to find sustainable methods to continue harvesting rice as resources such as water and land are becoming scarcer, to ensure food security for all its citizens.

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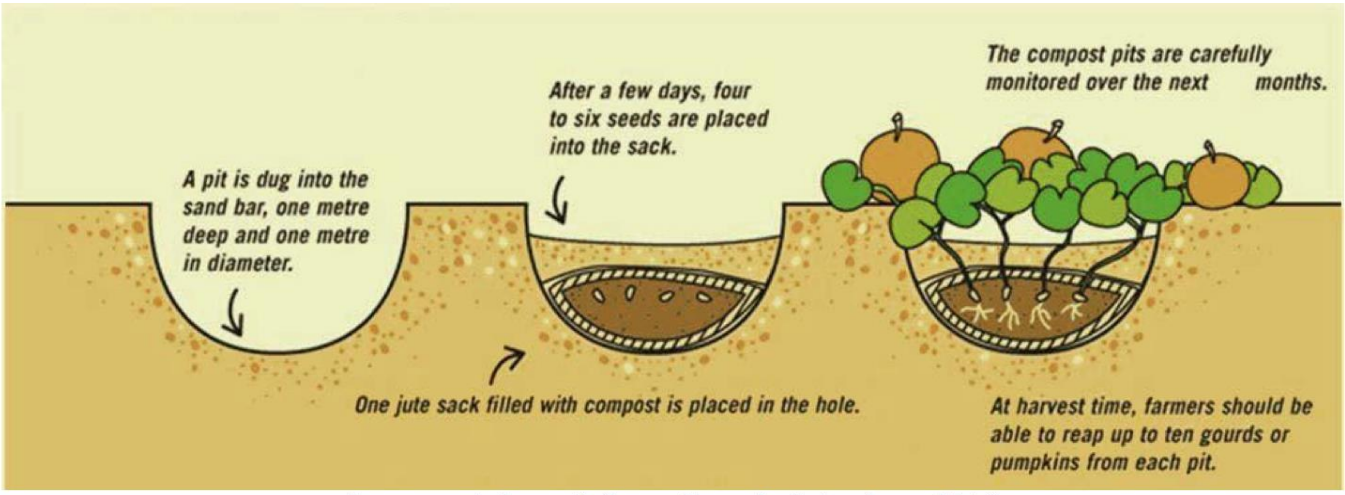
Appendix A. Pictures of Baira Cultivation and Pumpkin Farming on Char

Sources: Down to Earth and Turning Compost into Food, Practical Action



Source: Adapted from Practical Action, 2012

Appendix B. Informed Consent Form for Telephone Interviews

Tahsin Rahman
Student I.D: 215111743
Masters in Environmental Studies
Email: Tahsin.rahman20@gmail.com
Phone number: 416-303-6021
York University, Toronto, CA

Verbal Consent Script for long-distance telephone interviews to Bangladesh

Addressing Climate Change and Flooding in Bangladesh

Introduction:

Hello. My name is Tahsin Rahman and I am conducting interviews about the impacts of more frequent and severe floods in Bangladesh due to climate change. I'm conducting this as part of my Masters research for my major paper under the Faculty of Environmental Studies at York University in Toronto, Canada. I'm working under the direction of my supervisor Dr.Ellie Perkins of York's Faculty of Environmental Studies.

Study procedures:

I'm inviting you to do a one-on-one telephone interview that will take around half an hour to an hour. If you agree to participate in this study, I will ask you questions about the impacts of annual flooding on your livelihood and what the government and NGOs have done to help you in the past and what are they doing now to help you prepare for future floods? I will take notes to record your answers as well as use an audio recorder on my laptop to make sure I don't miss out on anything that you say. You will not be paid for taking part in this study.

Risks:

The risks involved in participating in this study are minimal. There will not be any serious harm associated with the interview that you may face. However, you might find some questions uncomfortable to answer or you may worry that people around you are listening. If such a situation arises, then you do not need to answer questions that make you feel uncomfortable or that you do not want to answer. Also you can withdraw/stop-taking part in this study at any time.

Benefits:

It is unlikely that there will be direct benefits to you but by better understanding this issue, there can be steps taken in the future to help your society.

Maintaining strict confidentiality:

I will now explain to you how I will protect your privacy;

I will keep the information you tell me during the interview confidential and my notes will be stored securely. Information I put in my study that could identify you will not be published or shared beyond the research team unless we have your permission. **If your consent is given (this will be asked to the participants during the beginning of each interview for example "Do you give me your permission to audio record your responses?) I will record your responses using a voice-recording program on my laptop.**

Any data from this research, which will be shared or published, will be the combined data of all participants. That means it will be reported for the whole group not for individual persons.

Voluntary participation:

- Your participation in this study is voluntary.
- **You can either provide me with your name or choose to remain anonymous (this will be asked in the beginning of each phone interview with each participant)**
- You can decide to stop at any time
- If you decide to stop participating, there will be no consequences to you.
- If you decide to stop we will ask you how you would like us to handle the data collected up to that point.
- This could include returning it to you, destroying it or using the data collected up to that point.
- If you do not want to answer some of the questions you do not have to, but you can still be in the study if you want to.

Consent questions including naming of participants:

- You can either provide me with your name or choose to remain anonymous
- Do you have any questions or would like any additional details?
- Do you agree to participate in this study knowing that you can withdraw at any point with no consequences to you?
  [If yes, begin the interview.]
  [If no, thank the participant for his/her time.]

If you have any questions about this study or would like more information, please do not hesitate to contact me at tahsin.rahman20@gmail.com and I will be glad to answer your questions.

If you have any further questions you can contact:
Senior Manager & Policy Advisor for the Office of Research Ethics, 5th floor, York Research Tower, York University, 416-736-5914 or ore@yorku.ca

Appendix C. Telephone Interview Questions

Tahsin Rahman
Student I.D: 215111743
Masters in Environmental Studies
Email: Tahsin.rahman20@gmail.com
Phone number: 416-303-6021
York University, Toronto, CA

Questions to ask participants over Telephone Interviewing

1. What is your name and age? When did you last face flooding?
2. Did you have time to prepare for the flooding?
3. Did you take any steps to save your belongings at your house before the water got there?
4. How high did the water get around your house? How long was the property under water?
5. How did the flood affect the rice crops and the farm where you work? What got destroyed in the flood?
6. Are there any positive impacts on the rice production and cultivation even after being damaged by the floods?
7. Are there any methods that that you use to adapt to floods such as by creating floating gardens/'baira'?
8. What did the properties look like once the flood waters receded and how long did it take?
9. What are the reasons do you think for the occurrence of floods?
10. Did the Government or NGOs offer any help/support?
11. How did the floods affect your health? Do you know anyone that got sick during the flood or right after it? Were you able to get any medical assistance?
12. During the flood were you provided temporary accommodation/shelter?
13. Were any warnings given prior to the flood?
14. Has any scheme been launched to help you reconstruct your houses?