Co-benefits as an enabler of sustainable adaptation to climate change: the case of Bangladesh

Syed Mahbubur Rahman

December 2020

Acknowledgements

This research was supported by JSPS RONPAKU (PhD Dissertation) Program through JSPS Research Grant Number 26285041.

Executive Summary

Adaptation at the local level is one of the core functions for the adoption of the 2030 Agenda for Sustainable Development, which includes 17 Sustainable Development Goals and 169 targets with a particular focus on people, planet, prosperity, peace, and partnership. However, not all adaptation interventions, irrespective of implementing agencies like the government and non-government organizations (NGO), bring positive changes; maladaptation results in negative consequences. Adaptation co-benefits are the additional social, economic, and environmental benefits beyond the stated objectives, which may have been identified or not during the initial phase of planning and implementation. There are confusions among researchers whether adaptation interventions are socially or environmentally sustainable or ever contribute to poverty alleviation or social well-being. Knowledge about the dynamism of co-benefits, which many interventions do not sufficiently take into account, is a prerequisite for ensuring sustainable adaptation. Hence, this research aims to assess and compare adaptation co-benefits from the project level. This study intends to answer are the following research questions: (i) what are the co-benefits of the selected interventions, measured by employing an adaptation co-benefits assessment methodology? (ii) What does the community perceive about co-benefits from an adaptation intervention? (iii) Are adaptation co-benefits necessary for sustainable adaptation? This research employed a case study method where sources of data were focus group discussions and in-depth interviews. Measurement of adaptation co-benefits followed an index-based method and residents' perception. After introductory Chapter 1, Chapter 2 and 3 discuss the theory and background of adaptation, maladaptation, and sustainable adaptation along with the Bangladesh context. After explaining research methods in Chapter 4, Chapter 5 and 6 describe the case studies of Rajshahi and Barguna, respectively. Chapter 7 discusses the findings, while Chapter 8 concludes the dissertation.

Bangladesh is among the highly climate vulnerable countries and has been hosting numerous adaptation interventions. Since purposeful sampling is appropriate for certain conditions, this study investigated three distinct projects: region-wide solar irrigation in the northwestern part of Bangladesh implemented by the Barind Multipurpose Development Authority (BMDA), and homestead plinth level raising and pond sand filter in the southern coastal zone implemented by SANGRAM, a local NGO. Selected projects vary in terms of funding sources, implementing entities, the number of beneficiaries, and the financial contribution of the beneficiaries.

From the analysis of the BMDA-initiated solar irrigation project in northwest Bangladesh, as shown in Chapter 5, this research finds that although the residents are adapting to climate change, there is a general lack of information about climate change and co-benefits therefrom. The index-based co-benefits assessment identifies that the project returns high climate adaptation co-benefits. Dissemination of information about co-benefits by government officials is very minimal. Nonetheless, employment in agriculture, family peace, willingness for schooling, and limited temporary migration are the co-benefits perceived by the community people. The intervention helps conserve natural resources and also contributes to disaster mitigation and management. By contributing to income and agricultural employment, the intervention has reduced vulnerability and raised the adaptive capacity of the community people, with obvious mitigation benefits. The only possible challenge for irrigation is the use of groundwater since it depletes. The overall returns ensure the region-wide irrigation program a sustainable adaptation.

From the analysis of the NGO-implemented projects in the coastal south, as shown in Chapter 6, this research finds that raising the homestead plinth level and constructed pond sand filter bring some positive changes to the community. The index-based assessment shows that raising the plinth level has resulted in adaptation co-benefits, while pond sand filter brought negative co-benefit. Dissemination of adaptation co-benefits by the project implementers is not sufficient. Nonetheless, the community perceives some co-benefits, including temporary employment, homestead gardening, reduced migration, improved sanitation, and the reduced cost of health services. The co-benefits have resulted in resilience enhancement, disaster mitigation and management, vulnerability reduction, and enhanced adaptive capacity. The potential problem remains with the operational aspect: ownership attitude is missing for pond sand filter.

Adaptation interventions in Bangladesh provide both positive and negative co-benefits, irrespective of the scope of the intervention strategy, implementing entity, location, and the number of beneficiaries. Adaptation interventions may fail to provide intended benefits, but not necessarily be argued as maladaptation. Communities' low level of awareness and knowledge is due to a lack of education and insufficient communication by both government and the NGO. The selected interventions resulted in vulnerability reduction, as well as enhanced adaptive capacity and resilience of the community; accordingly, evaluated as sustainable adaptation. The findings also suggest that the positive co-benefits are a necessary condition for sustainable adaptation. This research contributes to the global environmental studies by providing examples of adaptation of resource constraints vulnerable communities and human-environment-climate interactions. Finding a sustainable way of living through various adaptation interventions from a community perspective would enrich existing literature. Yet, further investigation may include a quantitative approach to assess co-benefits, and nation-wide research to list and specify co-benefits from various adaptation interventions.

Table of Contents

List of Tables

List of Figures

List of Abbreviations and Acronyms

ACP	Asian Co-benefit Partnership
AR4	Fourth Assessment Report
AR5	Fifth Assessment Report
BDT	Bangladesh Taka
BADC	Bangladesh Agricultural Development Corporation
BMDA	Barind Multipurpose Development Authority
CARB	California Air Resources Based
CBACC-CA	Community-based Adaptation to Climate Change through Coastal Afforestation
CDM	Clean Development Mechanism
CO_2	Carbon dioxide
COP	Conference of the Party
EU	European Union
FAO	Food and Agriculture Organization
GEF	Global Environmental Facility
GHG	Greenhouse Gas
GIZ	Gesellschaft für Internationale Zusammenarbeit
GOB	Government of Bangladesh
IDCOL	Infrastructure Development Company Limited
IGES	Institute for Global Environment Strategies
IISD	International Institute of Sustainable Development
IKI	International Climate Initiative
INGO	International Non-Governmental Organization
IPCC	Intergovernmental Panel on Climate Change
LDC	Least Developed Countries
MOE	Ministry of Environment (Japan)
MOFA	The Ministry of Foreign Affairs
MOEF	The Ministry of Environment and Forest
NAPA	National Adaptation Plan of Action
NAMA	Nationally Appropriate Mitigation Actions
OECD	Organization for Economic Co-operation and Development
REB	Rural Electrification Board
SHS	Solar Home System
TNA	Technology Need Assessment
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNDP	United Nations Development Program

CHAPTER 1
INTRODUCTION

1.1 Introduction

In an extensively lengthier timespan climate change appears natural and legitimate to the mankind. The earth experienced several considerably longstanding climatic changes in the past; for instance, the latest ice age persisted till 10,000 years ago (Monroe and Wicander, 2009, p. 358). However, the unprecedented trajectory of climate change and global warming has raised a universal concern to initiate actions against climate change. The Fifth Assessment Report (commonly known as AR5) prepared by the Intergovernmental Panel on Climate Change (IPCC) affirms that warming of the climate system is indisputable, and the argument is supported by the evidences of mounted atmospheric and ocean temperature, reduced amounts of snow and ice as well as rise in sea level (IPCC, 2007; 2013). The IPCC AR5 also informs that the annual emission of greenhouse gases (GHGs) – the major reason for anthropogenic climate change – between 2000 and 2010 have increased by ten Giga ton carbon dioxide (CO_2) equivalent (CO_{2e}) (IPCC, 2014). Although daily global CO_2 emissions during Corona Virus Disease 2019 decreased by 17% in early April 2020 compared with the mean 2019 levels, such decline will have little impact on overall CO_2 concentration (Le Quéré et al., 2020; Borunda, 2020). The argument holds true since it is demonstrated by the recent global CO_2 concentration in the atmosphere, which was 411.28 parts per million in October 2020 (NOAA, 2020). Scientists and researchers believe that on top of other factors to influence climate change, human deeds are the foremost reason and accountable for the warming occurred during the last five decades. The emissions global population already generated have some obvious consequences. Accordingly, the United Nations Framework Convention on Climate Change (UNFCCC) has adopted two fundamental approaches – mitigation and adaptation – to address climate change and its impacts.

IPCC (2007) defines mitigation as “an anthropogenic intervention to reduce the anthropogenic forcing of the climate system” that “includes strategies to reduce green-house gas sources and emissions and enhancing greenhouse gas sinks.” Adaptation, on the other hand, is an “adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities” (IPCC, 2007). While the methods and tools used for execution of climate change strategies are different, i.e. adaptation and mitigation, the two basic tools to address climate change and its impacts are integrally allied because of their relations in a way that more effective immediate mitigation action necessitates less effort for adaptation in the future (Ayers and Huq, 2009). However, mitigation should preferably be implemented by developed countries and adaptation is preferred in developing countries (Klein et al., 2007). The argument is backed by the phenomena of varied economic conditions of different countries. Mitigation requires investment in technology, and hence developing countries may find it difficult. Adaptation to climate change has the potential to assist economic development (Reif and Osberghaus, 2020), which requires local-level adaptation to be supported by the local and international policies and measures (Chatterjee and Huq, 2002).

Adaptation is basically a process through which all units of the society, starting from an individual to a nation as a whole, initiate tools and techniques to contest against the adverse consequences of climatic change. Adaptation Policy Frameworks, a comprehensive guideline to adaptation policy making, defines adaptation as “...a process by which strategies to moderate and cope with the consequences of climate change, including variability, are developed and implemented" (UNDP-GEF, 2004). There are however actions taken to avoid or reduce vulnerability that impact other system, sector or social group adversely, termed as maladaptation (Barnett and O'Neill, 2010). Maladaptation increases vulnerability of the targeted or external actors. The unintended impacts from adaptation include positive, negative or neutral consequences (Atteridge and Remling, 2018; Eriksen et al., 2011). It is reasonably assumed that adaptation ensures positive returns while maladaptation results in negative returns including negative co-benefits. If an intervention strategy explicitly brings negative co-benefits to the community where it is implemented or to the neighboring community, it is an example of maladaptation. Adaptation impacts extend beyond human development perspectives, often termed as co-benefit, when viewed from the UN Sustainable Development Goals (SDGs) (Doundoulakis and Papaefthimiou, 2020). The UN SDGs include 17 goals and 169 targets targeting people, planet and prosperity. The Agenda 2030 was adopted in 2015 which also include peace and partnership. Climate change and the relevant impacts have a close connection with the achievement of many SDGs.

Implementation of various adaptation interventions are done by both government and non-government organizations (NGOs), financed by both government and donors under bilateral and multilateral arrangement. Individual adaptation strategies are also in practice (Anik and Khan, 2012). NGO involvement in response to climate change had substantially grown during the 90s, which included among others participation in the negotiations of the UNFCCC processes, local government and municipalities (Carpenter, 2001). NGOs have shown their capacity in delivering environmental services to communities and vulnerable groups while also have played key roles in various activities including adaptation campaign, mobilizing climate fund, communicating climate change and policy partnership (Tahiru et al., 2019). Various case studies showed that government played role in national and/or provincial policymaking for instance in Bangladesh and China, while NGOs were the main initiators and actors in Kenya and Senegal; in India local communities were found the main initiator and actor (Huq et al., 2005). In Vietnam, NGOs were found engaged in community advocacy or poverty alleviation (Singer et al., 2014). It has also been found that knowledge mobilization by government and NGO shows some differences (Haque et al., 2017a).

The 2030 Agenda for Sustainable Development (specifically, SDG 13) urges for actions against climate change and its impacts, where adaptation at local level is one of the core functions. Various nature-based solutions contribute and support in generating social, economic and environmental co-benefits; hence, sufficient knowledge about dynamism of co-benefits is a prerequisite for successful adaptation interventions at local level (Martin et al., 2020). In many cases, co-benefits have been highlighted, and in many other cases are ignored (Nika et al., 2020; Wu et al., 2020; Srinivasan et al., 2018). Many adaptation initiatives do not sufficiently take in to account co-benefits and social benefits (Van Oijstaeijen et al., 2020), while these interventions have high potential to assist achievement of the 2030 Agenda.

During the beginning of last decade, some researchers raised questions about actions addressing climate change: whether the actions were socially or environmentally sustainable or if the actions contributed for poverty alleviation or human well-being, or had the potential to increase vulnerability (Barnett and O'Neill, 2010; Eriksen and Brown, 2011). Potential beneficiaries' low perception of adaptation co-benefits, among others, (Rahman and Mori, 2020) has prevented beneficiaries from enhancing ownership to (for instance, externally funded) adaptation interventions, and thus hindering these interventions from scaling-up. The bottom-up approach to climate change generate knowledge from community people through assessing and analyzing climate change, its impacts, risks and responses in which perception of residents plays pivotal role (Conway et al., 2019). Bottom-up approach takes a qualitative stance to characterize the social vulnerability, and later to evaluate and implement adaptation. In contrast, the top-down approach is more quantitative in nature and involves assessment of expected impacts of climate change (Bhabe et al, 2014).

Therefore, recent literatures have started to focus on co-benefit approach to climate policy in order to fill the research gap in the linkage between transformation adaptation projects and various sectors addressing sustainable development, and approaches towards the action (Gao and Jiang, 2020; Schneider, 2020). Adaptation intervention depends on various sets of factors including versatile impacts of a disaster, different socio-economic variables, geographic characteristics, and early warning information (Saroar and Routray, 2010; Paul and Routray, 2011; Islam et al., 2014). Individual adaptation action that brings benefits, including co-benefit, for the broader community is an underexplored arena (i.e. 'has been neglected in the conceptualization of the adaptation process, yet a critical component of the action…') of climate change adaptation research (Tompkins & Eakin, 2011).

It is evident that environmental issues have gained increasing attention due to growing environmental crises and natural disasters, increasing awareness among decision and policy makers, as well as collective media involvements in favor of environment protection (Kieu et al., 2016; Leszczynska, 2010). There is considerable level of environmental concerns and awareness towards climate change, one of the most discussed global issues that significantly influence behavioral changes (Said et al., 2003; Halady and Rao, 2010). Components of environmental awareness include environmental knowledge, values, attitude, willingness to environmental act and actual behavior (Zsoka, 2008). Research has shown that there is a need to raise awareness and knowledge about various aspects of climate change, for an instance, energy savings (Ma et al., 2011). Besides, since country's socio-economic condition affects attitude towards environment, there is a need to raise ecological awareness in less developed countries (Leszczynska, 2010). Laroche et al. (2001) used eco-literacy to measure peoples' ability to identify or define a number of ecological symbol, concept and behaviors, and pointed out that education of consumers are important to act environmentally friendly. Prior awareness has been identified as key determinant of acceptability where awareness is related to gender, age, education and environmental knowledge, for instance, knowledge about hydrogen fuel influences acceptance of hydrogen vehicles (O'Garra et al., 2005). Various interventions have also addressed lack of knowledge, awareness and skills about nature conservation and sustainable use of natural resources, for instance Hariyo Ban project in Nepal (Gyawali et al., 2017). Climate change awareness including knowledge about adaptation co-benefits is also assumed to influence adaptation practices. Hence, this research focuses on adaptation co-benefits.

1.2 The Problem Statement

The term co-benefits is used in different ways, making it difficult to explain using a single taxonomy to cover a wider range. Based on an extensive review it has been suggested that intentionality, scope and scale of co-benefits are the three core elements policy makers should concentrate (Floater et al., 2016). Intentionality refers to the design and implementation of adaptation intervention to bring either deliberate or accidental climate benefits; scope refers to capturing climate benefits through adaptation and mitigation alone or both together; and, scale refers to temporal or geographical dissemination of co-benefits. IPCC (2001; 2007; 2014) in its various documents highlighted positive effects as climate co-benefits. In contrast, various literatures have identified terminologies like co-harm and co-impact with regard to climate actions (Scovronick et al., 2019; Schneider, 2020; Hamilton and Akbar 2010), which is rational.

There are enough evidences of both adaptation success and adaptation failure which have provided lessons to be learnt (Klöck and Fink, 2019). For successful adaptation, capacity to adapt is a necessary condition (IPCC, 2007). Although contested, the broad definition of adaptive capacity refers to the ability of an individual or unit to adapt to the current and possible future effects due to climate change (Williams et al., 2015). However, there are growing evidences that many of the climate adaptation interventions, irrespective of its types, have been implemented against the principles of sustainable development; a specific adaptation policy and/or intervention targeting to minimize the impact of a unique problem may adversely affect other group(s) (Ahmed et al., 2017; Eriksen and Brown, 2011; Barnett and O'Neill, 2010). Individual adaptive practices reduce risk levels of the individual, while harmful in larger regional context; for instance, shrimp cultivation causes mangrove forest destruction (Ahmed et al., 2017, Rawlani and Sovacool, 2011; Wamsler and Brink, 2015). Instead of looking only at mechanical and/or technical solutions to a climate change-induced problem, a holistic view including social, political and cultural issues is essential for sustainable adaptation, along with understanding the risks and impacts (Eriksen and Brown, 2011), which is missing in practice. Besides, in regard to individual adaptation actions a particular group from citizens may show less interest in climate action, and tendency towards handing over the responsibility to the authority. Due to such lack of interest, it has been argued that adaptive capacity does not ensure sustainable adaptation always (Wamsler and Brink, 2015). If no action is taken, achievement of SDGs would be hindered. Co-benefits have the potential to significantly exceed primary benefit (Markandya and Rübbelke, 2004), but underexplored as of yet. It is also not clear whether co-benefits are necessary or sufficient conditions for sustainable adaptation.

The promotion of the co-benefits approach and hence widespread research is hindered by lack of awareness about co-benefits, lack of capacity to quantify it, as well as the differences in priorities and interests by the stakeholders (Goco, 2005), though the approach is considered as the only assessment framework that proactively considers systemic linkages, synergies, and trade-offs for instance between cities and climate change (Sethi, 2020; Martin et al., 2020). Co-benefits highlight the shorter-term impacts of climate investment (Herrero et al., 2013). Within climate change interventions it is foregrounded to accommodate immediate economic needs with the likely benefits from climate change mitigation and adaptation (Smith, 2013). There is also argument and evidences that co-benefits serve for better climate actions (Kundzewicz et al., 2020). Co-benefits are often disregarded since many non-market benefits plays role (Herrero et al., 2013). At national level many countries have shown substantial progress in terms of economic growth simultaneously by tackling climate change and environmental degradation; yet a comprehensive level of co-benefits to be achieved (Gao and Jiang, 2020). During the last two decades the number of studies on co-benefits, especially related to emission mitigation from transport sector policies, increased significantly (Mrkajic et al., 2015); however, there is a dearth of research about co-benefits from adaptation interventions already implemented, especially those in the context of climate vulnerable developing countries. Climate change in developing countries is deep-rooted in the core economic development issues, hence making the study of adaptation complex (Halsnæs and Verhagen, 2007). Adaptation on different time scales, both short-term and long-term, along with different bureaucratic levels - local, regional or national, is practiced throughout the globe (UNDP-GEF, 2004); nevertheless, it rarely takes into account the intended and unintended positive and negative consequences as a strong deciding criteria. Sethi (2018) has explored many grey areas in the conceptual, methodical, empirical and governance issues which may conceal some of the co-benefits. To resolve such issues, greater application of spatial, temporal and real time analysis among others are also proposed.

Along with the circumstances mentioned above, the study of co-benefit seems important for the following reasons. First, the national adaptation program provides considerable co-benefits, which subsequently create opportunities to access international climate finance (Pathak and Shukla, 2016). Second, if co-benefits with varied degree of intentionality, scope and scale from climate actions are accentuated, people tend to become proactive in climate action or become more supportive towards pro-climate government (Bain et al., 2016; Floater et al., 2016). Third, co-benefits from adaptation may have, depending on the nature of the intervention strategy, mitigation benefits (Dovie, 2019). For an instance, Torres et al. (2015) have found that co-benefits from proximate projects may become more significant than mitigation benefits of more distant cheaper projects. If co-benefits are taken into account, a far stronger case for climate policies may be initiated, and it may convince mass people, especially including those who do not accept that climate change is real (Smith, 2003). It has also been argued that assessment of co-benefits is important since it allows incorporation of a range of positive side effects of climate investments in decision-making tools. However, globally accepted tools for assessing co-benefit are yet to emerge.

Sustainable adaptation, which roughly features the types of interventions that simultaneously address climate change, poverty and development together, has become a debatable issue during the last decade, particularly for developing countries in choosing the best way to respond to climate change (Brown, 2011). Sustainable adaptation intervention reduces vulnerability and enhances long-term resilience in a changing climate (O'Brien and Leichenko, 2007). It has been argued that the post-implementation adaptation interventions should strive to ensure sustainability through improvement in program quality suitable to institution and community (Barrera et al., 2017). However, there is a lack of empirical evidences about sustainability of various adaptation interventions and how knowledge about co-benefits helps implement sustainable adaptation. There is also lack of evidence that country-driven bottom-up approach is preferred instead of top-down approach to climate change (Carraro, 2006).

Recognizing the gap numerous researchers have urged for further investigation about how capacities of the stakeholders be supported and incentivized, as well as how individual adaptation affects other interventions' needs and resources (Wamsler and Brink, 2015). Evaluation of the extent to which co-benefits arise upon completion of a specific adaptation intervention and the way stakeholders' involvement affect co-benefits have also been suggested (Schneider, 2020). Besides, variations in results due to different implementing entity require manifestation. Concentrating on adaptation co-benefits, this research aims to fill out the gap. The following conceptual framework is being followed for the intended research.

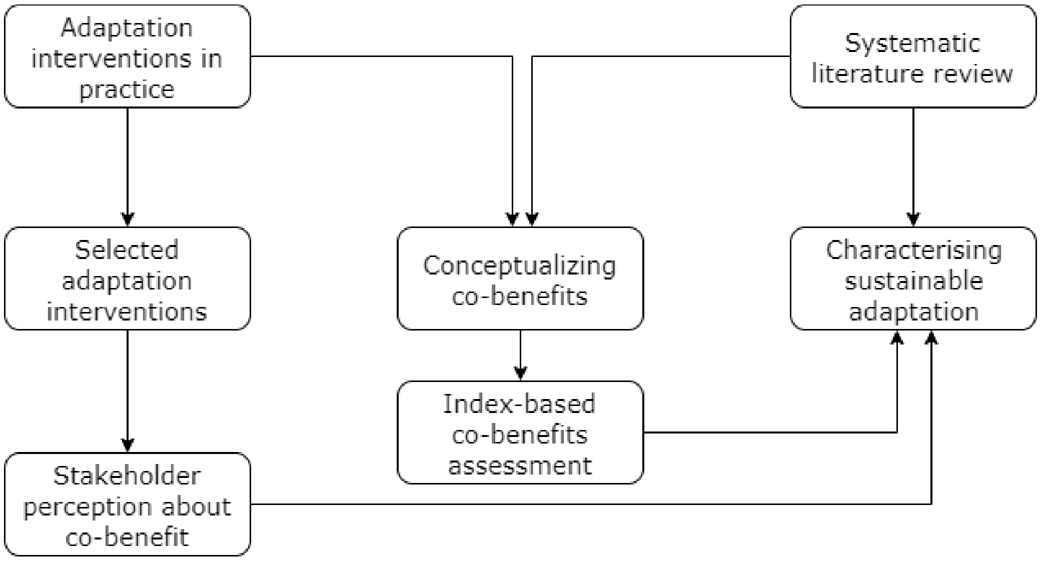

Figure 1.1: Conceptual Framework

1.3 Research Objectives and Research Questions

The goal of this research is to analyze adaptation co-benefits as an enabler for sustainable adaptation from project-level. Answers to the following specific research questions would serve the purpose:

1. What are the co-benefits of the selected interventions, measured by applying the adaptation co-benefits assessment methodology?

A suggested index of adaptation co-benefits assessment methodology has been used to answer the research question.

2. What does the community perceive about co-benefits from an adaptation intervention?

Stakeholders' perception about adaptation co-benefit from project level has been analyzed to answer this question.

3. Is adaptation co-benefits a necessary condition for sustainable adaptation?

Assessment of vulnerability, adaptive capacity and resilience of the community has been conducted from co-benefits perspective at project level to answer the research questions.

1.4 Scope and Limitations of the Research

Since among the countries highly vulnerable to the impact of climate change, Bangladesh has initiated and implemented a handsome volume of adaptation interventions in different communities with varied climatic threats throughout the country financed by the government and various donors. This research investigated only three examples of different measures that address distinctive impacts of climate change. There are a couple of hundreds of diverse adaptation measures in practice in different cities, semi-urban and rural areas. Questions may rise if three examples are sufficient to conclude a judgment. Since, the community, particularly the beneficiaries, possesses similar social and economic status, this research with selected cases is assumed to represent overall adaptation practices in Bangladesh (explained in detail in Chapter 4). The research has encountered troubles in the data collection phase due to the lower level of education and literacy of most of the participants. This was overcome by explaining the questions and context first to the respondents for several minutes, and then by asking the questions. Time was another constraint. This study relied mostly on in-depth interviews of various key stakeholders and focused group discussions, without use of any inferential statistics. Chapter 4 discusses the methods, study area, data collection and analysis in detail.

1.5 Structure of the Dissertation

This dissertation has started with a background analysis followed by the objectives and the rationale combined in the Introduction, Chapter 1. Chapter 2 discusses about the theories and backgrounds about adaptation, co-benefits and sustainable adaptation in detail. Chapter 3 explains the Bangladesh context including her vulnerability towards climate change and various measures in practice. The literature also covers the discussion about the Barind Tract at the northwestern part of Bangladesh and the coastal region of the south. Chapter 4 explains the research methodology, sources of data and methods of data collection and the way the data is being used for analysis. Chapter 5 focuses on analysis and findings from the case Rajshahi, the drought prone area followed by Chapter 6, which focuses on Barguna, a coastal district from the south. Chapter 7 discusses the findings from the cases explained in previous two chapters. Chapter 8 concludes the dissertation..

CHAPTER 2
SUSTAINABLE ADAPTATION AND CO-BENEFITS: THEORY AND BACKGROUND

The aim of this chapter is to highlight the relevant literatures. The chapter starts with the basic idea of adaptation, maladaptation and sustainable adaptation. Maladaptation and sustainable adaptation are the two opposing consequences of adaptation depending on the way an intervention is implemented and maintained. This chapter also discusses the concept of adaptation co-benefit and co-benefit assessment method. Both top-down and bottom-up approach of adaptation are practiced around the world. A mixed approach combining both has some merits and demerits; besides NGO and government interactions in adaptation actions are of importance, and hence, have been explained in this chapter. Co-benefit approach in adaptation planning and implementation is hindered by many factors, which has also been addressed. Based on the review of literature, working hypotheses of this research are summarized at the end. A structured method for selecting literature from SCOPUS database relevant for this study has been followed, which is shown in Appendix 2. Set key words were sequentially used to find the most relevant literatures. Finally, manual investigation was conducted to find the appropriateness of the literature for this study.

2.1 Adaptation, Maladaptation and Sustainable Adaptation

The IPCC (2007) extended the definition of adaptation as any "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities." Later, Moser and Ekstrom (2010) have identified few limitations of the IPCC definition; for instance, adaptation may be initiated to address the impacts from nonclimatic issues, and effective results from adaptation are contingent on multiple factors, which the IPCC definition does not specify. Taking into account the limitations, Moser and Ekstrom (2010) define adaptation as follows:

> *Adaptation involves changes in social-ecological systems in response to actual and expected impacts of climate change in the context of interacting nonclimatic changes. Adaptation strategies and actions can range from short-term coping to longer-term, deeper transformations, aim to meet more than climate change goals alone, and may or may not succeed in moderating harm or exploiting beneficial opportunities.*

Successful adaptation reduces the risks associated with climate change and the vulnerability results from the impacts to a predetermined level without compromising economic, social and environmental sustainability (Doria et al., 2009).

Based on differentiating concepts or attributes adaptation may be categorized in many different ways (Smith and Pilifosova, 2003). According to one method, there are three major categories of adaptation: coping response, incremental adaptation and transformative adaptation (Fedele et al., 2019). Coping strategies are taken to maintain business-as-usual scenario. Incremental adaptation, which is more anticipatory than coping strategies, accommodates small-scale changes in existing socio-ecological systems. The transformative adaptation, a long term result-oriented strategy, eliminates the root causes of vulnerability.

Adaptation measures may fail and increase vulnerability instead of reducing, which is often termed as maladaptation (IPCC, 2001; Barnett and O'Neill, 2010). Maladaptation has been defined as *action taken ostensibly to avoid or reduce vulnerability to climate change that* *impacts adversely on, or increases the vulnerability of other systems, sectors or social groups* (Barnett and O'Neill, 2010). Juhola et al. (2016) defined maladaptation as *a result of an intentional adaptation policy or measure leading to negative outcome(s) for the targeted or other* actors. Maladaptation has been evidenced in various locations and sectors. In five different ways maladaptation may arise: activity increasing GHG emission, disproportionate distribution of burden to the vulnerable, high opportunity cost, reduced incentives for adaptation, and limited path choice for future generation (Barnett and O'Neill, 2010). Juhola et al. (2016) later identified three categories of maladaptation with (i) rebounding vulnerability, (ii) shifting vulnerability, and (iii) eroding sustainable development.

Adaptation policy may increase the resilience toward, including non-climatic disasters like, earthquakes, volcano eruptions, and technological disasters (Reif and Osberghaus, 2020). Analyses of the differences between adaptations that produce co-benefits and maladaptation that produce adverse side effects are the keys to ensure that policymakers choose the most suitable courses of action to address climate change. It is found that adaptation project developers and various climate funds as well highlight explicit or implicit positive effects only from the adaptation intervention (Atteridge and Remling, 2018). Showcasing the positive impact only has a manifold effect on vulnerable communities. Analysis of the gap between adaptation and maladaptation is much needed to ensure today's investment decision right and adaptation choice smarter. Besides, if risks and vulnerabilities are redistributed through adaptation, reassessment of adaptation finance is necessary to ensure justified future allocation of fund (Atteridge and Remling, 2018). Accordingly, it requires investigation whether and how these possibilities are taken into consideration while intervening at the local level adaptation in countries highly vulnerable to climate change like Bangladesh.

There are no globally accepted criteria or yardstick to identify maladaptation (Grangberg and Glover, 2013). Maladaptation outcomes may span across time and space. An adaptation action does not necessarily remain; instead it may be failed policy that does not reduce vulnerability to climate change impacts (Juhola et al., 2016). Assessment of maladaptation would help identify various aspects of vulnerability, sensitivity towards risk and adaptive capacity (Juhola et al., 2016; Barnett and O'Neill, 2013). These three aspects are also relevant for analysis of sustainable development.

Sustainability has been a catchphrase both in science and policy for the last couple of decades across private and public sector, business and industry as well as from cities to regions to countries. Although the motives and the determinants for such popularity of the term are contingent to actors and phenomena, both politics and scientific agenda globally have acknowledged mainstreaming the concept to national development priority (Latawiec and Agol, 2015). Accordingly, adaptation interventions to address the negative impacts of climate change and climate change-induced disaster consider sustainability issues in its planning and implementation phases.

Not necessarily all of these are sustainable, nor the popular adaptation means sustainable adaptation. It requires a set of indicators to be measured in order to term an adaptation intervention sustainable or not. *Sustainable adaptation can be defined as a set of actions that contribute to socially and environmentally sustainable development pathways, including social justice and environmental integrity* (Eriksen et al., 2011). A transparent political process supporting enabling environment and access to information for decision making may result in sustainable adaptation, which ensures the following key principles (Eriksen et al., 2011):

i) Recognizing the context for vulnerability caused by multiple stressors.
ii) Acknowledging various values in vested interests in specific intervention strategy, which may hinder accomplishing sustainable adaptation.
iii) Integrating indigenous knowledge into adaptation practices.
iv) Recognizing positive and negative feedbacks generated from interaction between local and global processes.

Research about connection between local adaptations and intervention outcomes should be a priority (Barrera et al., 2017). Such research is likely to explore sustainability of various interventions. It has been argued that sustainable adaptation must focus on three core criteria (Eriksen and O'Brien, 2007). First, minimizing risks while maintaining the current well-being; second, strengthening adaptive capacity of the marginalized; and third, addressing the causes of vulnerability among the poor. Besides, it should be ensured that focus on any of the three associations does not negatively affect the other or both. Sustainable development and sustainable adaptation share some unique characteristics (Brown, 2011). Based on substantiated reviews research has found that only a small fraction of global adaption interventions was conforming to the broader definition of sustainable adaptation (Brown, 2011). It has also found evidences of adaptation, which were not sustainable at all and found to be detrimental to the environment and marginalized.

Climate variability at present and the anticipated longer-term changes in climate represent a major impediment to enhance sustainability (Hay and Mimura, 2006). Adaptation needs to go beyond climate-proof existing development plans, and climate proofing needs to be placed within wider climate risk management frameworks (Brooks et al., 2011). It has to be acknowledged that development of an outcome-based adaptation indicator is challenging, especially where adaptation actions are targeted at managing change, and hence an alternative approach should focus on good evidence of effectiveness for measuring adaptation (Morecroft et al., 2019).

Sustainable adaptation requires extending the boundaries of current practices giving full concentration on vulnerability, resilience and poverty reduction (Eriksen and Brown, 2011). Sustainable adaptation and development discourse assists in learning about formation of governance and policies in developing countries (Eriksen and Brown, 2011). Knowledge transfer has been seen as a way to support physical measures for adaptation, scale-up local adaptation and risk assessment (Wamsler and Brink, 2015). By addressing social justice and environmental integrity, it urged for societal transformation and organization to ascertain sustainable adaptation (Eriksen and Brown, 2011). The former two are the pillars of sustainable development, achieving which provides the working definition of sustainable adaptation (Brown, 2011).

2.2 Conceptualizing Adaptation Co-benefit

The term 'co-benefit' has derived from 'environmental externality', which may be positive, negative or pecuniary in nature. A positive externality is co-benefits and negative externality is co-damages or co-harm or negative co-benefits, which is either intended or unintended from the process or system (Schneider, 2020; Yedla and Park, 2009; Turner et al., 1994; Tietenberg, 1996). Co-benefits are also referred to as the additional benefits, which may have been or have not been noticed during the initial stage of risk reduction measures as an intended output from the system (Samarasekara et al., 2017; Khew, et al., 2015). The term has been used interchangeably with secondary benefits, policy spillover effects, or ancillary benefits: the benefits that accrue as a side effect of targeted policies (Pearce, 2000). Co-benefits are the added paybacks beyond the direct benefits community receives from any act of controlling climate change (Smith, 2013).

On a different flair, co-benefits are defined as additional environmental, social, and/or economic benefits. They range from transportation, disaster risk reduction, health, land use and water sector to agricultural production as well as food security (Floater et al., 2016). Floater et al. (2016) have also found that health, land use and transportation are the top three priorities in co-benefit analysis. Co-benefits are viewed broadly both as multiple environmental and development benefits, and narrowly as a single benefit, for an instance reduced air pollutants (ACP-IGES-MOE, 2014). Although unnoticed in many cases, intended or unintended positive or negative co-benefit across sectors, scales, and timeframes both in mitigation and adaptation strategies are common (Spencer et al., 2017; Berry et al., 2015; Hamilton and Akbar 2010; Füssel, 2007). Coverage of co-benefits may spread to various collective factors including economics and social capital; and, co-benefits bringing tangible benefits have the potential to multiply the positive impacts of mitigation and adaptation efforts (Spencer et al., 2017). Within a selected set of domains, co-benefits are manifold and possibly reinforcing, while potential co-harms are rarely observed in many other interventions (Schneider, 2020). Hence, the study of co-benefit is important, particularly in the places where the population is vulnerable to the impact of climate change (Spencer et al., 2017).

Researchers across countries differ in their opinion in conceptualizing co-benefits. Academic and practitioners need a shared understanding and a common definition of adaptation co-benefit. For instance, contribution of climate-resilient economic development through investments in education and training to improve labor skills, and in market connectivity and efficiency is argued as co-benefits in the Ethiopian perspective (Yalew et al., 2018). Managing adaptation for the persistence of fodder production provides co-benefits for erosion control in the French Alps (Lavorel et al., 2018). Health sector has shown that green prescription provides a wide range of co-benefits from individual skills to social, environmental and socio-economic benefits which include among others ecological knowledge, social inclusion, restoration of ecosystems, and creation of new jobs (Robinson and Breed, 2019). Therefore, a common understanding in conceptualizing adaptation co-benefit is much needed to advance adaptation co-benefit research.

Initially, co-benefits were assumed to be associated with climate change mitigation only; especially, health-related co-benefits from mitigation were more in focus (IPCC, 2007). The mitigation-centric co-benefit analysis and evaluation, however, has shifted its concentration, and been reflected in the Fifth Assessment Report (AR5) of IPCC. AR5 has pinpointed that successful adaptation strategies have to ensure inclusion of co-benefits (IPCC, 2014). The twenty-third Conference of the Parties (COP23) of the UNFCCC, held in Bonn in 2017, requested the Parties to submit methods and approaches for assessing adaptation co-benefits along with adaptation and resilience (UNFCCC, 2018). All of the positive outcomes associated with multiple and simultaneous emission reduction measures are co-benefits (Fitzgerald and Villarin, 2005). The opposite is co-harm or negative co-benefit, which is also common in many practices (Schneider, 2020; Hamilton and Akbar 2010). However, a clear definition of co-benefit is still missing (Mayrhofer and Gupta, 2016).

Co-benefit has gained special attention in the Paris Agreement, and recommendations were made to activate co-benefits for implementation of the Paris Agreement. Article 4 of the Paris Agreement recommended inclusion of a dedicated section about co-benefits in the nationally determined contributions to portray and communicate social and economic opportunities of the commitment. Besides, Article 5 recommended a connection between existing national social and economic opportunities, which were also co-benefits. Article 6 asked for developing a set of principles to guide the assessment and reporting of co-benefits of mitigation and tools for the evaluation of co-benefits. Article 9 recommended climate finance to showcase nonclimatic benefits, and also to consider co-benefits in project selection criteria (International Climate Initiative (IKI), 2018). All of these guidelines raised question about co-benefits from adaptation interventions, and thereby sustainability.

Co-benefits are not the primary benefits any intervention brings to the community or to the neighborhood where adaptation intervention takes place; instead, these benefits arise due to systematic approach or procedural application. Both in policy and academic literature, the term 'co-benefit' has been defined differently (Floater et al., 2016; Krupnick et al., 2000). Floater et al. (2016) listed more than 20 vocabularies, for instance, win-win situations, triple-win situations, and consequential benefits, which are used interchangeably with co-benefits. Krupnick et al. (2000) did not differentiate between co-benefits and ancillary benefit. Miyatsuka and Zusman (2009) identified three different ways to conceptualize co-benefits: development co-benefit, climate co-benefit, and climate and air co-impact. However, this argument was too narrow, which considered local benefits from climate policies, and prioritized development before climate considerations and air pollution.

A development initiative can yield positive adaptation co-benefits, provided it takes into account climate change during the design phase. If co-benefits were taken into account, a far stronger case for climate policies may be initiated, and it may convince mass people, especially those who do not accept that climate change is real (Smith, 2013). In addition, adaptation actions have the potential to provide significant co-benefits including poverty alleviation and overall development. Maximizing these synergies require integration of adaptation actions with existing policies (Martin et al., 2020). Hence, it has been argued that co-benefits should be factored into decision making, which ultimately suggests that with equivalent level of ancillary effects from two competing adaptation projects, projects with larger positive impacts would be favored. The use of soft, short-term and reversible adaptation options with co-benefits for local governments hence are preferred. However, the broad scope also limits comprehensive consideration of adaptation options, non-market co-benefits, equity issues, and adaptation decision making (Chambwera et al., 2014).

From the theoretical evidences discussed above, this research considers any intentional, incidental or accidental positive and/or negative return beyond the stated objective(s) of an adaptation intervention, irrespective of recognition in any stage from intervention design to implementation to post-implementation impacts, that the community in which the intervention carried out, or the neighboring community, encounters as adaptation co-benefits. If favorable returns are ensured, it is positive co-benefits, otherwise negative co-benefits. Following the classification identified by Floater et al. (2016), both climate adaptation benefits and non-adaptive benefits including economic, social and environmental benefits have been considered in this research. For instance, use of common resources by individuals and households increases social interactions. Obvious mitigation benefit has also been considered, where has found relevant. This research relied both on both literature and stakeholders' perception, which led to divergence in understanding few terminologies, for instance, adaptive capacity. Adaptive capacity has been observed as direct benefit, while in many components in the capacity can be seen as co-benefits.

2.3 Assessment of Adaptation Co-benefits

Before assessing adaptation co-benefit, measurement of adaptation needs to be conducted. It has been argued that feasibility, efficiency and effectiveness, acceptability and legitimacy, equity and sustainability are the most important criteria for evaluation of adaptation intervention (Brooks et al., 2011). Evaluation of adaptation also depends on the type of adaptation approaches: utilitarian and egalitarian. While utilitarian approach ensures benefits to the maximum number of people with highest efficiency, egalitarian approach provides benefits to them who are in most need of it (Brooks el al., 2011). Effectiveness and progress made towards adaptation is measured by adaptive capacity, level of resilience, and level of vulnerability to climate change, where many of the indicators are easily measurable and some are hard to measure (Morecroft et al., 2019). Timeliness, shifting in baselines and vulnerability indicators also play important role in evaluation of adaptation. However, it has to be noted that there is no single metric for measuring adaptation (Pringle and Leiter, 2018; Brooks et al., 2011).

Since co-benefits provide a win-win situation for both local and global advantages, especially to the developing countries, Kwan and Hashim (2016) have argued that to face the triple challenges of development, pollution and climate change adaptation, co-benefits should be integrated with the strategies for sustainable development. To ensure climate change strategy-inclusive development agenda, co-benefits approach would play an important role by showing its maximum positive effects from any development activity (Kwan and Hashim, 2016; de Oliveira, 2013). In that case, assessment of co-benefits from adaptation intervention is the priority. It has also been argued that achieving climate compatible development requires realization of co-benefits (Wise et al., 2016). However, assessment of adaptation co-benefits is an under explored area of research.

After reviewing several classifications of ancillary benefits suggested by the IPCC AR5 (2014), various research have categorized co-benefits of adaptation into economic, social and environmental aspects (Klein et al., 2014; Dovie, 2019; Surminski and Tanner, 2016; de Murieta, 2020). Spencer et al. (2017) analyzed four case studies from the tropics, two each from mitigation and adaptation, which emphasized accessible and manageable co-benefit strategies. While for mitigation, waste, air quality, transport and energy have attracted more researchers to assess co-benefits, literature about adaptation co-benefits concentrates otherwise (Floater et al., 2016). Overall, land use, health, water, and education have been observed to be the stronger assessment criteria for both mitigation and adaptation co-benefits. For adaptation co-benefits, social and economic aspects may also be investigated (Martin et al., 2020). There is a potential for investigation about how a specific adaptation intervention provides co-benefits (Mrkajic et al., 2015), especially using an index-based assessment tool.

One such tool, the adaptation co-benefit assessment methodology, has been jointly developed by the University of California, Berkeley and California Air Resources Base (CARB) (2018) (Appendix 1a). This is an index-based tool applicable to various adaptation interventions, explained in methodology section. This measure of adaptation co-benefits first showed different levels of co-benefits from different interventions. While some interventions ensure positive co-benefits at varied level, some interventions may provide negative co-benefits. This variation may be the result of different indicators used. The index proposed by the CARB includes a limited number of positive and negative co-benefits. A list including couple of hundreds of co-benefits is possible from a set of adaptation measures or even from an individual intervention. Such listing requires extensive research for a vast number of adaptation interventions in the global scale. Since not all interventions have similar co-benefits, co-benefits assessment would be context specific, and hence be made separately. Even an adaptation intervention implemented in two regions would have the potential to provide several distinctive co-benefits. For an instance, saline tolerant variety of agriculture in a drought-prone area and in a coastal area would come up with different sets of co-benefits, which are influenced by for example the economic status of the community, level of unemployment in the community and proximity to sea or source of water for irrigation.

It is to note that index-based assessment is not free from flaws. The major problem of index-based assessment of co-benefit, along with other value of interest, lies with the process of development of such index. These indices are not developed following a global dialogue. Different organizations, institutions and universities develop various indices for instance vulnerability index, global climate risk index and the recent Notre Dame Global Adaptation Initiative (ND-GAIN) for their own interest or for others. These indices have not been discussed or have not been placed in the global dialogues like COP of the UNFCCC for instance, to include it in the global climate change governance process. Accordingly, such indices are not commonly accepted.

Many individuals initiate adaptation interventions on the basis of their cost-benefit analysis (Mendelsohn, 2006). Srinivasan et al. (2018) have measured resilience, risk reduction and vulnerability in order to assess adaptation co-benefits in natural resource conservation, disaster risk reduction and livelihood development, respectively. In many other complex situations, initiatives and support from higher level and incentivize actions are crucial (Nainggolan et al., 2014). Co-benefits have the potential to offset financial cost of intervening along with boosting their political acceptability. Efficiency of adaptation intervention is measured by the benefits and costs associated with the actions (Mendelsohn, 2006). Cost-benefit analysis in financial terms may provide better yardstick for adaptation; nevertheless, it is not always possible to measure. Recognizing the losses from expected climatic change in global scale and valuing them in absence of adaptation intervention is still complex. Adaptation paradox (Ayers, 2011; Dupuis and Knoepfel, 2013) makes it more complicated. The common paradox is, climate change is a global problem but vulnerability is locally experienced (Ayers, 2011).

The Paris Agreement urge for adaptation to consider SDGs including poverty, gender dimension, living and livelihood of people (Lin, 2019). Different specific SDGs, for instance, SDG 13 along with SDG6, SDG7 and SDG9 are more or less much related to adaptation (Bleischwitz, 2019). It has been argued that to operationalize SDGs as a framework for considering sustainability of adaptation it would require formulation of specific services adaptation measures can deliver, matching the services with SDG targets and indicators, and formulation of indicators at project level aligning SDG indicators (Sørup et al., 2019). Accordingly, a project level investigation seems rational.

2.4 Top-down vs. Bottom-up Approach to Adaptation

Top-down approach focusing on direct cause-and-effect relationship is convenient, while bottom-up approach considers the human-environment interaction more in a social context [Adger and Kelly, 2004; New Zealand Climate Change Centre (NZCCC), 2010]. The bottom-up approach includes multi-level stakeholder involvement, and the top-down approach involves technical soundness from policy perspective (Bhabe et al., 2014). Both bottom-up and top-down applications are based on some assumptions, methods, scales and analytical designs. With associated strengths and weaknesses, both approaches may suffer from bias and lack of flexibility (Conway et al., 2019). Hence, a combined bottom-up and top-down approach is suggested (Bhabe et al., 2014). In case agriculture, seed companies and farmers may collaborate to develop drought-tolerant rice varieties; for technology adoption to ensure sustainable adaptation, government implementing adaptation may train, educate and collaborate with local organizations, leaders and citizens (Amaru and Chhetri, 2013). In Bangladesh, adaptation interventions are usually formulated by the policymakers, leaving the opportunities to include community inputs. If community or NGOs initiate ideas for adaptation and then funding and other arrangements are made from the top, a combined effort becomes visible. A combined effort to identify, prioritize and evaluate the performance of adaptation seems more practically applicable (Bhabe et al., 2014).

The Bottom-up Climate Adaptation Strategies towards a Sustainable Europe (BASE) project of the European Union (EU) has found that suitable and successful adaptation policies, planning and actions are highly context-specific, and thus require adjustment depending on locations and sectors (EU, 2016). The same project also highlighted that since resources are limited, systemic adaptation planning should be initiated to identify measures that provide co-benefits (EU, 2016). The project also raised the importance of systematic assessment of co-benefits of adaptation interventions. Therefore, it has been argued that developing a framework for mainstreaming climate change in national development strategies may provide a solution to the problem (Ayers et al., 2014; Yedla and Park, 2009). Setting up new institutions, improving awareness as well as an inclusive valuation of policies for ensuring co-benefits from actions against climate change are also suggested (Yedla and Park, 2009).

To achieve health related co-benefits, for instance, through climate actions integrated framework of top-down and bottom-up approach is suggested as a key feature, which also calls for shared responsibility among individual, community groups, public interest groups and government at spatial scale (Harlan and Ruddell, 2011). Bottom-up approach is found in greater attention in adaptation process, for instance in agriculture sector in New Zealand (NZCCC, 2010). In Chinese context, multi-level approach has been found functional for adaptation model from-national-to-local level and knowledge transfer from-local-to-national policymaking (Lo and Broto, 2019). In another research in Chinese context, the official evaluation has the claimed the integrated top-down and bottom-up approach is successful; however, in the evaluation of individual cases it has been found that top-down approach was not equally appropriate due to variability in leadership, community and interest (Lo et al., 2019).

2.5 Obstacles to the Dissemination of Co-benefit Approach

Although a wide array of co-benefits have already been identified, adaptation co-benefits is yet to attract a substantial number of researchers. After analyzing 138 relevant articles through a methodological selection process, Mayrhofer and Gupta (2016) have categorized co-benefits in a wider spectrum including climate-related, economic, environmental, social, as well as political and institutional. Recent studies on co-benefits have been conducted more in the non-industrialized South (47%) and especially in emerging economies (32%) (Mayrhofer and Gupta, 2016). More than half of the literature has used a single case and very few have comparative case studies in their research design. Only around five percent of the literature deals with theorizing the concept of co-benefits.

It is been argued that due to policy and institutional failure many environmental problems are not solved by the government initiative (Mori, 2016). It is identified that some factors, for instance, lack of co-planning and co-operation in the process of designing and implementing policies, and the leakage of emissions hinder the overall achievement of co-benefits (Jiang et al., 2016). Developing countries need to be cautious in spending financial resources, and also to ensure positive spillover effects, for instance in case of technology import, and national capacities for operation and maintenance of the imported technologies (Jochem and Madlener, 2003). Imported second-hand technology does not return effective co-benefits compared with the benefits as it provides with the latest and up-to-date technologies, which usually requires massive initial capital. Green and sustainable infrastructure ensures healthier living and working environments for the inhabitants, along with thermal comfort and more natural ventilation and lighting that also require higher investment (Balaban and de Oliveira, 2016). In such cases, the net-benefit from the system may not remain positive (Jochem and Madlener, 2003). Concerning adaptation, physical infrastructure provides some protections against natural hazards even if the infrastructure is not deliberately designed, for instance against a tsunami. However, such up-gradation of structure to ensure more resilience against hazards might become costly (Samarasekara et al., 2017; Balaban and de Oliveira, 2017).

Political usage of the term co-benefits has gained little attention (Mayrhofer and Gupta, 2016). Existing research on co-benefits rarely addresses the meaning, contestation and practical use. Since the results from actions against climate change are realizable only after certain period of time, the superiority of co-benefits analysis, however, lies with its advocacy potentials (Mayrhofer and Gupta, 2016). The authors have also summarized that analysis of co-benefits helps reduce society's cost of climate change, is politically advantageous, and helps leverage mainstreaming and integrating climate change in national development plans. While a strong appeal in practice in favor of co-benefits exists, the issues have rooms for criticism, not severe though. Methodological approaches are not unique yet to analyze co-benefits. Besides, the analysis of co-benefits suffers from a lack of available data and different accounting treatments. It has been recommended that to ensure coherent, cost-effective and sustainable climate adaptation, potential co-benefits should systematically be considered by the decision makers; besides, different sectors should actively search for solutions that provide co-benefits (EU, 2016).

2.6 NGO-Government Interaction and Realization of Adaptation Co-benefits

In the beginning NGO representations in the global environmental and climate issues were formal, while few were informal contact group meetings (Carpenter, 2001). “A small NGO might lead laboratory research but still be considered a bottom-up actor based on its scale and its supporters” (Amaru and Chhetri, 2013). The awareness raising campaigns towards climate change has continued to grow by the NGOs, along with involvement in project implementation. This change led to the disagreement within the NGO community (Carpenter, 2001). Recognizing the importance of NGOs, researchers have devoted attempts to investigate the role of such non-state actors in environmental politics (Corell and Betsill, 2001). Accumulation of evidences in a systematic way is likely to enable researcher examine NGOs contribution to environmental negotiation (Corell and Betsill, 2001) and implementation of project both by NGOs and government. There is very limited research about NGO-government interaction resulting in adaptation co-benefits.

NGOs contribution in different countries shows different dimensions. There are evidences of varied level of independent works by NGOs, cooperation with the state actors is also visible in the cases from the Philippines (Allen, 2006), South Africa (Ziervogel et al., 2010), Bangladesh (Karim and Thiel, 2017), and India (Singh et al., 2017) for instance. In the Indian context, NGOs’ intervention increases awareness about climate change adaptation (Singh et al., 2017). If awareness building is additional to the core activities NGOs perform, such increase in awareness may be seen as co-benefits. In the Philippines, government and NGO conduct excessive number of trainings that the participants, who are the same set in most of the cases at the community level, become bored of learning and memorizing what they have taught or trained for (Allen, 2006). Such outcome may not be treated as positive co-benefits. In contrast, vulnerable farmers engaged in rigorous training praised the NGOs who conducted those sessions in Ghana (Tahiru et al., 2019). In Bangladesh, NGOs play a vital role in the formation of various committees at different level addressing adaptation to climate change and community disaster management programs; however, lack of coordination exists between government and NGOs (Karim and Thiel, 2017). In case of South Africa, it is argued that government must take the leading role, although government cannot be trusted always (Ziervogel et al., 2010). Sufficient interaction between both the actors is likely to enhance and help realize adaptation co-benefits. It has been argued that NGOs may keep an eye on government and also assist in developing adaptation interventions prioritizing the local needs (Ziervogel et al., 2010). There are opportunities to develop a more coherent policy mix across sectors including both state and non-state actors in case of southern African states: Malawi, Tanzania, and Zambia (England et al., 2018). In Indonesia context, a higher proportion of NGO practitioners considers government investment and infrastructure poor (Butler et al., 2015) and unsustainable resource consumption. This may require climate governance coordination among all stakeholders.

Since prominent community members play roles in developing beneficial links with government and NGO actors (Allen, 2006), the roles of such members may be explored to ensure adaptation co-benefits. In case of South Africa, NGOs work closely with communities on various issues, disseminate climate change information and help people understand climate change adaptation (Ziervogel et al., 2010). However, there are some challenges. NGOs contributing to local climate change adaptation in Ghana are also confronted buy some challenges including lack of continuity or sustainability of projects, inadequate collaboration and networking as well as poor governance, besides political interferences (Tahiru et al. 2019). Difficulty in demonstrating benefits of adaptation is also being identified as a challenge. In case of the Philippines, households were found reluctant to invest their own resources in community projects, and hence it is argued that this unwillingness is the key factor which undermines the capacity of community from developing independent projects without state or NGO support (Allen, 2006).

Besides common understanding, there are opposing views in prioritizing issues related to adaptation at local levels. In Indonesia, climate variability, food and water security are considered more important by the government and community, while NGOs have different opinion. NGOs prefer a transformational strategy through balancing traditional values and practices with existing government structure, and government stakeholders prioritize incremental strategy (Butler et al., 2015). Considering this diverse perception, Butler et al. (2015) have argued that strengths from integration between top-down and bottom up planning may generate greater adaptive capacity. It has also been argued that although community stakeholders are included in top-down approach, it is often problematic (Butler et al., 2015).

2.7 Working Hypotheses for the Research

Past research has explored various aspects of climate impacts and adaptation measures, counteractive nature of adaptation, and lack of awareness about co-benefits. However, perception about adaptation co-benefits from diverse set of adaptation intervention is not been sufficiently addressed. To fill this research gap, this dissertation aims at empirical studies taking the case of Bangladesh. The working hypothesis, this study intends to answer are as follows:

Hypothesis 1: Adaptation interventions implemented by various implementing entities result in both positive and negative co-benefits to the community.

Hypothesis 2: There is a general lack of information and awareness about adaptation co-benefits due to insufficient dissemination by the adaptation implementing entity.

Hypothesis 3: Positive adaptation co-benefits is a necessary condition for sustainable adaptation.

CHAPTER 3
THE BANGLADESH CONTEXT

3.1 Vulnerability towards Climate Change

Apart from the emerging economies like China, India and Brazil, many developing countries, like Bangladesh, are the greatest sufferers while emit the least GHGs (UNFCCC, 2007). Bangladesh is frequently cited in academic discussions, international conferences and dialogues for its susceptibility towards climate change. Various studies identified different climatic risks Bangladesh is prone to (Eckstein et al., 2019). The World Bank (2009) ranked Bangladesh among the top vulnerable countries. World Risk Index 2012, study of Alliance Development Works (2012), shows that Bangladesh is the fifth most vulnerable country. Bangladesh is the fourth and fifth most affected country for the period of 1992-2011 and 1993-2012, according to Global Climate Risk Index 2013 and 2014, respectively (Harmeling and Eckstein, 2012; Kreft and Eckstein, 2013). Climate Change Vulnerability Index 2013, steered by Mapplecroft (2013) ranked Bangladesh as the top vulnerable country towards climate change.

Bangladesh was ranked among the top 12 countries for each of the six threats – drought, flood, storm, one-meter and five-meter sea-level rise as well as agriculture – while was found the most vulnerable towards flood, second-most vulnerable towards storm and 10th and 3rd most vulnerable towards one-meter and five-meter sea-level rise, respectively (World Bank, 2009). Recent study of Alliance Development Works (2015), with special focus to food security, has categorized risk on susceptibility, lack of coping and adaptive capacity, level of vulnerability and exposure to natural disaster; and the overall risk index ranked Bangladesh 6th most vulnerable country. Global Climate Risk Index 2016 has ranked Bangladesh 6th most vulnerable towards climate change (Kreft et al., 2015). This index measures the death tolls, total losses and losses per unit of gross domestic product (GDP) and the number of natural disasters during the last 20 years.

Ali (1999) has discussed four impacts of climate change in Bangladesh- tropical cyclone, coastal erosion, storm surges and floods; where the author has argued that even not a cyclone-prone area in terms of quantity of global cyclones, Bangladesh is among the top in terms of death tolls of a cyclone. Another study has identified Bangladesh as prone to droughts, multitude of flood, tropical cyclone, and storm surges; fifteen percent of total population resides within one meter elevation of high tide making them vulnerable to the climatic change; and more than 40 million people are at risk of salinity intrusion and irrigation (Sovacool et al., 2012a). Climate change has already affected agricultural and fishery sector in *haor* (low lying waterlogged area) areas; communities are experiencing climate variability in those areas (Rahman et al., 2007, cited in Anik and Khan, 2012). In addition to the climate threats mentioned above, Anik and Khan (2012) identified heavy rainfall as one of the major climate events in Bangladesh. Once in every 3-5 years, two thirds of Bangladesh experience flood substantially damaging housing and infrastructure, agriculture and livelihoods; once in every three years, on an average, severe cyclone hits the coastline; and the northwestern region sometimes faces droughts too (World Bank, 2010).

In a detail study of vulnerability of Bangladesh to climate change, one research has identified five sectors most vulnerable to climate change. Water resources and coastal zones were identified as the most critical affecting saltwater intrusion, drainage congestion, changes in coastal morphology and damage by the natural disasters (Rawlani and Sovacool, 2011). Infrastructure and human settlement would be affected by creation of around 25 million climate refugees from coastal districts, if 15% of landmass were inundated by the year 2050. Government of Bangladesh estimates that by 2050, rice and wheat production throughout the country may decline by eight and thirty-two percent, respectively. The mangrove forest, Sundarbans, may be severely affected; human health would also be at risk (Rawlani and Sovacool, 2011). Table 3.1 provides an overview of climate related vulnerability of different areas of Bangladesh and the main sectors exposed to risk.

Table 3.1 Critical areas and impacts of climate change in Bangladesh

Threats	Critical area	Most impacted sectors
Temperature rise and drought	▪ North West	▪ Agriculture (crop, livestock, fishery) ▪ Water ▪ Electricity supply ▪ Health
Sea level rise and salinity intrusion	▪ Coastal areas ▪ Islands	▪ Agriculture (crop, fishery, livestock) ▪ Water (water logging, drinking water) ▪ Human settlement ▪ Electricity supply ▪ Health
Floods	▪ Central region ▪ North East region ▪ Char (Riverine island) Land	▪ Agriculture (crop, fishery, livestock) ▪ Water (urban, industry) ▪ Infrastructure ▪ Human settlement ▪ Electricity supply ▪ Health ▪ Energy
Cyclone and storm surge	▪ Coastal and Marine Zone	▪ Marine fishing ▪ Infrastructure ▪ Life and property
Drainage congestion	▪ Coastal area ▪ South West ▪ Urban area	▪ Water (navigation) ▪ Agriculture (crop)

Source: Rawlani and Sovacool (2011), MOEF (2005)

Combined effect of climate change may result in 3.9% decline in rice production each year; and agricultural GDP may go down by 3.1% each year for the period of 2005-2050. Total risk of inundation in the year 2050 and risk for the poor vulnerable group of becoming more vulnerable are substantial (World Bank, 2010; Huq and Ayers, 2008). In a policy paper, Huq and Ayers (2008) has showed the sectoral risks for agriculture and fisheries, water resources, coastal zone, forestry and biodiversity, human health, urban areas and rural vulnerable group. Coastal risk has increased for the imprudent behavior of the people, for instance, historically Bangladesh had a natural buffer of mangroves of around 500 meters, which is now 12-50 meters in most locations due to illegal deforestation and pest attacks (Sovacool et al., 2012a).

3.2 Adaptation Initiatives

Bangladesh is said to be the ‘adaptation laboratory’ (Paprocki, 2018; Huq, 2011). Substantial numbers of adaptation interventions are in practice throughout the country due to its vulnerability towards climate change. During analysis of a national adaptation program on “Community Based Adaptation to Climate Change through Coastal Afforestation (CBACC-CA),” It has been found that adaptation program contributes to all of infrastructural, institutional and community as well as social adaptive capacity even though there is sometimes a lack of organization and coordination (Rawlani and Sovacool, 2011). The authors argue that technology is a partial solution to successful adaptation and hence, integrated adaptation measures are required along with government commitment. To minimize disaster related risk, Bangladesh has invested more than $10 billion during the last 35 years. If adaptation investments are not in the same pace with vulnerabilities and risks in coastal areas of Bangladesh, alternative action, like relocation of communities to higher ground, may become inevitable (Sovacool et al., 2012a). Four primary components have been identified by Sovacool et al. (2012b) in their study of coastal afforestation in Bangladesh - income generation through coupling afforestation with livelihood, capacity development, improvement of coastal management practice and development of climate related data.

In analyzing perception of community people in two divisions of Bangladesh and it was found that perception of rural people was similar in dimensions; for instance, people observed hotter summer and warmer winter along with reduced rainfall (Haque et al., 2012). However, the study focused to rural people whose means of survival was agriculture and their perception had shaded by the problems relating to agriculture with respect to heat, cold and rainfall patterns. The prediction made by the respondents in the study also included more natural disaster. One of the strongest arguments of the study is about the process of development of NAPA – in the process in 2008 no information was collected from the community, rather the government heavily relied on stakeholders meeting, reports and mathematical models; hence, this sort of report may not provide efficient inputs in policy making for sustainable adaptation actions. But Ayer (2011) has argued that –

> *[t]he process was to some extent successful in reflecting community perceptions around risk and factors that exacerbate vulnerabilities -*

while developing NAPA in Bangladesh. Ayer (2011) has also argued that communities have few opportunities to share their experiences meaningfully.

Key adaptations in agricultural sector include changes in agricultural practices to improve water efficiency and crop diversification (Abedin and Shaw, 2013), setting aside biotechnological advancement of which developing countries have limited capacity to take advantage. Ecosystem-based adaptation, which has gained a momentum since its integration to sustainable use of biodiversity and ecosystem services into a comprehensive adaptation strategy, proves to provide flexible, cost effective and broadly applicable alternatives for reducing the impacts of climate change, also generates co-benefits to communities, such as clean water, food provision, climate change mitigation and protection of biodiversity (Munang et al., 2013). In this line, bench-terracing, drip irrigation, new varieties of crop, and mixed farming are often adopted in the Adaptation Fund (AF) financed projects (Adaptation Fund, 2012; 2013a; 2013b).

Adaptation interventions in Bangladesh, whilst suffer from lack of organization and coordination, target infrastructural, institutional and community development through enhanced social adaptive capacity (Rawlani and Sovacool, 2011). Technology has been observed as a partial solution to successful adaptation. There are many success stories about adaptation interventions, for instance the Community Based Adaptation to Climate Change through Coastal Afforestation which contributed to infrastructure by creating a natural buffer of mangrove forest and also developed ‘Forestry, fishery and food – Triple F’ model. Such model has an explicit economic motivation, and hence promoted by the policy makers for improvement of social adaptation.

Adaptation governance structure of Bangladesh is characterized as hierarchical led by central government following a top-down approach, horizontally disintegrated, and mostly implemented within ‘development’ and ‘disaster response’ sector (Haque et al., 2017b; O’Donnell et al., 2013). NGO-led projects, some of which are research oriented in nature, in Bangladesh have been more open in mobilizing knowledge for adaptation including participatory risk assessment and co-management (Haque et al., 2017b). In selected cases in Bangladesh, limited number of stakeholders and more participatory approach have been found in government and NGO-led projects, respectively (Haque et al., 2017b). However, NGO initiatives are on an ad hoc basis and isolated from other NGOs. While government-led projects follow their own lines of communication between knowledge producers and users, NGOs focus on how knowledge can be mobilized and communicated with the communities (Haque et al., 2017b).

Some common intervention strategies in the coastal areas of Bangladesh include raising the homestead plinth to remain unaffected from high tide during cyclones, filtering water and saline tolerant variety of seeds for agriculture (Aryal et al., 2020; Rahaman et al., 2020). These measures can generate important co-benefits including improvement of soil and its fertility, clean air and water, and biodiversity conservation (Smith 2013). Particularly for southern part of Bangladesh, although construction of polders for instance had a goal, among others, to reduce the impacts from salinity intrusion, an integrated approach is still needed since it has implications for daily lives and livelihood of the coastal people (Gupta et al., 2005). In the northwestern part, irrigation through solar is an adaptation intervention with high potential to reduce the GHG emission. Co-benefit approach may add value to such integrated measures, which require further investigation. Co-benefits in the domain of social and economic gains are underexplored area of research.

3.3 Coastal Dynamics of Bangladesh

Bangladesh has 710km long coastline along the Bay of Bengal and coastal zones are categorized on the basis of three criteria - tidal fluctuation, salinity intrusion and cyclone risk. The entire Bangladesh, in addition to the risk associated with coastal zone, is exposed to flood, drought and riverbank erosion. The northwestern part comprising two divisions: Rajshahi and Rangpur, is prone to drought which affect agricultural production. Nineteen administrative districts are in the coastal zones that cover around 32% of the total area of Bangladesh. Geomorphological segregation includes three coastal regions; western region includes part of Khulna and Barisal divisions, central region includes very small part of Barisal division and Chittagong division and Eastern part is entirely with Chittagong division. During the period of 1960-2009, 15 cyclones washed away the coastal zones of Bangladesh, out of which nine cyclones passed through southeast and four passed through southwest coastline (Karim and Mimura, 2008; Penning-Rowsell et al., 2012). In the Technology Needs Assessment (TNA) report, an outcome of TNA project, a joint initiative of the UNEP and the GEF, Bangladesh has prioritized energy and agriculture sectors for mitigation; for adaptation three sectors, namely agriculture, coastal zone and water resources have been prioritized (UNEP-GEF, 2012). Height of the storm surge in excess of 10 meters is also common to Bangladesh; sea level rise and backwater effect of flood have impacts on coastal erosion (Ali, 1999). A recent study by the World Bank (2010) has explained that two thirds of the country is less than five meters above the sea level and subject to flood during monsoon. The coastal areas of Bangladesh suffer from frequent cyclones, severe waterlogging and salinity, while the northern part suffers from drought resulting in severe loss of production in agricultural and shortage of safe drinking water (Abedin et al., 2019; Sovacool et al., 2012a; MOEF, 2005). Changing climate has worsened the overall situation over the years.

3.4 Renewable Energy in Irrigation

Renewable energy generates feedback effect (Mori, 2018; 2019). Agriculture is currently a major source of GHG emissions (Li et al, 2020), and as such is called for a transition towards carbon neutrality. There are numerous carbon-neutral measures ranging from emission reduction from fertilizers and livestock, conservation tillage, avoidance of over-application of synthetic fertilizers and tree plantation to consumption of less animal products. Renewable energy in agriculture in the form of, for instance, solar powered irrigation in the northwestern part of Bangladesh is remarkable (Rahman et al., 2020). A vast majority of the land areas in Bangladesh get adequate solar radiation, which is sufficient to generate electricity through the utilization of photovoltaic technology (Hasanuzzaman et al., 2015; Baten et al., 2009; Mondal and Denich, 2010). The share of renewable energy for greater access to electricity, particularly in rural Bangladesh, underpins the arguments in favor of solar energy. Besides, photovoltaic technology is considered a cost-effective mode of electricity supply in remote off-grid locations (Twidell and Weir, 2015). Among the multiple options to lower GHG emissions, renewable energy has the potential to play a key role to mitigate climate change along with the provisions for other tangible benefits (IPCC, 2011).

Rural access to electricity has almost doubled from 30-35 percent to its current rate of around 60 percent in just five to seven years (World Bank, 2011; Urmee and Harris, 2011; Rahman et al., 2013; Kurata et al., 2018). This radical increase is the result of diffusion of solar home system (SHS), which has reached more than four million, as of May 2017 (IDCOL, 2018). Rural electrification provides multiple benefits including poverty reduction (Mondal and Klein, 2011; Urmee and Harries, 2011; Lahimer et al., 2013), health condition improvement (Komatsu et al., 2011; Mondal and Klein, 2011; Lahimer et al., 2013), quality of life (Komatsu et al., 2011; Urmee and Harries, 2011), environmental sustainability (Komatsu et al., 2011; Mondal and Klein, 2011; Lahimer et al., 2013), education improvement (Mondal and Klein, 2011; Lahimer et al., 2013), reduced household expenses (Chakrabarty and Islam, 2011; Sharif and Mithila, 2013), and more leisure time (Wijayatunga and Attalage, 2005; Urmee and Harries, 2011; Mondal and Klein, 2011) in addition to mitigation of emissions. Some of these benefits can enhance adaptive capacity, which relate to the economic, social, institutional, and technological conditions that facilitate or constrain the development and deployment of adaptive measures (IPCC, 2001). An increase in income and reduction in electricity expense can enhance financial capital, and improvements in health and education help raise human capital. Although education was mentioned in many literatures, it focused on increased duration of homework for school only. The literature did not mention about length of schooling or dropout. However, length of schooling and dropout rate matter much more than simple registration to school (Kim et al, 2019).

The widespread use of renewable energy has impacted little at a micro-level (Rahman and Ahmad, 2013). Specialized financing, and government provision of technical knowledge to launch a renewable energy business are expected to encourage rural entrepreneurship, which would eventually benefit an integrated approach linking irrigation (Shrimali and Rohra, 2012; Khan et al., 2019). While substantial potential is there, agriculture in rural Bangladesh is yet to attract renewable energy sufficiently.

A solar irrigation system is framed as alternative to conventional electricity and diesel-based pumping systems for agricultural irrigation. It is expected to conserve electricity by reducing the usage of grid power and conserves water by reducing water losses, thus increase local farmers productivity and their living conditions, particularly in arid regions of Africa and Southern Asia. It is estimated that farmers of those regions would increase their yield by

300% if they could have access to a motorized pump (Roblin, 2016). Hence, many analyses have focused on economic viability and technological feasibility rather than climatic impacts. Initial analyses suggest technical and economic feasibility only for the applications with enough land coverage available for the solar array (Kelley et al. 2010) or with long-term operation (Senol, 2012). This accrues to high initial investment and non-sustainability of the system due partly to lack of qualified and fine-caliber staffs that can operate and maintain the system properly (Sontake and Kalamkar, 2016). Recent analyses, in contrast, provide evidences of economic viability in comparison to electricity or diesel-based systems for irrigation and of shorter investment payback period (Pullenkav, 2013; Chandel, Naik, and Chandel, 2015). However, co-benefits from climate change mitigation and adaptation are not counted on in these estimations.

Solar irrigation pumps provide many co-benefits including source of safe drinking water, gender empowerment and electricity supply to households when irrigation is not required (Agrawal and Jain, 2019), as well as significant poverty reduction (Gupta, 2019) that enhance the social impacts of the system. Such impacts have not been investigated sufficiently in the Bangladesh context as of yet. This comes to an attention to solar irrigation system—an irrigation system using solar powered irrigation pump—as a would-be suitable option in agricultural application, especially for distant rural areas (Mekhilef, 2013). Coupled with significant decline in the cost of PV module and Balance of Systems (BoS), technological developments based on the guidelines to domestic manufacturers to ensure quality product with better performance and long life, for instance under the Jawaharlal Nehru National Solar Mission in India, resulted in lower costs, while improved water discharge (Chandel, Naik, and Chandel, 2015). Hence, solar irrigation systems become economically viable and attractive as compared to diesel-based pumping systems. Perceiving an additional in-kind income from home garden, a solar irrigation system is increasingly adopted as a component of community-based adaptation projects in drought prone rural areas (Alexandre and Nimul, 2014). Net positive feedback effect from renewable energy results in further dimensions for instance political economy. Mori (2018) identified feedback effects as relevant to technology and policy. Changes in norms, policies and regulations are the example of technology feedback effect, while distribution of resources and material incentivizing to strengthen particular social interest groups are the examples of policy feedback effect (Mori, 2018).

3.5 State and non-State Actors in Climate Change

Both mitigation and adaptation projects in Bangladesh have a certain level of integration with NGOs. The common examples of such involvement in the southern part of Bangladesh include aquaculture and disaster management, while agriculture in the northern part (Brouwer et al., 2007; Pouliotte et al., 2009). NGOs are also involved with safe drinking water, coastal flooding, afforestation and waste management. NGOs in Bangladesh also play a significant role in mainstreaming climate change adaptation into national development agenda through isolated pilots and projectized interventions (Ayers et al., 2014).

One of the largest initiatives has pointed out the obvious action of relocation of the community irrespective of success rate of the CBACC-CA program (Rawlani and Sovacool, 2011). The authors find that CBACC project has made significant contribution to infrastructure by creating a natural buffer; has developed community and social responsiveness through innovative approach of 'Triple F' model; and also, has developed institutional capacity. 'Forestry, fishery and food – Triple F' model has an explicit economic motivation and hence, promoted by the policy makers for improvement of social adaptation (Sovacool et al., 2012a), whereas combined benefits are expected to be enjoyed for long time.

Custom of indigenous knowledge and technology has a long history in adaptation practices in Bangladesh. However, in many cases vulnerable community does not find the required technology, although the knowledge somehow available to them. Anik and Khan (2012) have named the local fishermen and farmers as ‘soldiers without sword’, since local people are found trying to cope with adverse impact of climate change without adequate equipment and technology. The authors have found 16 popular adaptation strategies, out of which ten practiced at individual level and six at community level. Six out of 16 strategies were supported by the NGOs or government organizations, and the rest were through indigenous knowledge.

With regard to energy, the government of Bangladesh allocates most of the subsidies to the centralized power system. It did not take strategies of rural development through supply of energy in the past (Mondal and Klein, 2011). Due to dispersed location and distance, extending electricity grid in the rural areas is not perceived as a feasible solution (Urmee and Harries, 2011). Most of the rural areas are not connected to the national grid. This raises cost of water access, and prevents farmers from cultivating dry lands to meet their income deficits for basic needs. In addition, inadequate billing and maintenance system and other technical difficulties impair economic viability (Biswas et al. 2004). Despite, low investment along with supportive policy initiative and innovative ideas for renewable energy from both public and private sector has influenced growth of solar energy (Sharif and Mithila, 2013). This doubles for instance diffusion of solar home systems and raises rural access to electricity from 30-35 in 2011 to 69 percent in 2016 (World Bank, 2011; Rahman et al., 2013; Kurata et al., 2018). Prominent NGOs like Grameen Shakti, a sister concern of Noble laureate Grameen Bank, have been contributing in solar home systems and solar irrigation systems, along with government owned non-bank financial institutions like Infrastructural Development Company Limited (IDCOL).

CHAPTER 4
RESEARCH METHODOLOGY

4.1 Research Design and Tools

In the analyses of co-benefits quantitative approach, both financial and non-financial, is dominant; for instance, quantification of air pollution measures and the number of jobs created. Although have found diversity in sectoral and spatial analyses of co-benefits, only one-fifth of the academic literature employs a qualitative research design to analyze co-benefits (Mayrhofer and Gupta, 2016). It has been argued that by going beyond quantitative estimations qualitative, non-market and non-monetary aspects should also be assessed to explore the importance of ancillary benefits including equity and justice as well as distributional effects (de Murieta, 2020; UNFCCC, 2009). To fill the gap a qualitative approach has been used for the research, which includes focus group discussions (FGD) and in-depth interviews with a semi-structured questionnaire.

FGD and interviews with semi-structured questionnaire are suggested for various categories of research (Creswell, 2009, p 98; Le and Mori, 2017). FGD protocol and questionnaire for in-depth interviews are provided in Appendix 3 and 4. Qualitative semi-structured open-ended interviews have been successfully used in various issues related to the impact of climate change, and it is assumed that might best represent the accuracy and complexity of adaptation in Bangladesh (Rawlani and Sovacool, 2011; Sovacool et al., 2012a; Osbahr et al., 2008; Whitmarsh, 2009). An inductive approach, where an initial question is asked and the respondent is allowed to say as much as he/she wants in detail, has been followed.

4.2 Case Selection

Case studies are analytical instead of being statistically generalized, and purposeful sampling is considered appropriate for certain conditions (Shakir, 2002). In order to avoid the danger of selection bias there is argument why researcher should select cases randomly; however, there are still potential serious problem that may arise from randomized selection of cases (Seawright and Gerring, 2008). Gerring and Cojocaru (2015) have argued that selection of cases following a certain protocol creates some problems. These problem arises when the research question is vague and the population is not well understood, lack of useful cases (which is very common social science), and when statistical model does not fit. In such cases a qualitative method is suggested (Gerring and Cojocaru, 2015). Since the evidence from multiple cases is more assorted and reliable, representative multiple case study approach is preferred for various research (Mori, 2020; Shakir, 2002). Due to insufficiencies from random selection and also problems from pragmatic selection, some forms of purposive sampling of cases are stronger, although the later *cannot entirely overcome the inherent unreliability of generalizing from small* samples (Seawright and Gerring, 2008).

There are innumerable approaches for selection of case in case study research, and there is hardly any agreement among researchers on how to choose a best case (Gerring and Cojocaru, 2015). Following the cross-case methods of case selection guidelines by Seawright and Gerring (2008), this research followed methods those are diverse and most different. Diverse method is suitable for exploratory and confirmatory research where the cases show variation of population. Besides, most different case method provides strong basis for generalization. However, carefully selected paired cases may also be challenged (Klotz, 2008). The selection of cases for this research may also be justified as diverse-case method, since the goal is to capture a wide range of variation in variables of interest (Gerring, 2008). Diverse case methods include minimum two cases that provide various values of interest with some sorts of associations between variables. Some of the variables of interest for the research are categorical, and the diversity among the scenarios is readily visible. Case selection for this research may also be matched with one of the two categories of predetermined criteria of case selection strategies: snowball and opportunistic sampling strategies, since the cases were selected based on fieldwork (Shakir, 2002). Some of the strategies for selection of case are exploratory in nature (Gerring and Cojocaru, 2015). The selected cases are outcome-case which is designed to construct an explanation for adaptation co-benefits in situations, which are assumed to be little known (Gerring and Cojocaru, 2015). Two categories of adaptation approaches were also in consideration; i.e. both utilitarian and egalitarian approaches of adaptation were under investigation. Solar irrigation follows a utilitarian approach while, plinth level raise and safe drinking water are egalitarian approach.

Since a wide array of adaptation interventions has been implemented in the region through various units including both government and NGOs, and financed by different bodies including international donors and national government, a study of all categories of adaptation interventions seems practically almost impossible. Hence, this research selected two categories of projects: project both funded and implemented by the government, project funded by donor or government but implemented by NGO. Projects selected for the study and their respective characteristics are listed in Table 4.1.

Table 4.1: List of selected adaptation interventions and core characteristics

Explanation	**Barguna Sadar**	**Godagari**
Projects	Homestead plinth level raising	Water sufficiency for irrigation
	Safe drinking water through pond sand filtering	-
Project Characteristics	**Barguna Sadar**	**Godagari**
Duration	Usually 2-3 weeks for implementation	Ongoing program
Funding	Donors and government. Bangladesh Climate Change Resilience Fund, a multi-donor trust fund, entrusted PKSF to channel he investment under Community Climate Change Project (CCCP)	Government
Implementers	NGO	Government
Number of beneficiaries/scope of project	A few households to maximum of a hundred households	More than 28000 ha of land under project coverage
Gender balance	Female involvement is high	Female involvement is from negligible to nil
Financial contribution of beneficiaries	Minimal; even without any contribution one can gain benefit	Pay-as-you-go options for beneficiaries

Solar powered irrigation in the Barind area is expected to bring some social and economic benefits while ensures GHG mitigation. To capitalize on this cost effective technology in order to boost farm production in drought prone rural areas of the Barind Tract, the northern part of the country, the Bangladesh Rural Electrification Board (REB) set up a solar powered irrigation pump in an experimental basis at Mirjapur under Godagari upazila (the study location for this research) of Rajshahi in 2012 . While the authority has neither framed this project for energy nor climate purpose, it does take climate impacts into account. The project also aims at reducing dependence on ground water. By replacing groundwater for surface water, it is expected to save more than 38% of the Barind Tract from desertification, and to protect its ecological balance (Alauddin and Sarker, 2014). It is estimated that irrigation through surface water in the whole district would raise the cropping intensity to 228 percent from the then 192 percent to result in an additional production of 211,000 tonnes of food grains (Alauddin and Sarker, 2014), while has the potential of ensuring various co-benefits.

Raising homestead foundation is an adaptation option to remain protected from storm surge and flood. Pond sand filter is a technology used to clean contaminated surface waters from freshwater ponds. Normally the pond stores the rainwater. The pond water passes through a pre-treatment chamber of gravel, and a filter made from sand to block sand and solids in the water and remove pathogens (APAN, 2015).

4.3 Study Locations and the Geography

This research selected two diverse locations: Godagari upazila a drought prone area, and the other from the coastal areas named Barguna Sadar upazila. Godagari is among the nine upazilas of Rajshahi district with an area of around 475 km^2, which includes two municipalities. Two rivers cross Godagari, namely the Padma and Mahananda. It has five cannels. Figure 4.1 shows the map mentioning the study locations.

Godagari belongs to the Barind Tract situated in the northwestern part of the country and suffers from severe drought. High frequency of local droughts in northern part caused greater agricultural losses relative to other threats like flooding and submergence (Alauddin and Sarker, 2014; Alam et al., 2012; Shahid, 2008). Drought resulted in massive production loss of crop in the country during the years 1978-79, 1982 and 1997 (Ramsey et al, 2007; Paul, 1998). Drought vulnerability depicted diverse conditions, however consistent year-by-year (Alam et al., 2012). The more severe water scarcity and drought condition make it harder for the Barind area to gain its regular cultivation activities, and the region fails to produce expected crop yield. It affects socio-economic stability, which propped up farmers’ demands for adaptation strategies.

Tectonically Barind part of the Bengal Basin is divided into two major divisions: the Precambrian Rangpur Platform and the Bengal Foredeep. The Barind Tract falls in the Precambrian Rangpur Platform of the Bengal Basin. The area lies between latitudes 24º00´26º00´N and longitudes 88º00´-89º30´E. The Barind Tract region is about 340 km long and about 205 km wide covering an area of about 35,000 km2. It is an alluvial plain with slightly elevated Pleistocene terraces, which slope towards the south and southeast. The elevation of the Tract varies from 47.0 m above mean sea level in its central part to 11.0 m in the southeastern floodplain area. It is one of the many Pleistocene terraces presents within the Bengal Basin that spreads over 9324 km2 of parts of the Rajshahi, Naogoan, Chapai-Nawabgonj, Joypurhat, Dinajpur, Rangpur and Bogura Districts in Bangladesh, and about 2650 km2 of the Maldah District of the West Bengal in India.

In contrast, Barguna Sadar upazila belongs to Barguna district. Barguna Sadar is among the six upazilas of Barguna district with an area of around 454.39 km^2. Three main rivers cross

Barguna Sadar; namely the Payra, Bishkhai and Khakdon. Barguna is a disaster-prone coastal area, which has experienced severe cyclones during the last decade, for instance, Sidr in 2007. Core economic activities in the region are based on sea and river fishing. Intense cyclones, salinity, storm surges and riverbank erosion are common phenomena that affect the life and livelihood of the local population. The expected sea-level rise would worsen the situation. Residents also suffer from scarcity of fresh drinking water.

Source: OpenStreetMap (n.d.) (https://www.openstreetmap.org/copyright)

Figure 4.1: Location map of the study areas

Three distinct regions: southeast, south central and southwest form the coastal area of Bangladesh, which is dynamic and somehow unique in nature, and so are its people (Dewan et al., 2015; Brammer, 2014; Minar et al., 2013). The delta formation is a continuous process in Bangladesh; however, the southwest coastal region is highly influenced by tidal surges and salinity intrusion (Islam and Gnauck, 2008). During the four months of monsoon the region experiences rain fall of about 1550 mm which results in severe waterlogging, inundation and siltation of internal drainage channels (Brammer, 2014). Along with poverty and high density of population, the region is heavily dependent on water and at the same time vulnerable to it (Dewan, 2012). Land subsidence is another dynamic factor the southwestern region faces (Brammer, 2014). During the dry months, scarcity of freshwater is a regular phenomenon and consequently management and governance of saline water emerges as one of the most important priorities in the coastal area (Abedin et al., 2014).

4.4 Sample Size and Profile of Respondents

It is suggested that experts of any community-based survey rarely exceed 15-25 professionals (Trotter, 2012), and accordingly, this study selected 27 respondents for in-depth interview form the both communities (Table 4.2). In a community-based survey, it was assumed that the respondents from same location share similar characteristics, and since random selection of respondents for qualitative questions may not be as productive as respondents from the specialized field (Marshall, 1996), this study purposefully selected 13 the respondents in Barguna Sadar, and 14 respondents in Godagari.

Table 4.2: Profile of the respondents for in-depth interview

Profession/organization of respondent for interview	**Number of respondents (Barguna Sadar)**	**Number of respondents (Godagari)**
Agriculture	3	9
Fishery	1	-
Government official	3	4
Local NGO	4	-
International NGO	1	-
School teacher	1	1
Total	13	14

4.5 Data Collection and Analysis

In order to assess co-benefits from adaptation interventions, the adaptation co-benefit assessment methodology (CARB, 2018) jointly developed by the University of California, Berkeley and California Air Resources Base (Appendix 1a) has been used. The method suggests that adaptation co-benefits generally address six topic areas: extreme heat, drought, sea level rise and inland flooding, agricultural productivity, species habitat, and wildfire. Since wildfire is not common in the study locations, this research assessed the selected adaptation interventions with five topic areas. According to the assessment guideline, +1 or -1 is assigned for each of the listed positive and negative co-benefits, respectively, and summed up for each topic areas. For a net positive value of at least one in any topic areas, the intervention is regarded as providing ‘climate adaptation co-benefits’ for that particular topic area. If two or three topic areas have net positive climate adaptation co-benefits, the overall classification is ‘high climate adaptation co-benefits’ and for four or more topic areas with net positive co-benefits, an intervention is ranked as ‘exceptional climate adaptation co-benefits.’ Assessment questionnaire was filled by a collaborative discussion with project implementers and beneficiaries.

This research also conducted three focus group discussions (FGDs): two in Barguna and one in Godagari. Profiles of participants in the FGDs are shown in Table 4.3 and 4.4. All of the participants in Godagari were male.

Table 4.3: Profile of the participants in FGDs conducted in Barguna Sadar

Profession/organization	**Number of male participants**	**Number of female participants**	**Total**
Participants for FGD 1			
Agriculture	4	-	4
Small business	1	1	2
Day laborer	2	-	2
NGO	2	1	3
School teacher	-	1	1
Community leader	2	-	2
Total	11	3	14
Participants for FGD 2			
Agriculture	1	-	1
Housewife	-	7	7
Small and seasonal business	1	2	3
Community leader	-	1	1
Total	2	10	12

The interviews both in Barguna Sadar and Godagari were conducted in respondents' offices and vicinities, and the duration ranged from 33 minutes to 67 minutes. The respondents were asked similar types of questions for achieving the goals of the research objectives. In Barguna Sadar, one FGD was conducted in an office of the SANGRAM, where male dominance was observed. The other was conducted in a residence of a community with more female participants (Table 3.3). In both of the cases, the respondents were chosen from the beneficiaries of the NGO. In Godagari, FDG was conducted in a village bazar. FGDs' durations were 80 minutes and 55 minutes in Barguna and 65 minutes in Godagari.

Table 4.4: Profile of the participants in FGD conducted in Godagari

Profession/organization	**Number of participants**
Agriculture	5
Small business	2
Day laborer	1
Community leader	2
Total	10

While overall sustainability transition takes longer time (Mori, 2019) sustainability of individual adaptation intervention may be examined faster. There are many indicators available to assess sustainability. International Institute for Sustainable Development (IISD) (2007), a renowned NGO, identified eight key indicators to assess any intervention: policy relevance, simplicity, validity, availability of time series data, availability of affordable data, ability to aggregate information, sensitivity and reliability. Spangenberg (2002) proposed four markers: general, indicative, sensitive and robustness. Garrett and Latawiec (2015) proposed six indicators for sustainability: simple, measurable, feasible, flexible, dynamic and user-inspired. However, this study has chosen the criteria for assessing adaptation co-benefits provided by Srinivasan et al. (2018). Three measures: resilience, risk reduction and vulnerability were tested in an Indian context to categorize adaptation co-benefits in natural resource conservation, disaster risk reduction and livelihood development, respectively. Accordingly, this research has analyzed and categorized the co-benefits from the selected projects based on the FGDs and interviews. In some cases, existing literature was used to evaluate co-benefits from the selected project.

Spiggle's (1994) seven-step methodology for qualitative data analysis and thematic analysis proposed by Boyatzis' (1998) were implemented in the analysis of qualitative data. In the beginning data were generalized to generate initial codes related to the core research questions this research intends to answer; and later categorization, abstraction and comparison were performed to compartmentalize the information according to the three research questions.

CHAPTER 5
THE CASE OF RAJSHAHI: A DROUGHT-PRONE AREA

The goal of this research is to assess how adaptation co-benefits functions as an enabler for sustainable adaptation; and the related research questions are: (1) what are the co-benefits of the selected interventions, measured by applying the adaptation co-benefits assessment methodology? (2) What does the community perceive about co-benefits from an adaptation intervention? And, (3) is adaptation co-benefits necessary condition for sustainable adaptation? This chapter explains the findings from one of the selected cases, solar irrigation in the drought-prone northwest part of Bangladesh.

5.1 Introduction

The Barind area encounters more droughts than any other part of the country. It has mainly three seasons: winter (Nov-Feb), cold and dry with almost no rainfall; pre-monsoon (Mar-May), hot and dry; and monsoon (Jun-Oct), a rainy season. Annual average rainfall in the area is much less than that of the national annual average. Rainfall is inadequate in terms of time, intensity and distribution throughout the seasons and varies widely from year to year as well as from location to location. In 2000, for instance, the total annual rainfall in this area was 1,690 mm, whereas in 2010 it went down to 793 mm. In 2006, the annual total rainfall of Bangladesh was 2178 mm, whereas in drought-prone areas it was 1193 mm (Habiba et al., 2011). The monthly mean rainfall distribution in the area varies. Average monthly humidity varies from 62% (in March) to 87% (in July) with a mean annual of 78% (Jahan et al., 2010). Irregular rainfall and increased temperature of the area result in water scarcity during the summer. Being agriculture dominant, Bangladesh requires sufficient irrigation for food production. However, due to water scarcity and drought condition, the Barind area was losing its regular cultivation, and often failed to produce expected crop yield in the near past.

To address such continuous massive crop loss, the Barind Multipurpose Development Authority (BMDA) under the Ministry of Agriculture was launched. The primary objectives of BMDA are, among others, augmentation of surface water resources and its use, and to facilitate irrigation through using ground water through installation of deep tube-wells. The surface water is sourced from nearby rivers, the Padma and the Mahananda (Figure 5.1). River water is transmitted to irrigate land in different upazilas of Rajshahi districts including Godagari, the study location, through constructed underground pipelines (Figure 5.2). With an aim to reduce dependence on groundwater, this project has been implemented with a potential to save more than 38% of the Barind Tract from desertification, and to protect its ecological balance (Alauddin and Sarker, 2014). The agricultural land are privately owned in the region, and irrigated and cultivated under private arrangement with the support from BMDA. The users of the facility have to pay through a pre-paid metering system for the volume of water used. Pumps are used to collect water from the rivers and then flowed a long way to store it in secondary storage. Distribution is made through permanent large size pipes made of cast irons installed underground. The surface water source in the study location is the river Mahananda. It was estimated that irrigation through surface water in the whole district would raise the cropping intensity to 228 percent from the then 192 percent to result in additional production of 211,000 tonnes of food grains (Alauddin and Sarker, 2014).

5.1.1 The Case Description

A. Water Sourcing and Storage

Pumps are used to collect water from the river Mahanada (Figure 5.1); then water is flowed up to 7.3 km long way to be stored in secondary storages. Distribution is made through permanent large size pipes made of cast irons installed underground (Figure 5.2, 5.4). The secondary storages consist of ponds and canals (Figure 5.3). The ponds are not private; instead on government *khas* land (i.e. government-owned fallow land, where no one has property rights). Before, these storage facilities were not maintained; however, when a pump house is set-up near a pond or cannel, BMDA takes the responsibility to maintain it. Since the siltation rate of the ponds is negligible, the re-excavation of ponds is made around every ten years and maintenance cost is very low. While the water bodies were not under the project, i.e. before the project was initiated, local people used the water bodies for their own purposes like fishing. Later, when BMDA acquired those water bodies for storage of water sourced from the river, it has started maintaining through building embankment and afforestation along the bank. Although local beneficiaries opposed at the beginning to restrict acquiring of pond and cannel by BMDA, through negotiation and explanation of better future BMDA convinced the beneficiaries to allow the use of selected ponds and canals as secondary storage for water from the river. There are no unique distances among the secondary storages. It basically depends on proximity between a pond and potentially cultivable land requiring water for agriculture, and whether the pond is along the main permanent pipelines connected to the river. The elevation of the secondary storage is much higher than the primary source, i.e. the river Mahananda in this case, and hence requires much energy to lift water from the river and transport till the secondary storage.

Figure 5.1: Water sourcing from the river for irrigation in Godagari

B. Water Distribution

Water from the secondary storage is distributed to the nearby agricultural land through pump houses. There are several pump houses; however, there are no clear rules where to set up a pump house. The only criterion is that the pump house would be established near a pond. The coverage of a pump house (Figure 5.4) is not unique. The different pump house has different capacities to support irrigation. This basically depends on soil type, land elevation, the capacity of the pump, along with the judgment of the BMDA officials who wants to cover irrigable land as more as possible. In order to roughly estimate the area covered under a single pump house the air vents (circled in Figure 5.4) installed along the pipeline provide a guideline. Assuming the pump house the center one may get an idea about the coverage of land area under irrigation from that particular pump by observing the installed air vents.

Figure 5.2: Irrigation through underground pipes (Vents indicate the underground lines)

Figure 5.3: Secondary storage for collected water from the river

C. Energy Consumption of Water Pump

Initially the irrigation program of BMDA started with diesel-based deep tube well and conventional irrigation. Later the diesel-based pumping system was replaced with grid connected electricity (Rashid and Hossain, 2019); however only the pump houses near the national grid were able to get connected. In analyzing pump performance, it was found that pumps used in the Barind area used mostly one cusec capacity under 120 ft. One cusec capacity pump with the given depth enjoyed a combined efficiency of 64% and consumed electricity of 17 kW. Energy consumption varies according to season and hence the cost of irrigation; for instance, in June the cost is maximum while in November the cost is the lowest. Since the ground water level goes up by 25% in October/November the efficiency of pump increases by 81% (Haque et al., 2017b).

D. Problems with Irrigation Management

Crop production was hampered by low efficiency of diesel engines. The cost of irrigation was also high. Besides, one of the major problems was with group managed system, where conflict among the members was visible. This conflict also led to collapse of the system in many instances. The influential group leaders were found reluctant to pay for the irrigation charges which accumulated to a large unrealized amount by the end of the year (Rashid and Hossain, 2019). This was a great challenge BMDA faced earlier. Besides, coupon-based payment option which was checked and ensured by the pump operator before discharging allowable water created another problem. Some people started making fake coupon and sold to the farmers. In some cases, operators were unable to verify if the coupon is genuine or fake, and in some cases operators provided water without coupon. Ultimately the irrigation became operator dependent from which BMDA was able to ensure reasonable cash inflow (Rashid and Hossain, 2019).

Figure 5.4: Air vents adjacent of pump house

5.1.2 Major Achievements of BMDA

BMDA, during a period of ten years ended December 2017, achieved significant milestones in providing irrigation support to the region as a whole (Table 5.1). These include irrigation to around 500,000 ha of land that resulted in around 4.5 million tonnes of food grain production every year, and 53 solar operated pump houses with a capacity of 1060 kW (BMDA, 2018). Besides, BMDA installed many cross dams, one rubber dam, underground pipelines and many dug wells for safe drinking water in the region.

Table 5.1: Major achievements of BMDA during 2009-2017

Activity	Quantity
Cross dam construction	696
Rubber dam	One (65 meters long)
Underground pipeline	6621
Dug well installation	216
Pre-paid metering system to pump house	7000
Safe drinking water point	1143
Solar powered irrigation pump	53
Increase in crop intensity	From 117% to 226%
Land area covered under irrigation	496,000 ha
Crop production	4.5 ml tonnes per year

Source: BMDA (2018)

BMDA supports installation of midsize application so that the system intakes comparatively large amount of surface water from river instead of pumping up underground water and water harvesting ponds, and deliver it to vast areas of dry land for agriculture located in a distance through underground pipeline. It is to note that the major crops cultivated in the region requiring irrigation include rice (*aus*, *amon* and *boro*), corn, wheat, potato, mustard and lentil.

5.1.3 Use of Renewable Energy in Irrigation

The most fascinating part of running the pump house in remote locations is the use of a solar panel installed by BMDA (Figure 5.5). Each panel has a capacity of 16 kW, which is sufficient to run the water pump requiring 12 kW in each station. BMDA issues prepaid smartcard including a photo of cardholder. There are some authorized dealers who sell balances for the prepaid card. Users buy balance from those dealers, use the card in the pre-paid machine and start the water pump (Figure 5.6). As long as the balance remains, the machine pumps water. Smallholder farmers collectively buy a prepaid card, while owners of a large volume of land own single prepaid card for own use. In order to overcome the inadequate billing and maintenance system, the BMDA authority has implemented a pre-paid metering system for the volume of water used in order to ensure user's charges who intake irrigation water from the pump houses. Pre-paid metering system provides multiple benefits (Rashid and Hossain, 2019). The benefits include reduced cost, higher average irrigation water quantity, and higher average gross income for the farmers.

Figure 5.5: Solar energy operated pump house in Godagari

Since a zero-emission technology, life cycle assessments of solar irrigation shows that there is a potential 95 to 97 percent reduction of emission per unit of energy used for water pumping if operated with grid connection, and 97 to 98 percent if diesel operated (FAO-GIZ, 2018). Experience from different countries, for instance Senegal, showed a reduction of one ton of CO_{2e} GHG due to solar irrigation (Noubondieu et al., 2018).

5.2 Results

5.2.1 Index-based Co-benefits Assessment

According to the adaptation co-benefit assessment methodology, the irrigation project of Godagari ensures high climate adaptation co-benefits. Out of six topic areas, four were evaluated, since sea-level rise and inland flooding category and wildlife mitigation were found irrelevant. Extreme heat, agricultural productivity and drought category showed net positive co-benefits, while species habitat showed no net co-benefit (Table 5.2). Appendix 1b explains the details in a filled index for solar irrigation in Godagari region.

Figure 5.6: Prepaid metering system for irrigation water

Table 5.2: Assessment of co-benefits from agricultural irrigation in Godagari

Topic areas	Positive co-benefit	Negative co-benefit	Net co-benefit	Evaluation
Extreme heat	3	1	+2	High Climate Adaptation Co-benefits
Drought	3	2	+1	
Sea-level rise and inland flooding	N/A	N/A	N/A	
Agricultural productivity and conservation	3	1	+2	
Species habitat	2	2	0	

5.2.2 Community Perception about Co-benefits

The categorized direct benefits and co-benefits are shown in Table 5.3. At the local level, solar irrigation provides additional water for irrigation. This enables local farmers increase cultivation of staple food, increase food productivity and diversify portfolio to cultivate cash crops, bringing them additional in-kind and cash income as direct benefits. Increased income, as a result of higher production and/or additional farming, enhances farmers' resilience to climate change through diversification of crop production which has the potential to reduce vulnerability as well. Both growth and stability in income bring a positive impact in societal change of the farmers, especially for education. Replacing diesel or electricity pumping system can reduce fossil fuel consumption, thus can enhance energy security and contribute to attain the nationally determined commitment to the Paris Agreement, although to a marginal extent. On the other hand, excessive water pumping can bring adverse impacts on water sources, and thus cause water shortage at downstream, even if solar irrigation system reduces water loss.

As shown in Table 5.3, most of the climate co-benefits are brought at regional and national level, and those brought to local farmers are less visible. Farmers do not see the benefits of reduction of fossil fuel consumption unless they are accustomed to bookkeeping. They have no way of recognizing how crop diversification and longer years of schooling bring additional benefit in the form of raised adaptive capacity.

Table 5.3: Direct and co-benefits from solar irrigation system

<table>
<tr><th rowspan="2"></th><th colspan="2">Local</th><th>National</th><th>Global</th></tr>
<tr><th>Direct benefits</th><th colspan="3">Co-benefits</th></tr>
<tr><td>Staple food cultivation</td><td>In-kind income</td><td rowspan="3">Adaptive capacity via education

Vulnerability reduction</td><td>Food security</td><td>-</td></tr>
<tr><td>Water use efficiency</td><td>Water saving</td><td>Water security</td><td>-</td></tr>
<tr><td>Diversification of crop production</td><td>Cash income</td><td>Poverty reduction</td><td>-</td></tr>
<tr><td>Reduction of fossil fuel consumption</td><td>Energy saving</td><td>-</td><td>Energy security</td><td>CO_2 emissions reduction</td></tr>
<tr><td>Water source protection</td><td>-</td><td>-</td><td>Regional water conflict</td><td>-</td></tr>
</table>

Source: Rahman, S. M. and Mori, A. (2020) (unpublished)

A. Resilience enhancement

i) Natural resource conservation

BMDA operated solar irrigation conserves natural resources to some extents. The temporary water reservoir like the ponds and canals from which water for irrigation is pumped using solar power is ideal for amphibians and a variety of invertebrates along with small fishes. It also helps protect and conservation of indigenous plant species. Fishing and other types of domestic use of the dedicated ponds for water reservoir are prohibited, which also ensures protection and preservation of natural resources. One of the beneficiaries from the FGDs stated:

> *The air gives some comfort during summer due to water availability in the ponds and canals.* (Translated from Bengali)

ii) Restoration of natural resources

It is well said that conservation is not the end; restoration besides enables the living things on the earth, including the human being, prepare for long term sustenance. Although the local residents and the BMDA authority do not have any significant instruments for measuring land degradation due to drought in the region, restoration, as an impact from solar irrigation, benefits the rural community, and thereby enhances their resilience to climate change. The pace of desertification in the region is likely to slow down due to widespread irrigation activities, where solar power plays a role.

B. Risk mitigation

i) Contribution to disaster mitigation

The northwest part of Bangladesh has already experienced severe to moderate levels of drought in various years due to high rainfall variability (NDMC, 2006; Shahid and Behrawan, 2008). Droughts of different intensities adversely affect crop production of Bangladesh (Habiba et al., 2011). However, rainfed agriculture only option in the past has been turned to irrigation-based agriculture due to widespread irrigation including part with solar power.

Hence, the local residents and BMDA officials argue that solar powered irrigation has the potential to disaster mitigation.

ii) Contribution to disaster management

Disaster management includes organizing and managing resources and responsibilities to prepare, response and recovery to minimize impacts from disasters (IFRC, 2010). From the general definition, it is visible that solar powered irrigation in the study region contributes to disaster management, since it organizes resources including community people who participates and supports the program. Besides, the BMDA and local residents take responsibilities to ensure success and sustainability of the program.

C. Vulnerability reduction

i) Contribution to employment and income security

At the national level, an increase in staple food production enhances national food security and strengthen the adaptive capacity (Plummer and Armitage, 2010), and production of cash crop helps poverty alleviation at individual level. The BMDA operated solar panels used for running the pump house are found very efficacious. In case of solar energy, especially with respect to SHS for instance, only a small fraction of the total rural population is able to afford, and the benefits were concentrated. In contrast, the BMDA operated common resource solar panels provide benefits to a wider selection of population irrespective of their social status and economic strength. One beneficiary uttered:

> *In earlier days we had to cultivate rice once a year during the rainy season only; but after the BMDA started irrigation program, throughout the year the lands are cultivated with various crops including rice, wheat and lentil.* (Translated from Bengali)

Hence, improved financial strengths of both landowner and day labours/farmers have been observed. Farmers, who used to remain idle or were involved in other temporary employments in earlier times, particularly when irrigation was not supported by the BDMA, have become active in farming after the launching of BMDA supported irrigation. A limited number of non-agricultural jobs have also been generated in the region as a result of widespread cultivation resulting from irrigation program. Before the program, the fields were used for cattle grazing only, which did not bring sufficient earning for family sustenance. Selling part of milk produced from the animals in the market, or even sometimes selling the whole to earn required family expenditure were practiced for most of the marginalized and land-less farmers. The yearly income family used to earn was lower than what they have started to earn after flourishing of agricultural activities as a result of extended irrigation in the region.

The other example is diversity in farming, which has also increased. In order to enjoy increased income, local farmers change their preference towards cash crops. One farmer said,

> *Now a day, we have the flexibility to choose among crops. We cultivate according to the market value of the crops. High value crops are preferred, although it depends on family needs for core crops, like rice and wheat.* (Translated from Bengali)

ii) Community improved access to information provided by BMDA

According to the Instruction on Information Disclosure-2015 within the premises of Right to Information Act- 2009, BMDA has ensured public access to information related to agriculture and farmers. It ensures transparency and good governance of the system. BMDA has dedicated unit of operations for providing information. There are various types of information, both mandatory and voluntary, which people can access, unless the information is classified or subversive the nation or state. Information about the benefits of surface water for irrigation and benefits of safe drinking water became available through BMDA initiatives. Many people with limited or little more education was already informed about these benefits, but for marginalized group, BMDA is a source of practical information.

iii) Improved access to technology

Prepaid metering system is the example of community access to improved technology. No other neighbouring districts have experienced such automatic metering system, which BMDA has provided for the rural less educated or illiterate people. Even without more than primary education, people know how to operate the machine with prepaid card. Since, people already know about prepaid mobile phone operation system, this technology was easily understood by the rural community.

iv) Development of marginalized group and participatory decision making

Some informal group has been formed in response to the initiation and implementation of solar irrigation by the BMDA. In selection of ponds, people agree together which pond to dedicate for secondary storage of water from the river. Farmers having less land collectively buy one smartcard, while owners of large volume of land own one a card for single use. All these processes show the evidences of participatory decision-making process.

Most of the farmers comply with the BMDA guidelines, and pay user charges. Very few incidents about illegal pumping from the canals or the water stream were surfaced. Since the system is run by automatic pre-paid metering system, there is no opportunity for tempering the system in order to enjoy illegal benefit. One BMDA official explained;

> *There are few cases we come to know about illegal attempts of water collection from the drains for the nearby fields. This does not affect the system at all. Besides, this is automatically monitored by the community members and the pump house operators.*

Since the evidences are not many, and in most cases the farmers with very little land ownership try such attempt, considering the economic status of the farmers, BMDA officials overlook the issue from humanitarian perspective.

D. Adaptive capacity

The more exposed an individual, community or system towards a particular climate stimulus, the greater the vulnerability; and contrariwise, the greater the adaptive capacity of the individual, community or system to a given climate event, the lower its vulnerability (Swanson et al., 2007). Adaptive capacities include the social and technical skills and strategies responding to the changes in environment and socioeconomic condition. The local residents who enjoy the benefits of irrigation from solar operated pumps are not aware of climate change or environment. Only very few people, for instance teacher and community leader, are aware of the mentioned issues. To the beneficiaries the principal concern is higher production. One machine (pump house) operator stated:

> *Farmers can run the machine whenever they need, as long as they have balance in their prepaid cards, to irrigate their lands. Besides, the owners*

of small pieces of land buy prepaid card on a sharing-basis, while owners of more cultivable lands buy cards alone for themselves. (Translated from Bengali)

Although not aware enough about vulnerability reduction and adaptive capacity, the residents indeed enhance their adaptive capacity.

Potential benefits of education encourages farmers invest in children education (Kim et al. 2019). This action eventually raises farmers' adaptive capacity. FGD has revealed that residents' motivation towards children schooling has increased, which would enhance adaptive capacity and human capital in the long run. Non-enrolment, low persistence and attainment, and poor performance of children in primary school resulted from constant poverty, one of the identified most pervasive factors, was common in the earlier time. While agriculture was not practiced, due to poverty families used to send their children, particularly girls, to other solvent families in the region or even outside the region to work as housekeeper, which ensured food security for their kids. In many cases, parents were not able to meet their son or daughter for up to couple of years if sent to big cities far from the home. Family used to earn money for the services of their child. This practice has substantially changed after agricultural activities received momentum due to region-wide irrigation, which has also been fuelled by the primary education stipend program in which parents do not need to spend money for education of their children. In response to a question whether the family would do the same if government stipend program were not there, one male farmer replied,

Definitely we would send the kids to the school, even if the stipend were not provided. We do not have severe financial hardship now, why not to send them (children) *to school!* (Translated from Bengali)

Domestic violence in the areas has reduced substantially, as a result of financial solvency. Although no respondents specifically mentioned the term 'domestic violence', instead they mentioned 'peace' in conjugal life. In the past, since only once a year the fields were cultivated, male members have less work and they used to spend more time in home and had higher interaction with females, especially wife. While financial solvency was not present, more likely it was to engage in arguments, which sometimes resulted in violence. However, the situation has changed in the recent year as the FGD respondents shared. Although these benefits are not directly the influence of solar irrigation, region-wide solar irrigation program is likely to bring similar benefits.

Roughly, many of the indicators for rural development have been met with widespread irrigation. One farmer said,

Large-scale agriculture has ensured family peace inside. Arguments between couples become less due to the better financial condition of the family. (Translated from Bengali)

A few of the FGD participants agreed about family crisis during the period the head of household had low income due to no or limited agricultural activities in the region. Once irrigation started, income condition improved and family started to experience fewer crises.

5.2.3 Emissions mitigation co-benefits

Agriculture is currently a major source of GHG emissions (Li et al, 2020), and as such is called for a transition towards carbon neutrality. Research focusing Bangladesh showed that CO_2 emission from irrigation pumps in 1990 was 1.43 million tonnes and sharply raised to

6.73 million tons in 2012, which was due to increase in the number of irrigation pumps irrespective of the fuel used for operation. If the diesel- or electricity-powered irrigation pumps were replaced with solar, Bangladesh could mitigate substantial CO_2 emission each year (Hossain et al., 2015). Another recent report argues that Bangladesh has 1.34 million diesel pumps which consume at least one million tonnes of diesel valuing around USD900 million a year (Kanojia, 2019). Rough estimation indicates that such amount of diesel consumption would produce around 2.64 ml tonnes of CO_2 emission, which is around two tonnes of CO_2 emission annually per diesel-generated pump.

Accordingly, 53 solar-powered pumps in the BMDA jurisdiction have the potential to reduce around 106 tonnes of CO_2 annually. The share of agricultural emission in Bangladesh decreased from 61.23% in 1994 to 43.36% in 2005. Emissions from rice cultivation reduced from 49.4% in 1994 to 18.3% in 2005 (UNFCCC, 2019). This reduction may be attributed, at least partly, to the widespread use of solar pumping for irrigation. Although it is not significant as of now, the enormous potential solar irrigation carries must be appreciated.

5.2.4 Dissemination of Adaptation Co-benefits

A common denominator expressed by all of the FGD participants is the general lack of information about climate change, its impacts, co-benefits and the actions to address them. The response was piecemeal, lacking a holistic view about potential and actual agricultural losses from the impacts of climate change, adaptation interventions the farmers were implementing, and the mitigation potential solar irrigation system had. Most of the residents with no or very elementary literacy did not have the concept of emissions and emission reduction. Nonetheless, the farmers are adapting to the impact of climate change through BMDA supported irrigation while also acting to mitigate emissions unknowingly. If these were known to them, the scope and frequency of action and enthusiasm would increase. The inclusion of the primary stakeholders i.e. the farmers in climate change management is, intentionally or unintentionally, absent in the region, at least from the beneficiary point of view as revealed during FGD. There were no learning platform for raising awareness; for instance, Community Learning and Action Center (CLAC) in Hariyo Ban project in Nepal was successful in improving awareness about natural resource management, minimizing water conflict and in increasing income. Attitude and social mobilization were also achieved at a satisfactory level. Information about adaptation co-benefits would have similar benefits, if institutional attempts were made in the irrigation program in Rajshahi region.

5.3 Discussion

Since part of the BMDA irrigation system uses surface water, instead of consuming groundwater reservoir, it is not making the community vulnerable to ground water reserve. Groundwater table in the northwest region is passing a serious time through constant declining, and ultimately causing anxiety for the expansion of the irrigation system. Groundwater consumption has reached a critical stage and dropped below shallow wells in many places (BADC, 2005), while Rahman et al. (2016) have shown that the trends in spatial and temporal changes in the groundwater table in the northwest part of Bangladesh are steadily declining with a rate of change varying from 0.82 to 0.2 m/year in dry season, and from 0.67 to 0.2 m/year during monsoon season, and at an annual average from 0.6 to 0.1 m/year. Therefore, sustainability of groundwater use for irrigation is now attributed as an important concern in the region. In response, river water for irrigation is better in a way that ground water reservoirs are safe somehow.

BMDA is an autonomous body and does not require external funding for operation of the irrigation program. The documented water user group and cooperative groups are practically non-operative. Water user groups include various Water Management Groups and Water Management Associations formed under the Cooperative Societies Act 1986. The uniqueness of the stakeholders, i.e. the farmers, is heterogeneity, since there are literate and literate farmers, rich and poor peasants, and landowner and sharecroppers. By hardly considering residents' opinion BMDA follows a top-down approach to select, implement, and operate the program (Islam et al., 2020). BMDA's performance in terms of institutional capacity, economic efficiency and effectiveness is better than any other water management government or autonomous institutions operating in Bangladesh. However, in terms of transparency, accountability, participation in decision making, social equity and environmental integrity performance is below what the other organizations has achieved (Islam et al., 2020). Low score in decision making seems rationale since the community people have no voice in the selection and operation process. Nonetheless, BMDA has been running successfully with its own revenues and the community people are satisfied with BMDA operation. There is no involvement of non-state actors starting from the project idea generation through selection to final implementation; thus the possible impact of non-state actors are difficult to assess.

The participants in the FGD agreed that the BMDA implemented solar pump house in the region provided the opportunity to a segment of the local community to get involved in business through gaining dealership for selling pre-paid balances for specific pre-paid card farmers own to run pumps for their water requirement. However, non-agricultural jobs, particularly dealership of the BMDA, are subject to scrutiny, since community people argue that the selection of a candidate for a dealership is influenced by some factors. The other job opportunity observed is for the maintenance of the pump house. In response to the remuneration from pump house maintenance, one employee has argued that the hourly compensation they receive for maintaining the pump house is not competitive. The current rate for the job is BDT8 per hour (equivalent USD0.095). This opportunity is not available to a broader community; instead, a selected group of people is able to manage such a dealership or maintenance position.

Informal social group formation has been another benefit as shared by the FGD participants. Since marginal farmers are less able and also less interested to own individual prepaid cards due to less requirement of water for a smaller sized agricultural field, they maintain a group to fulfill their water requirement from the pump house using a commonly purchased single prepaid card.

Irrigation has helped both categories of farmers who own land and who do not. Due to poverty, as a result of minimal cultivation, families were not able to send their children to school before; however, after booming of agriculture financial solvency enjoyed by the farming families has influenced families' motivation for schooling. Such motivation helps retain enrollment in schools that has long-term impact on family, society and the nation as a whole.

Majority of the marginalized and land-less farmers have experiences of temporary migration to ensure earning for survival of the family. Rural residents used to go to nearby cities and also to Dhaka, the capital city, in search of earning sources. Since illiterate most of the people who migrated used to engage themselves in rickshaw pulling or day labor in the construction industry. Agricultural expansion in the region has reduced such temporary migration. It has been found that the price of irrigation has risen substantially, almost doubled, during the last couple of years. While one user could run the machine one hour for around BDT60-65, now a day, the cost is around BDT110-120.

The residents in Godagari have started to suffer from shortage of ground water. Besides, the rivers from where the irrigation water is sourced have some trans-boundary issues with neighboring country, which makes the water flow uncertain. During dry season water level goes down both in surface and ground water. Many users intentionally receive the service from a far pump house instead of a nearby one. Because due to shortage in ground water level, with the same time of machine running users get more water for their field. Hence, they choose the pumps that provide more water or the river-sourced water, which is deposited in cannel or ponds. However, energy consumption for surface water distribution remains a big question. Pump house near the national grid connection uses electricity from grid. Few remote pump houses are run by solar energy, which is a fantastic evidence of integrated approach against climate change; however, the use of energy to pump water from the main sources, i.e. rivers to destinations like ponds or cannels, in a distant location ranging up to couples of kilometers is substantial.

While financial health of families has been improved, challenges remain with the maintenance and operation costs of the system that was born by the BMDA in earlier days. Now a day, the BMDA is reluctant to provide such support, and the local committee for pump house bears the cost, as the FGD has revealed. BMDA's annual budget is sufficient to cover the maintenance and operation costs of the system. However, one BMDA official has explained that if it remains free, and community perceives that it will remain free forever, and consequently farmers' motivation towards maintaining the system or owning the system may decline. The long-term impact may become negative. Hence, it is somehow BMDA's intension to help keep the system sustainable for the sake of long-term benefits, instead of a failure case what many adaption interventions in Bangladesh have experienced.

5.4 Conclusion

In this chapter co-benefits from the case of solar irrigation in Godagari upazila under Rajshahi district has been explained. Solar irrigation in the Barind Tract has contributed to vulnerability reduction, enhance adaptive capacity and resilience, and also to reduce disaster risk. Enhancing resilience through natural resource conservation and restoration of varying scale is an adaptation co-benefit from the solar irrigation program. Adaptation co-benefits from solar irrigation may be engendered in the form of disaster mitigation and management, if carefully handled. The region-wide program has generated social, technological, financial and economic co-benefits for the residents. Adaptive capacity in various forms of the local community is a visible adaptation co-benefit besides. Primarily an adaptation measure has the potential to provide substantial mitigation benefit, which may reasonably be termed as co-benefit. However, poor operation of the adaptation intervention along with careless attitude towards maintenance has the potential to turn positive co-benefits to negative ones. The next chapter discusses two other cases from the coastal south of Bangladesh.

CHAPTER 6
THE CASE OF BARGUNA: A COASTAL DISTRICT

The goal of this research is to assess how adaptation co-benefits functions as an enabler for sustainable adaptation; and the related research questions are: (1) what are the co-benefits of the selected interventions, measured by applying the adaptation co-benefits assessment methodology? (2) What does the community perceive about co-benefits from an adaptation intervention? And, (3) is adaptation co-benefits necessary condition for sustainable adaptation? Following a qualitative design this research employed a case study method. This chapter elaborates the results, discusses the issues and concludes the findings from two other cases, in addition to the one explained in Chapter 5, homestead plinth level raise and pond sand filter for safe drinking water selected from the coastal district of Barguna.

6.1 Introduction

Bangladesh is not only among the highly vulnerable countries towards climate change, but also among the top in terms of death tolls from disasters and cyclones (Ali, 1999). Two thirds of the country is less than five meters above the sea level and subject to flood during monsoon; and once in every 3-5 years, two thirds of Bangladesh experience flood substantially damaging housing and infrastructure, agriculture and livelihoods (World Bank, 2010). Since the height of storm surge in excess of 10 meters is a common phenomenon, backwater effect of flood results in coastal erosion. Although the death toll reduced considerably in the recent years due to various adaptation interventions implemented throughout the country, especially in the coastal areas, vulnerability has not been reduced, as observed in various vulnerability indices. The 710 km long coastal zone experiences tidal fluctuation, salinity intrusion and cyclone risk, while the other parts are exposed to flood, drought and riverbank erosion.

The coastal zone is divided into three regions: southeast, central and southwest region. There are 19 districts and 153 upazilas in the coastal belt (BBS, 2015). Twelve districts including Barguna, another study location of the research, have already started experiencing severe impacts of changing climate (Dasgupta et al., 2014). A home of around 40 million population coastal zone of Bangladesh is characterized by daily tidal surges, frequent seasonal cyclones, floods, higher salinity because of reduced upstream freshwater flows, and over-abstraction of groundwater (Dasgupta et al., 2014; Mahmuduzzaman et al., 2014; Rahman and Rahman, 2011).

6.1.1 The Case Description: Homestead Plinth Level Raise

Raising homestead compound is considered as one of the most effective adaptation interventions in the coastal zone (Rahaman et al., 2020; Fatemi et al., 2020). This intervention addresses two important criteria of adaptation definition: ‘moderate harm’ and ‘exploits beneficial opportunities’ are fulfilled (Figure 6.1). This intervention helps dwellers that are vulnerable to both flood and storm surge. Especially for the poor communities it minimizes the probable effects from various disaster shocks. Based on the severity of the impact, residents can plan and prepare whether to evacuate the house or not, thereby ensures minimum loss of assets.

Homestead raising intervention targets the poor and ultra-poor. The implementation process includes engagement of community people for part of the construction components for instance, earth filling and panting the turf. While most of the community people voluntarily support this function, some paid employments are also created. Usually beneficiary has to bear the cost of re-building the house over the raised plinth. In the whole process female participation remains around 35-40% (CARE, 2011).

Figure 6.1: Raised plinth level of a house in Barguna Sadar

The project under investigation at Barguna Sadar was implemented by the NGO SANGRAM, funded by Palli Karma-Sahayak Foundation (PKSF), a development organization with an aim to reduce poverty through employment generation in the rural areas of Bangladesh. Under the project, 25 households were selected for raising the plinth level up to three feet from the historically observed flood level in two clusters (SANGRAM, n.d.). The residents were vulnerable to water borne diseases, and unhygienic conditions along with storm surges during cyclones. After the project implemented, it has supported the residents to install deep hand tube-well, to initiate homestead gardening, favorable conditions for small poultry and dairy farm and to use hygienic sanitary latrines. These together have reduced their vulnerability towards climate-induced risks. Family income went up by homestead gardening, as well as duck and goat rearing. Through the project safe drinking water supply has been ensured, and water, soil and air pollution caused by unhygienic toilet facilities although have not been removed entirely but reduced.

6.1.2 The Case Description: Safe Drinking Water through Pond Sand Filter

Noltona union of Barguna Sadar upazila is located adjacent to the river Bishkhali and close to the estuarine zone of the Bay of Bengal. Scarcity of drinking water is a common phenomenon, since installation of tube-well is not possible in the area. Residents of the community depend on ponds for their basic drinking water demand. SANGRAM, financed by PKSF again, installed 14 pond sand filters and re-excavated 14 ponds in order to ensure safe drinking water under a project named Adaptation with Alternative Livelihood Opportunity (AALO) in order to make the community climate resilient (Figure 6.2). The ponds selected for installing pond sand filter are highly protected where showering, dish or clothes washing are prohibited. It is also ensured that no polluted water from outside enters the ponds. Since the ponds are also a source of income for many households, not every pond owner is willing to dedicate it for pond sand filter. Pond sand filter are installed at a higher altitude near the pond. Roughly more than a thousand families from different locations collect drinking water from these ponds and pond sand filters.

Water borne diseases, which were very common to the villagers before the construction of the pond sand filters, have reduced substantially (Abedin et al., 2019). The community itself manages the ponds and sand filters. The maintenance cost, which is very low, is borne by the users, i.e. the maintenance committee for each pond sand filter is responsible for any issue. The construction of pond sand filter is made in a way that severe cyclone like *Sidr* may not devastate the structure.

Figure 6.2: Pond sand filter in Barguna Sadar

Construction of pond sand filter in the coastal areas is nothing new in Bangladesh (Yokota et al., 2001; Hasan et al., 2013). Many NGOs initiated similar projects, however most of the interventions failed due to defective infrastructure and lack of community management. It has been observed that many of such facilities survived only for a limited time, for instance two to three months. In the study area as well not all of the 14 pond sand filters were operative. Only four were operative due to its better management and voluntary services like bearing of maintenance cost only by few households. Only a limited number of households have the feeling of ownership. Normally, the pond dedicated for sand filter is a private property and the house that owns the pond is more dedicated for warranting smooth operation of pond sand filter. Along with the pond owner, very few able households contribute for maintenance of the pond sand filter, while the remaining beneficiaries are free riders. Contribution for maintenance expense is very minimal unless the structural deficiencies are observed; if it is shared by all of the beneficiaries the cost per household would come to a very small double digit, which is equivalent to below USD 0.5. Yet, contributions from the beneficiaries are absent, which leads to the confusion about sustainability of the interventions.

6.2 Results

6.2.1 Index-based Co-benefits Assessment: Homestead Plinth Raise

According to the adaptation co-benefit assessment methodology, the homestead plinth raise project of Barguna Sadar ensures adaptation co-benefits. Out of six topic areas, sea-level raise and inland flooding provides one positive and one negative co-benefit resulting in a zero net co-benefit, and species habitat enjoys only one positive co-benefit. Overall, adaptation through plinth raise is evaluated as a provider of climate adaptation co-benefits (Table 6.1). Appendix 1c shows the filled-in index for co-benefits from homestead plinth raise in Barguna Sadar region.

6.2.2 Index-based Co-benefits Assessment: Pond Sand Filter

According to the adaptation co-benefit assessment methodology, the pond sand filter intervention in Barguna Sadar confirms adaptation negative co-benefits. Out of six topic areas, drought and sea-level raise and inland flooding provide one positive and one negative co-benefit for each resulting in a zero net co-benefit, and extreme heat category warrants one negative co-benefit. Overall, adaptation through pond sand filter is evaluated as a provider of climate adaptation negative co-benefits (Table 6.2). Appendix 1d shows the filled-in index for co-benefits from pond sand filter in Barguna Sadar region.

Table 6.1: Assessment of co-benefits from Homestead Plinth Raise in Barguna Sadar

Topic areas	**Positive co-benefit**	**Negative co-benefit**	**Net co-benefit**	**Evaluation**
Extreme heat	0	0	0	Climate Adaptation Co-benefits
Drought	0	0	0	
Sea-level rise and inland flooding	1	1	0	
Agricultural productivity and conservation	0	0	0	
Species habitat	1	0	+1	

Table 6.2: Assessment of co-benefits from pond sand filter in Barguna Sadar

Topic areas	**Positive co-benefit**	**Negative co-benefit**	**Net co-benefit**	**Evaluation**
Extreme heat	0	1	-1	Climate Adaptation Negative Co-benefits
Drought	1	1	0	
Sea-level rise and inland flooding	1	1	0	
Agricultural productivity and conservation	0	0	0	
Species habitat	0	0	0	

6.2.3 Community Perception about Co-benefits

The concept of co-benefits is not well understood among the community. To a group, strategies for surviving natural disasters such as cyclones are co-benefits. Yet most in the community believe that additional adaptation interventions would yield more co-benefits. Because Barguna Sadar has an embankment to protect the land from high tides, hard measures such as improved management of the embankment would bestow visible co-benefits, according to the results of the FGDs. Community perception varies according to the level of involvement in adaptation interventions. The beneficiaries of two adaptation interventions implemented by SANGRAM identified few co-benefits, which are listed in Table 6.3.

Local farmers, irrespective of their involvement in specific adaptation interventions, argue that the level of awareness among individuals and the community as a whole has risen substantially about the impacts of cyclone only. Decreased death toll from cyclone is the visible result. The co-benefit derived from such awareness is the protection of household assets. However, the level of awareness among the fishing community remains inadequate. A public awareness campaign targeting the fishing community should be conducted to reduce their disaster risk. Some fishermen choose to fish despite warnings about the potential for cyclones. The community has learned how to use technology (which is itself a co-benefit) to receive warnings about cyclones. Therefore, adaptive capacity has risen among individuals, households and the community as a whole; however, this is not adequate per se. As such, training, leaflets, posters, banners, mobile apps and group-based income-generating activities must be included in a targeted public awareness campaign.

Table 6.3: Objectives and co-benefits from the selected adaptation interventions

Intervention and intended core benefits	Co-benefits realized
Homestead Plinth Raise: Protection of houses from storm surges during cyclone.	Supports duck and pigeon farming; Homestead plantation of fruit trees; Temporary employment (day-labor basis); Reduced migration of local residents; Improved sanitation.
Safe Drinking Water: Ensuring safe drinking water in the region	Reduced cost of health services; More labor/working hours for the female in the community.

A. Resilience enhancement

i) Natural resource conservation

The ponds for safe drinking water are skillfully managed for operation of pond sand filter, which is a kind of preservation of natural environment. Protected used of ponds by restricting use of shower, and dish and clothe cleaning helps keep the quality of water better. In contrast, homestead foundation upraising does not directly help conserve natural resources. However, it provides some basis for homestead plantation with a business motivation to the house owners.

ii) Restoration of natural resources

Damaged coastal and estuarine habitats require restoration usually after heavy cyclones. The selected projects have less contribution to the restoration of natural resources except the ponds for sand filter. However, these ponds are not many in number.

B. Risk mitigation

i) Contribution to disaster mitigation

Compared to the contributions to resilience enhancement, both the selected projects are more effective in disaster mitigation. Spread and number of cases affected by water-borne diseases have substantially reduced in the region after implementation of pond sand filter. Community people realize and acknowledge the benefits of pond sand filter in the daily life. Raising homestead also has reduced the death tolls and loss of assets. However, during a cyclone of low intensity, residents are not going to the cyclone shelter assuming that the house is high enough that storm surge would not be enough to get in the houses. Such misperception may result in loss of lives and be termed as negative co-benefit.

ii) Contribution to disaster management

The selected projects also contribute, not in all aspects though, to disaster management by managing resources and responsibilities to prepare, response and recover losses from cyclones and storm surges.

C. Vulnerability reduction

i) Contribution to employment and income security

Temporary employment opportunities created by raising homestead plinth levels are perceived as co-benefits. However, these co-benefits are seasonal and, in most cases, context-specific. For instance, road maintenance and/or reconstruction are common immediately after a cyclone in coastal areas, where many local residents work for money or food. If someone already has a job, they may not be able to participate in temporary construction work. Furthermore, such work does not provide a path toward full-time or secondary employment for local residents. In addition, such jobs are often perceived as 'low-grade', and many people may shun such opportunities for fear lowering their social status. Therefore, although climate-related infrastructure projects may produce co-benefits, they are not attractive to all people. Temporary migration, a necessity for survival, is common occurrence immediately after a natural disaster. As one schoolteacher explained,

> *People migrate to Dhaka at the rate of 19%* due to the burden of microfinance repayment and other social considerations. Many individuals refuse to engage in low-grade jobs, such as rickshaw pulling, which would lower their social status. They leave their homes and go Dhaka to earn money, but do not let people know their income sources.* (Translated from Bengali)

*It is unclear where the respondent got this figure.

The frequency of temporary migration decreases (i.e. co-benefits increase), when adaptation interventions are implemented immediately after a disaster because some temporary jobs are created. The earnings from such jobs are used by many households to repay microcredits. Microfinance recipients often criticize NGOs for demanding payments even after disasters. Because NGOs do not grant temporary waivers, the recipients cannot earn enough money to repay their loans unless they go to Dhaka or another major city to look for work.

ii) Community improved access to information provided by NGOs

Local farmers, irrespective of their involvement in specific adaptation intervention, argue that the level of awareness among individuals and community has risen substantially, which leads to fewer death tolls from natural disasters. Level of awareness among the fishing community is not adequate yet. While sufficiently informed about the potential danger of cyclone, some fishermen still go for fishing while an early warning is circulated. The community has learned the use of technology, which helps them receive early warning during the cyclones. Adaptive capacity as well has risen among the individuals, households and community as a whole; however, those are not sufficient.

iii) Improved access to technology

Improved access has not been ensured by the selected projects; however, government has ensured access to early warning before cyclones.

D. Adaptive capacity

To some individuals, adaptive capacity is a co-benefit, whereas to others, income generation is considered an added gain. FGDs also revealed that the loss and damage from natural disasters are treated as co-benefits in addition to reduced mortality. However, these co-benefits are not always achieved. One senior manager of an NGO pronounced as below during one FGD, which was agreed by all of the participants:

> *In earlier days, people were reluctant to gather at the cyclone shelters. Now a day, they move into cyclone shelters as soon as early warning is being declared. Yet, many heads of the households do not go to cyclone shelter. They remain in the house to protect the assets till their last breadth, and also to reduce the chances of theft.* (Translated from Bengali)

Enhance and comparatively more secured livelihood positively influences adaptive capacity of the community people.

Some business intentions have risen among community members. For an instance, early warning helped fishing communities prepared, but they were not able to protect the fishes before significantly. They used to catch fish as much as possible to store in order to sell after disaster. However, market-based knowledge has enabled them to sell the fish early, i.e. before the disaster hits, with a less margin of profit. Training helps fishing community decide fishing time. Through various projects inland fishing volume has gone up which has risen their earning as an addition to earning from the deep-sea fishing. Such enhancement of adaptive capacity is the impact of NGO involvement, as the government office shares.

Using sand filtration to provide safe drinking water for the community is likely to enhance social interaction because water from a single pond may be shared by as many as a couple of hundred households, depending on the size of the pond and how far away it is. Easy access to drinking water allows women and girls to spend more time in household and social activities, and also reduces the cost of health services. According to the results of the FGDs, the frequency of doctor visits related to child rearing has substantially declined due to the improved quality of drinking water. It must be noted that the quality of water obtained from pond sand filtration remains below average standards because it is unable to completely remove coliform bacteria from highly contaminated water (Harun and Kabir, 2013).

6.2.4 Dissemination of Adaptation Co-benefits

It was observed that dissemination of co-benefits by the project implementers were not sufficient, although the local and international NGOs (INGO) possesses a clearer concept about co-benefit. Use of saline tolerant variety, homestead plantation of fruit trees, development of livestock and poultry, along with improvement in sanitation have been identified by NGOs as co-benefits depending on core variety of adaptation intervention implemented in the region. However, implementing NGOs rarely shared with the beneficiaries about co-benefits. Through various training INGOs are also been able to help change some behavioral aspects of the community people, which may also be considered as co-benefits enjoyed by the community. For instance, willingness of family to send children to school have grown, community people have also shown their interest in gaining first-aid training. INGO officials have found that follow-up after project implementation would ensure more co-benefits than that of the project generates during or after the implementation. This post-facto dissemination of co-benefits is likely to affect the next interventions in the region. Local NGOs recognize that the follow-up of projects on a regular basis over a longer term is not possible due to resource constraints and changes in priority of the donors.

Government officials perceive that sharing of information about potential co-benefits from various interventions would ensure spontaneous participation of the community. These would develop ownership attitude about adaptation interventions. In absence of such pre-informed co-benefits, community people, i.e. the beneficiary, may lose their motivation to participate. One government officer explained,

> *Because the government offices have insufficient manpower, it is nearly impossible to educate the community about the co-benefit of interventions.* (Translated from Bengali)

Government offices contemplate that the beneficiaries as well should take the responsibilities to share among the community, in addition to the project implementers, on behalf of the government to disseminate the potential co-benefits from various adaptation interventions.

6.3 Discussion

Findings from the analysis have revealed that there is variation between identified adaptation co-benefits following the index-based method and perception evaluation. Index-based assessment has assured that homestead plinth raise returns adaptation co-benefits, while pond sand filter has provided negative co-benefits. In contrast, community identified co-benefits from the selected two interventions strategies include specific co-benefits including opportunities for poultry farming, homestead plantation of fruit trees and improved sanitation from homestead plinth raise, and reduced cost of health service and more female labor hour from pond sand filter.

Community has also perceived that the selected interventions have enhanced resilience through natural resource conservation and restoration. It is to note that not both of the interventions equally perform to conserve and restore natural resources. The interventions also play role in risk mitigation through contribution towards disaster risk reduction and management. For instance, higher homestead plinth is safer than lower level of plinth during flood and storm surge. The interventions, through contribution to employment and income as well as access to information and technology, also help reduce vulnerability of the community people. Adaptive capacity of the community also goes up through implemented interventions.

While individuals in the community did not perceive any negative co-benefits from the selected interventions, they voluntarily avoided maladaptation. For example, the private pond owners who allowed their ponds to be used for the safe drinking water project gave up the opportunity to benefit financially by practicing small-scale fishery in the pond. Besides, if not fishery, pond is used to wash their dishes or clothes. However, they did not view this as negative. Instead, they considered it a social contribution from which they would benefit in the afterlife. Initiatives to unearth co-benefits would also help identify potential negative co-benefits.

Since not all households are covered under the project, community perceives unjustified selection for the household level adaptation interventions. It has been argued that the microfinance recipients from the particular NGO are selected for raising plinth level. This practice has the potential to lead towards generating negative co-benefits in the form of decreased community cohesion or conflict among community. However, the implementing NGOs argue that the selections of houses are based on need assessment, implying that NGO-implemented projects also follow top-down approach (Bhabe et al, 2014).

Government officers argue that NGOs are helping the community by providing loans, but not by providing substantial support to raise resistance and capacity building to the negative impacts from climate change. While criticizing NGOs for many issues, government offices praised the NGOs for their immediate supports after disasters and successes, which generate substantial co-benefits. Villagers and community people, even with low-level of education in many cases, have learned how to run cooperative or a small village organization or a social organization. Communication among the community people has been developed. NGOs recognize that adaptation interventions that could provide many co-benefits are not sufficient; and the reasons include lack of political commitment. NGO practitioners argue that many of the interventions are outsourced while indigenous technologies are available. For example, plantation of palm tree is a good measure to resist the wind during cyclone while provides a shield against lightening, a recent threat that has taken many lives, are not been under consideration of the government initiatives. Nonetheless, NGO practitioners argue that resilience among the community improves if any intervention is successfully implemented.

NGO practitioners perceive that the level of loss and damages may be reduced if government initiates structural measures, which would also help the region enjoy additional benefits. In order to enjoy additional benefits, for instance, the height of the embankment needs to be raised by at least 1.5 meters. More palm trees have to be planted instead of other existing trees to protect the dyke from high tide. Currently a routine maintenance takes place for embankment, which is not sufficient as the NGO observes. NGOs urge that the Bangladesh Water Development Board (BWDB) needs to initiate large-scale repair and maintenance, which is very long due. The initial height of the dyke has constantly been reducing due to wear and tear and frequent cyclones, few of which are devastating, and infeasible tree plantation, which are uprooted when cyclone hits. Besides, due to heavy rain occasionally, soil erosion takes place and the bottom of tree becomes shaky. When water pressure goes up, embankments are broken or leaked initially and later wrecked resulting in increased vulnerability of the community. To protect from such damage large-scale investment is required for which a separate budget is a prerequisite, which the BWDB have not been sanctioned by the government, government office replies.

The participants in the FGD agreed that the NGO implemented adaptation interventions in the region provided the opportunity to a segment of the local community, especially the microcredit borrowers. This goes against the philosophy of sustainability. Informal social group formation for water collection from a common pond sand filter is a good indicator. For both poor and ultra-poor pond sand filter is a free option for safe drinking water. More solvent families accept the burden of operations and maintenance costs.

Homestead plinth raise, besides providing a risk shield against flood and storm surge in the long run, has provided temporary employment during construction period, which leads to reduction in temporary migration for the rural community. It has also created opportunities for income generation through improving food security for the poor and extreme poor. Female members of the community have also been benefitted from the adaptation intervention. However, technical aspects of this type of intervention are not free from flaws. The height of the plinth is usually determined by the project implementers based on the past experiences of the estimated highest level of storm surge plus two feet. However, there are no such tools to accurately measure the height of the water during cyclone. Houses selected for the projects had different heights. Budget allocated for each house was another determinant to ensure how far the high of the plinth would be. Since the severity of the future impacts from climate induced disasters or other forms of disasters are not predictable, there is still a doubt if the raised homestead would be safer in future. Furthermore, there is fear among dwellers that if the house is high enough, destruction will be more during cyclone.

Soil erosion remains a big challenge for the plinths of the houses. Maintenance requires some investment. The project did not ensure any involvement for maintenance leaving the option to the house owner. This intervention did not cover the whole region; only 25 households in this case, which creates frustration among many other house owners who were not approved the opportunity. There is a feeling of deprivation. Community perceives that only the influential and reference groups are able to avail the service from the NGO, particularly the beneficiaries of the NGO. Beneficiaries are primarily the micro-credit borrower. Whoever among the borrower had a good record of payment were eligible to avail the investment to raise the plinth of his/her house. Although there are challenges, addressing them all would ensure a certain level of co-benefits to acknowledge the intervention a sustainable adaptation.

6.4 Conclusion

In this chapter co-benefits from homestead plinth level raise and pond sand filter have been discussed in light of the extent of co-benefits from the interventions using an index and what community perceives about co-benefits. If adaptation co-benefits are necessary condition for sustainable adaptation has also been assessed. Both homestead plinth raise and pond sand filter interventions in Barguna district have resulted in co-benefits. However, pond sand filter provided net negative co-benefits. Both interventions have contributed to vulnerability reduction, while heavily impacted in enhanced resilience. Adaptive capacity as well has increased to a limited extent, as the community perceived. Disaster risk reduction is another area where raised homestead plinth substantially contributed positively. Natural resource conservation by way of protected pond and natural resource restoration by way of home gardening have also been observed. This concentrated adaptation projects have generated social interaction, minimized health service costs to the community and ensured more leisure time for females, which belongs to the criteria of sustainable adaptation. This phenomenon implies that adaptation co-benefits are necessary condition for sustainable adaptation. However, in these cases as well human attitude towards operation and maintenance has the potential to turn positive co-benefits to negative ones, leading to another evidence of maladaptation.

CHAPTER 7
DISCUSSION

In order to achieve the research objectives, the study identified the following research question: (1) what are the co-benefits of the selected interventions, measured by applying the adaptation co-benefits assessment methodology? (2) What does the community perceive about co-benefits from an adaptation intervention? (3) Is adaptation co-benefits necessary condition for sustainable adaptation? This chapter answers the research questions critically in light with the working hypothesis based on the results from the previous sections.

7.1 Co-benefits from Selected Adaptation Interventions in Bangladesh

The results of this study indicate that adaptation interventions, irrespective of its scope, threat it addresses, implementing entity, number of beneficiaries and location, provide both positive and negative co-benefits both to the region and people. In some instances, positive co-benefits surpass negative ones and in some other instance vice versa, as found when two different methods of co-benefits assessment: index-based and perception-based are implemented in selected cases. The difference in assessed and/or realized positive and negative co-benefits seems rational, since not all adaptation interventions have similar goals. Adaptation in a drought-prone area provides a different set of co-benefits compared with that of an intervention in a coastal region. Nonetheless, a common set of variables have been identified in this research where co-benefits in varied scale have been realized in the form of social and economic return in addition to basic environmental benefits like restoration of pond and canals in drought-prone region (Table 7.1).

Table 7.1: Additional benefits from two paths of adaptation interventions

Co-benefits	Barguna Sadar (NGO implemented)	Godagari (Government implemented)
Employment generation	Minimal seasonal	Agricultural employment increased substantially; Limited number of permanent/long term employment for maintenance of pump houses; Very few secondary employments generated for couple of individuals.
Income generation	Raised through use of saline tolerant variety in agriculture, homestead fruits tree plantation, poultry (duck)	Opportunity created for few people, who earns through selling pre-paid balances for running water pump (i.e. consequence of secondary employment).
Social interaction	Raised among the community members as a whole	Raised among the farmers
Child education	Not specific; but very few evidences are observed	Indirect positive influence towards educating children; however, measurement is not possible

There are evidences that guaranteed employment schemes help reduce social vulnerability (Norton et al., 2020); however, this research did not find many of such opportunities for the vulnerable small communities. In region-wide solar irrigation project there are few options for long-term low paid employment along with overall employment in agriculture, but in other cases i.e. pond sand filter or homestead foundation raise no such options have been observed. Income generation is substantial in solar irrigation, but for other two projects it is minimal. Social interaction is more among farmers in irrigation project, while for pond sand filter it is among the community as a whole, and for homestead there is no evidence of enhanced social interaction. Although the extent to which child education opportunity varies between interventions is not clear, yet there are some influences.

These results further support the idea that many interventions do not take co-benefits and social benefits in to account and increase vulnerability as identified by Van Oijstaeijen et al. (2020), Barnett and O'Neill (2010) and Eriksen and Brown (2011). The findings are also in agreement with what Herrero et al. (2013) have argued that co-benefits highlight the shorter-term impacts and ranges from water to agriculture to food security among other as stated by Floater et al. (2016). This research did not find any evidence that co-benefits exceed the primary benefits as argued by Markandya and Rübbelke (2004). There is also no evidence of maladaptation in the selected interventions according to the criteria set by Barnett and O'Neill (2010) and Juhola et al. (2016), though negative co-benefits have been found.

7.2 Lack of Awareness about Adaptation Co-benefits

The result of the study has found that the identified benefits were not noticed during the initial phase of implementation, which agrees with the definition that argues adaptation co-benefits may or may not be noticed during the initial stage of risk reduction measure (Samarasekara et al., 2017). Motivation to act on climate change is found related to the perception about co-benefits, which is subject to sufficient communication (Bain et al., 2016); however, to the communities for whom the adaptation interventions have been implemented in Bangladesh were not communicated sufficiently about the potential co-benefits. The possible reasons may include low level of awareness among the project implementers, while a certain level of awareness few of the employees from the project implementing entity have shown, and the lack of resources available for the project. Usually all sorts of adaptations, and broadly the development projects, require early assessment of costs and budgets, which are very difficult to amend once the project starts. Since co-benefits are not considered during the initial stages of the project preparation, during the implementation phase the project manager is less likely to integrate additional costs for including the component for dissemination of co-benefits to the wider community. As a result, return from informed co-benefits to the beneficiaries is not realized.

This research has found that community perception of the residents from Godagari is somehow in line with the co-benefits as assessed by using the index-based measure. The community identifies various co-benefits and the index also ranks 'high climate adaptation co-benefits' from the intervention. In contrast, the residents' perceptions about co-benefits in Barguna Sadar vary substantially with the results from the index-based assessment. Pond sand filter project has shown negative co-benefits, while homestead plinth level improvement shows positive co-benefits. This variation is possibly due to lack of knowledge about, and the problem with conceptualizing the concept of co-benefits. Such variation is also possible if the people from Barguna Sadar possess different levels of awareness. Many awareness campaigns have been successful in raising awareness about climate change and its impacts

(Singh et al., 2017; Yedla and Park, 2009) but awareness campaign to raise knowledge and understanding about adaptation co-benefits is not evident in the region.

The argument that communicating co-benefits is less likely to affect climate actions of the residents (Bain et al., 2016) in a low-income country like Bangladesh found somehow valid in this research. This argument may not sustain if literacy rate among the community members were high. Since the people from the community are less aware about the concept of climate change and its impacts, climate actions have little to do with co-benefits. The climate actions initiated by the local residents are the results of motivation and drive towards survival, which is not related to mere knowledge about co-benefits. Mass awareness campaign for fishing community for instance may be initiated to reduce the risk fishing community encounters during disasters. As such, training, leaflet and posters, banners, mobile apps, and group-based income generating activities have to be launched. The current level of activity is not sufficient per se; however, if such activities were initiated longer-term co-benefits would be ensured, in contrast to the argument made by Herrero et al. (2013).

Since among the most vulnerable communities, Barguna Sadar has massive potential to work with awareness building and group-based efficiency development. Due to distance from Dhaka, industrialization does not seem feasible as of yet; instead agriculture, fishery, and livelihood-based practices is preferred. Besides, absence of market facility due to distance and disaster risk hinders private sector involvement. Local residents have to come forward to develop themselves. While local NGOs are coming forward with such commitments to develop the region, these are not sufficient. Also, many commitments are contingent to the availability of donor fund. Local successful NGOs are mostly involved with microcredit facility to ensure their own survival. Hence, adaptation intervention by the NGOs are not spontaneous enough; instead a way to show-up their involvement to the potential donors with an expectation to receive grants for addressing impact from disaster, irrespective of the disasters whether climate change-induced or not. Accordingly, dissemination of co-benefits does not get sufficient priority among the project implementers. Although the findings, as the community perceived, did not reveal any negative co-benefit from the interventions in the region, communication of potential benefit may help resident identify possible negative co-benefits. In case any negative co-benefit ascends adaptation may turn to maladaptation due to opposing impacts (Ahmed et al., 2017).

The public-private engagement in Barguna Sadar particularly is of great importance since the region experiences frequent cyclones. Experience has shown that immediately after cyclones NGOs take the lead from their own resources, although limited, instead of waiting for donor funding. Government offices also acknowledge the NGOs contribution. It requires time for government to come up with aid for affected communities, while NGOs can start helping the community immediately. While NGOs act faster in response to disaster, for raising awareness they wait until they get funded.

7.3 Co-benefits Leading to Sustainable Adaptation

Accounting of co-benefits supports ranking of adaptation options to prioritize alternative, and also helps assess a better cost-benefit ratio to maximize the benefits from climate policy implementation (De Bruine et al., 2009; Hallegatte, 2009, Riekkola et al., 2011). The implemented interventions in the region so far have raised the adaptive capacity of the community. Both the higher homestead plinth level and pond sand filter impacted the society by enhancing their adaptive capacity and resilience to the impacts of climate change. Improved financial health through income and employment and enhanced social interactions along with positive impacts on vulnerability, adaptive capacity and resilience has ensured the adaptation intervention to become sustainable.

However, low investment along with supportive policy initiatives and innovative ideas for renewable energy from both the public and private sector has influenced the growth of solar energy (Sharif and Mithila, 2013). Since, national grid is not available in many remote locations, and installation of solar operated pump house by the BMDA does not require investment from farmers, the BMDA has become a success story by helping turn a drought-prone area into a high-yield agricultural zone through widespread installation of solar powered pump house. This has reduced vulnerability.

Higher number of beneficiaries for any adaptation intervention is rationally preferred, especially in a country like Bangladesh, since developing countries have many other priorities along with addressing climate change. Maximum number of beneficiary hence is preferred to ensure optimum utilization of resources. Small-scale initiatives, usually undertaken by the NGOs, to address the impact of climate change are not sufficient to cover the whole community due to shortage of resources and small grant amount from the donors. This shortfall may only be covered by the involvement of the government, which is aligned with the goal of Agenda 2030, i.e. people and partnership. Poverty reduction through employment and income generation is another core challenge current adaptation interventions should particularly focus. NGO-implemented projects have less opportunity to impact poverty reduction, since the nature of the project is to raise resilience or to reduce vulnerability. In contrast, government-implemented interventions have sizeable benefits, which reduce poverty. While social and economic benefits are observed, environmental impacts are not always favorable. Depletion of ground water is not a long-term viable option for any region. Irrigation is required for ensuring food security, but not necessarily at the cost of environment. Continuation of projects after the implementation is subject to many factors, which raise a concern about ensuring sustainability of adaptation interventions.

7.4 Co-benefits: A Necessary or a Sufficient Condition for Sustainable Adaptation?

Positive co-benefit(s) of adaptation intervention is a necessary condition for sustainable adaptation, since positive adaptation co-benefits alone cannot guarantee sustainable adaptation. For instance, if social justice is not ensured, an intervention should not be termed as sustainable. For cases like homestead plinth raise people perceive that the selection of household for the intervention to be supported is biased. Although the beneficiaries enjoy some positive co-benefits, social equity has not been ensured. Besides, the absence of positive adaptation co-benefits guarantees the absence of sustainable adaptation. Hence, positive adaptation co-benefits is found a necessary condition for sustainable adaptation.

Rapid agricultural growth, social service for the poor, reduction of rural poverty, sustained improvement in the standard of living and welfare of the rural population, development in community conditions including economic, social, environmental, health, infrastructural and housing situation are the usual criteria for rural development (Anriquez and Stamoulis, 2007; Akyüerek, 2010), most of which have been met with widespread irrigation in Godagari upazila. Besides, economic empowerment has led to reduced migration, motivation towards children education and overall peace in family situation. Comparable benefits have also been observed in the coastal Barguna Sadar upazila as well. Although economic and financial development through raised homestead plinth and pond sand filter are not comparable to the benefits farmers enjoy in Godagari, cost of health services has reduced, welfare of the residents has improved and social interaction has enhanced. All of these are positive co-benefits, irrespective the way farmers perceive.

The geoengineering of solar irrigation system integrating both mitigation and adaptation helps reduce emission, while also provides benefits to a wider selection of population irrespective of their social status and economic strength resulting in improvements in the standard of living of the rural residents. Farmers having any volume of land ownership, and the income level they belong are eligible to enjoy irrigation from the pump houses. The government funding enables this project to avoid the policy and institutional barriers that past rural electrification projects have struggled at the initial stage (Khan et al. 2019). Along with financing, lack of awareness, availability and access to information related to renewable energy and insufficient trainings are few of the barriers. Vulnerability towards the impacts of climate change has been reduced; adaptive capacity and resilience have been enhanced by the BMDA solar irrigation. In the coastal areas, higher level of homestead plinth and constructed pond sand filter have assisted in reduced vulnerability, and enhancement of resilience and capacity. Accordingly, this can be concluded that this positive adaptation co-benefits are necessary to evaluate an intervention sustainable. However, only the positive co-benefits cannot guarantee that the interventions would be sustainable. To become sustainable adaptation, it has to fulfill few other criteria (Brown, 2011; Eriksen and Brown, 2011; Wamsler and Brink, 2015). If social justice is not ensured by an adaptation measure, or the intervention does not show evidence of environmental integrity, it is difficult to evaluate the interventions as sustainable. An implemented adaptation may result in co-harm or provide negative co-benefits (Schneider, 2020; Turner et al, 1994) or turn to maladaptation (Barnett and O'Neill, 2010; Atteridge and Remling, 2018). Evaluating such interventions as sustainable adaptation is neither logical nor accepted by the society. These arguments lead to the conclusion that positive co-benefits is a necessary condition for sustainable adaptation.

7.5 Policy Recommendations

Since there are no assessment indices to measure adaptation co-benefits, a global initiative may be taken to develop one. A global political process must be followed. Presence of a large variety of adaptation intervention would make it difficult to bring all co-benefits under one umbrella. An index based on specific intervention may be developed, and over time expanded to other interventions. Besides, a common questionnaire may be developed following a consultative process in order to analyze stakeholders' perception for each intervention. There are evidences that informed co-benefits from adaptation interventions are beneficial in many aspects; however, different stakeholders are less informed about various co-benefits in Bangladesh. Dedicated climate change learning center has success stories. Hence, for raising awareness specifically about co-benefits, learning centers may be launched within project area. Cost of such additional activities may be included in project cost during the planning phase, so that implementation does not result in cost overrun. Adaptation interventions should also ensure inclusion of income generating activities to impact poverty eradication.

A common platform is also suggested to provide information about adaptation measures. A publicly accessible database of various adaptation interventions may be developed centrally or at least regionally in the climate vulnerable locations. This would provide information about adaptation interventions implemented in the region, donor of the project, beneficiary, goal and scope of the project, time frame, volume of investment and other related information along with a list of potential co-benefits from the interventions. Prospective donors may consult the database before planning projects to be implemented in the region. Such database would also restrict duplication of projects. A structured database is likely to influence scaling-up of bottom-up approach as well for project design and implementation and also enhance better collaboration, where co-benefits have the potential to play a role. If the local administration is fully aware of adaptation interventions undertaken in the region, repetitive or similar projects may not be planned and initiated.

The overall adaptation intervention follows top-down approach, where the donors or the government initiate and plan a program or project, and later implement in the vulnerable community. While for large scale program this may work, for small to mid-size projects bottom-up approach seems better. Actual and potential co-benefits from adaptations would contribute in the formulation of bottom-up approach. Hence, a mix-approach would better fit the adaptation requirement.

CHAPTER 8
CONCLUSION

Adaptation at the local level is one of the core functions for the adoption of the 2030 Agenda for Sustainable Development, which include 17 SD goals and 169 targets with a particular focus to people, planet, prosperity, peace and partnership. SDG 13 particularly urges for action addressing climate change. Adaptation is a process through which individual and community initiate tools and techniques to oppose the adverse consequences of climate change. It is an adjustment of natural or human system to moderate harm (IPCC, 2007). Irrespective of efforts by various implementing entities, not all adaptation interventions bring positive changes; maladaptation results in negative consequences. An adaptation, initially intended for positive changes, may bring misfortune for the unit where adaptation takes place or for other sectors, systems or social groups by enhancing vulnerability or risk, which is termed as maladaptation. Adaptation ensures positive returns from the intervention, but maladaptation results in negative return including negative co-benefits or co-harms. It is to note that popular adaptation does not mean sustainable adaptation. Sustainable adaptation includes a set of action resulting in social justice and environmental integrity along with maintaining the core social, economic and environmental development path. Adaptation co-benefits are the additional social, economic, and environmental benefits beyond the stated objectives, which may have been identified or not during the initial phase of adaption planning and implementation. Many interventions do not consider co-benefits and social benefits. There are confusions among researchers whether adaptation interventions are socially or environmentally sustainable or ever contribute to poverty alleviation or social well-being. Knowledge about the dynamism of co-benefits, which many interventions do not sufficiently take into account, is a prerequisite for ensuring sustainable adaptation. Due to global environmental concern and media involvement in environment protection, awareness towards climate change has grown. However, awareness about adaptation co-benefits are underexplored area of research. Hence, this research aims to assess and compare adaptation co-benefits from project level. This study intends to answer are the following research questions: (i) what are the co-benefits of the selected adaptation interventions, measured by employing an adaptation co-benefits assessment methodology? (ii) What does the community perceive about co-benefits from an adaptation intervention? (iii) Is adaptation co-benefits necessary condition for sustainable adaptation? This research employed a case study method where sources of data were FGD and in-depth interview. Measurement of adaptation co-benefits followed an index-based method, and community perception. Adaptation governance in Bangladesh is mostly hierarchical, government controlled top-down approach, and horizontally disintegrated. Most of the interventions are implemented with broader ‘development’ and ‘disaster response’ sector. With a view to explore sustainable adaptation in Bangladesh this study investigated three different interventions from two diverse locations with distinct climatic risks: drought and coastal hazards, and assessed co-benefits. Since purposeful sampling is appropriate for certain conditions, this study investigated region-wide irrigation in the northwestern part of Bangladesh implemented by BMDA, and homestead plinth level raise and pond sand filter in the southern coastal zone implemented by SANGRAM, a local NGO. Although this research is not a comprehensive representation of the whole country, it provides a snapshot from two of the highly vulnerable regions of the country with different geomorphological characteristics to the impact of climate change.

As for the first research question, index-based assessment of co-benefit from adaptation interventions shows that a varied level of co-benefits, positive and negative, is being realized from the selected cases. Co-benefits from various adaptation measures ranges from high adaptation co-benefits to negative co-benefits. The individual elements in the index, i.e. heat, drought, sea-level rise, agriculture and species habitat, also vary with different measures of adaptation. However, such variation seems obvious since the objectives of different intervention strategies are different. The measures are addressed to improve the living and livelihood of the community people; however, the mechanisms the interventions follow are different, which lead to distinct level of co-benefits.

In contrast to the varied level of identified co-benefits as assessed by using a standardized index, the second research question about perception of various stakeholders shows different levels of understanding. Beneficiaries, government offices and project implementing NGOs show a minimum level of apprehension and knowledge about the concept of co-benefits from adaptation interventions. Only a few people with some levels of literacy understand the meaning and concept of co-benefits. The concept about climate change and its impact is much clearer to the stakeholders than the knowledge about co-benefits. This is may be due the frequency of natural disaster in the coastal areas and the subsequent flow of information in various media. Since access to information is easier now a day, people from far north for instance are also informed about the severity and impact of disasters like cyclone. This research finds that although the residents are adapting to climate change, there is a general lack of information and awareness about climate change and co-benefits therefrom in the region wide solar irrigation implemented by BMDA in Rajshahi district. Dissemination of information about co-benefits by the government officials is very minimal. Nonetheless, employment in agriculture, family peace, willingness for schooling, and limited temporary migration are the co-benefits perceived by the community people. The intervention helps conserve natural resources and also contributes to disaster mitigation and management. By contributing to income and minimal employment, the intervention has reduced vulnerability and raised adaptive capacity of the community people, with obvious mitigation benefits. The only possible challenge for irrigation is the use of groundwater since it depletes. Since a government initiative, it follows a top-down approach with minimal involvement of local people in decision making, and the program has been found successful. The overall returns ensure the region-wide irrigation program a sustainable adaptation. From the analysis of NGO-implemented projects in the coastal district of Barguna, this research finds that dissemination of information about adaptation co-benefits by the project implementers is not sufficient. Nonetheless, the community perceives some co-benefits including temporary employment, homestead gardening, reduced migration, improved sanitation, and the reduced cost of health services. The co-benefits have resulted in resilience enhancement, disaster mitigation and management, vulnerability reduction, and enhanced adaptive capacity. The potential problem remains with the operational aspect: ownership attitude is missing for pond sand filter operation.

In response to the third research question, this research argues that the positive co-benefit(s) of adaptation intervention is not a sufficient condition for sustainable adaptation. To be a sufficient condition, an intervention should raise awareness of potential beneficiaries over co-benefits among others. Hence, the positive co-benefit is a necessary condition for sustainable adaptation. Presence of positive co-benefits alone cannot guarantee sustainable adaptation, since there are other factors which are to be met to ensure sustainable development; for instance, equity and social justice. Besides, if negative co-benefits surpass positive co-benefits, the specific intervention is less likely to be evaluated as sustainable. An implemented adaptation may turn in to maladaptation. In such cases, achieving sustainable adaptation will not be possible.

Earlier research on climate change adaptation have focused on conceptualizing adaptation, maladaptation and sustainable adaptation (Smith and Pilifosova, 2003; Doria et al., 2009; Barnett and O'Neill, 2010; Eriksen et al., 2011; Fedele et al., 2019), application of tools and techniques (Anik and Khan, 2012), and mainstreaming adaptation to national development planning and framework development (Ayers et al., 2014; Yedla and Park, 2009), for instance. Linkage of sustainable development to sustainable adaptation was also in focus; for instance, the study of Eriksen and O'Brien (2007), Eriksen and Brown (2011) and Brown (2011). However, adaptation co-benefits was a missing idea in the literature to assess sustainable adaptation. This research has filled the gap by adding the concept of co-benefits in the assessment of sustainable adaptation. At the end, this research has provided some policy recommendations.

Achievement of the UN SDGs partly depend on awareness and knowledge about environment and resources, global warming and the consequences, as well as environment conservation, which are likely to be influenced by wide-spread research in the context of global environmental studies. In order to create awareness about pressing environmental problems and climate crisis, assessment of existing knowledge is a prerequisite. Such understanding would help design various interventions smarter to address specific impact of climate change. This research contributes to the global environmental studies by providing examples of adaptation of resource constraints vulnerable communities and human-environment-climate interactions. Finding a sustainable way of living through various adaptation interventions from community perspective would enrich existing literature. Bangladesh has been hosting substantial numbers of adaptation interventions addressing various climatic threats including, but not limited to, flood, salinity, waterlogging and drought. Other countries with similar types of vulnerability may learn and apply from the successful cases from Bangladesh. Research covering all adaptation measures is a way to initiate and plan national development program including climate aspects; however, it is practically difficult and resource consuming. A step-by-step research in various locations with diverse threat may help achieve the national goal for sustained future. Since this study did not focus on the technical efficiency of solar panels or the irrigation system, pond sand filter and homestead plinth level, further study may be conducted to investigate the technical efficiency of the entire system in order to specifically calculate the actual emission reduction from each pump house, saving in health service cost due to pond sand filter, or contribution to national or regional economy from higher plinth level. Further investigation may also help to address how co-benefits may be quantified and included in the initiative and development of adaptation measures.

REFERENCES

Abedin, M. A. and Shaw, R. (2013). Agriculture adaptation in coastal zone of Bangladesh, In: Shaw. R., F. Mallick and A. Islam (eds.), *Climate Change Adaptation Actions in Bangladesh*, Springer, Tokyo, 207-25, https://doi.org/10.1017/978-4-431-54249-0_12.

Abedin, M. A., Collins, A. E., Habiba, U., & Shaw, R. (2019). Climate change, water scarcity, and health adaptation in southwestern coastal Bangladesh. *International Journal of Disaster Risk Science*, *10*(1), 28-42.Abedin M. A., Habiab, U., & Shaw, R. (2014). Community perception and adaptation to safe drinking water security: salinity, arsenic, and drought risks in coastal Bangladesh. *International Journal of Disaster Risk Science 5*(2), 110-124.

ACP-IGES-MOE. (2014). Bringing development and climate together in Asia. White Paper, Asian Co-benefits Partnership, Institute for Global Environment Strategies, and Ministry of Environment, Government of Japan, Tokyo. Retrieved from https://pub.iges.or.jp/pub/asian-co-benefits-partnership-white-paper-2014 (Accessed 12 December 2018).

Adaptation Fund. (2012). *Enhancing the Resilience of the Agricultural Sector and Coastal Areas to Protect Livelihoods and Improve Food Security*, https://www.adaptation-fund.org/sites/default/files/Jam%20Proposal%20for%20posting.pdf, accessed on 31 March 2014.

Adaptation Fund. (2013a). Project/Programme Proposal, Retrieved from https://www.adaptation-fund.org/wp-content/uploads/2015/01/Cambodia%20AF_FPP_23%20May%2023%20clean%20copy.pdf, accessed on 27 May 2017.

Adaptation Fund. (2013b). *Request from Rwanda for Project Funding from Adaptation Fund: Final Draft*, https://www.adaptation-fund.org/sites/default/files/Rwanda%20AF%20Full%20Proposal%20Sep%2013.pdf, accessed on 31 March 2014.

ADB. (2014). *Asian Development Bank and Bangladesh: Fact Sheet*. Retrieved from http://www.adb.org/sites/default/files/publication/27753/ban_0.pdf

Agol, D., Latawiec, A. E., & Strassburg, B. B. N. (2014). Evaluating impacts of development and conservation projects using sustainability indicators: Opportunities and challenges. *Environmental Impact Assessment Review*, 48, 1-9

Agrawal, S., & Jain, A. (2019). Sustainable deployment of solar irrigation pumps: Key determinants and strategies. *Wiley Interdisciplinary Reviews: Energy and Environment*, *8*(2), e325.

Ahmed, S. (2008). *The Status and Challenges of Water Infrastructure Development in Bangladesh: Country Report*. The First Regional Workshop on Eco Efficient Water Infrastructure in Asia, November 10 -12, 2008. Seoul, Korea.

Ahmed, N., Cheung, W. W., Thompson, S., & Glaser, M. (2017). Solutions to blue carbon emissions: Shrimp cultivation, mangrove deforestation and climate change in coastal Bangladesh. *Marine Policy*, 82, 68-75.

Akyürek, A. (2010). *NGOs in rural development and drawbacks. Making the Invisibles Visible*. England.

Alam A.T.M.J., Rahman M.S., Saadat A.H.M. and Huq M.M. (2012). Gamma Distribution and its Application of Spatially Monitoring Meteorological Drought in Barind, Bangladesh. *Journal of Environmental Science and Natural Resources*, ISSN 1999-7361, Vol. 5, Issue 2, pp.287-293.

Alam, S. (2012, April 14). CDM projects in Bangladesh. *The Financial Express.* Retrieved from http://www.thefinancialexpress-bd.com.

Alauddin, M., & Sarker, M. A. R. (2014). Climate change and farm-level adaptation decisions and strategies in drought-prone and groundwater-depleted areas of Bangladesh: an empirical investigation. *Ecological Economics*, 106, 204-213.

Alexandre, B. and Nimu, C. (2014). *Terminal Evaluation Report: Promoting Climate Resilient Water Management and Agriculture Practice in Rural Cambodia*, Phnon Penh.

Ali, A. (1999). Climate change impact and adaptation assessment in Bangladesh. *Climate Research, 12*(2-3), 109-116.

Ali, L. (2002). *An integrated approach for the improvement of flood control and drainage schemes in the coastal belt of Bangladesh* (Doctoral dissertation, Wageningen University, The Netherlands). Retrieved from https://library.wur.nl/WebQuery/wurpubs/fulltext/121307 (Accessed 7 November 2020).

Allen, K. M. (2006). Community-based disaster preparedness and climate adaptation: local capacity-building in the Philippines. *Disasters, 30*(1), 81-101.

Alliance Development Works. (2012). *World Risk Report 2012.* Retrieved from https://www.ehs.unu.edu/file/get/10487.pdf

Alliance Development Works. (2015). *World Risk Report 2015.* Retrieved from http://www.worldriskreport.org/fileadmin/PDF/2015/WRR_2015_engl_online.pdf

Amaru, S., & Chhetri, N. B. (2013). Climate adaptation: Institutional response to environmental constraints, and the need for increased flexibility, participation, and integration of approaches. *Applied Geography*, *39*, 128-139.

Anik, S. I., & Khan, M. A. (2012). Climate change adaptation through local knowledge in the north eastern region of Bangladesh. *Mitigation and Adaptation Strategies for Global Change, 17*(8), 879-896. Doi: 10.1007/s11027-011-9350-6

Anriquez, G., & Stamoulis, K. (2007). Rural Development and Poverty Reduction: Is agriculture still the key? ESA Working Paper No. 07-02, The Food and Agriculture Organization of the United Nations.

APAN. (2015). Pond Sand Filters. Asia Pacific Adaptation Network. Retrieved from http://www.asiapacificadapt.net/adaptation-technologies/database/pond-sand-filters (Accessed 17 September 2020).

Aryal, J. P., Sapkota, T. B., Rahut, D. B., Krupnik, T. J., Shahrin, S., Jat, M. L., & Stirling, C. M. (2020). Major climate risks and adaptation strategies of smallholder farmers in coastal Bangladesh. *Environmental Management*, *66*(1), 105.

Atteridge, A. & Remling, E. (2018). Is adaptation reducing vulnerability or redistributing it? *WIRES Climate Change*, 9:e500. doi: 10.1002/wcc.500

Ayers, J. (2011). Resolving the adaptation paradox: Exploring the potential for deliberative adaptation policy-making in Bangladesh. *Global Environmental Politics, 11*(1), 62-88. Doi: 10.1162/GLEP_a_00043

Ayers, J. M., & Huq, S. (2009). The value of linking mitigation and adaptation: A case study of Bangladesh. *Environmental Management, 43*(5), 753-764. Doi: 10.1007/s00267-008-9223-2

Ayers, J. M., Huq, S., Faisal, A. M., & Hussain, S. T. (2014). Mainstreaming climate change adaptation into development: a case study of Bangladesh. *Wiley Interdisciplinary Reviews: Climate Change, 5*(1), 37-51.

BADC (Bangladesh Agricultural Development Corporation) (2005) The minor irrigation survey report of 2005, Bangladesh. Bangladesh Agricultural Development Corporation, Dhaka

Bain, P. G., Milfont, T. L., Kashima, Y., Bilewicz, M., Doron, G., Garðarsdóttir, R. B., ... & Corral-Verdugo, V. (2016). Co-benefits of addressing climate change can motivate action around the world. *Nature Climate Change, 6*(2), 154.

Balaban, O., & de Oliveira, J. A. P. (2017). Sustainable buildings for healthier cities: assessing the co-benefits of green buildings in Japan. *Journal of Cleaner Production*, *163*, S68-S78.

Barua, D. C. (2001). Strategy for promotion and development of renewable technologies in Bangladesh: Experience from Grameen Shakti. *Renewable Energy, 22*(1-3), 205-210. Doi: 10.1016/S0960-1481(00)00012-4

Baten, M. Z., Amin, E. M., Sharin, A., Islam, R. and Chowdhury, S. A. (2009, December). Renewable Energy Scenario of Bangladesh: Physical Perspective. In Developments in Renewable Energy Technology (ICDRET), 2009 1st International Conference on the (pp. 1-5). IEEE.

Barnett, J., & O'Neill, S. (2010). Maladaptation. Global Environmental Change, 20, 211-213.

Barnett J. and O'Neill S.J. (2013). *Minimising the risk of maladaptation: A framework for analysis*. In: Palutikof J., Boulter S.L., Ash A.J., Stafford Smith M., Parry M., Waschka M. and Guitart D. (Eds). *Climate adaptation futures*. John Wiley and Sons, UK. pp. 87-93

Barrera, M., Berkel, C., & Castro, F. G. (2017). Directions for the advancement of culturally adapted preventive interventions: Local adaptations, engagement, and sustainability. *Prevention Science, 18*(6), 640-648.

BBS. (2015). Population Projection of Bangladesh: Dynamics and Trends 2011-2061, Bangladesh Bureau of Statistics. Dhaka. Retrieved from http://www.bbs.gov.bd/WebTestApplication/userfiles/Image/PopMonographs/PopulationProjection.pdf (10 Oct 2016).

Below, T., Artner, A., Siebert, R. and Sieber, S. (2010). Micro-Level Practices to Adapt to Climate Change for African Small-Scale Farmers. IFPRI Discussion Paper 00953, Environment and Production Technology Department, IFPRI.

Berry, P. M., Brown, S., Chen, M., Kontogianni, A., Rowlands, O., Simpson, G., & Skourtos, M. (2015). Cross-sectoral interactions of adaptation and mitigation measures. *Climatic Change*, 128(3-4), 381-393.

Bhave, A. G., Mishra, A., & Raghuwanshi, N. S. (2014). A combined bottom-up and top-down approach for assessment of climate change adaptation options. *Journal of Hydrology*, *518*, 150-161.

Biswas, WK, Diesendorf, M., and Bryce, P. (2004). Can photovoltaic technologies help attain sustainable rural development in Bangladesh?, *Energy Policy* 32(10), 1199-1207, https://doi.org/10.1016/S0301-4215(03)00083-1.

Bleischwitz, R. (2020). Mineral resources in the age of climate adaptation and resilience. *Journal of Industrial Ecology, 24*(2), 291-299.

BMDA. (2018). Achievements of last nine years. Barind Multipurpose Development Authority, Ministry of Agriculture, Rajshahi. Retrieved from http://www.bmda.gov.bd/site/page/63e0acd5-f177-4adc-bb5e-06c0710beae4/- (Accessed 19 October 2019)

Bollen, J. Guay, B. Jamet S. and Corfee-Morlot, J. (2009). Co-benefits of Climate Change Mitigation Policies. Economic Department Working Papers No. 693. Paris: Organisation for Economic Cooperation and Development (OECD), p. 5.

Borunda, A. (20 May 2020). Plunge in carbon emissions from lockdowns will not slow climate change. National Geographic. Retrieved from https://www.nationalgeographic.com/science/2020/05/plunge-in-carbon-emissions-lockdowns-will-not-slow-climate-change/ (Accessed 24 July 2020)

Boyatzis, R. E. (1998). *Thematic Analysis and Code Development: Transforming Qualitative Information.* London and New Delhi: SAGE.

Brammer, H. (2014). Bangladesh's dynamic coastal regions and sea-level rise. *Climate Risk Management 1*, 51–62.

Brooks, N., Anderson, S., Ayers, J., Burton, I., & Tellam, I. (2011). Tracking adaptation and measuring development. International Institute for Environment and Development. London.

Brown, K. (2011). Sustainable adaptation: An oxymoron? *Climate and Development*, *3*(1), 21-31.

Butler, J. R. A., Wise, R. M., Skewes, T. D., Bohensky, E. L., Peterson, N., Suadnya, W., ... & Bou, N. (2015). Integrating top-down and bottom-up adaptation planning to build adaptive capacity: a structured learning approach. *Coastal Management*, *43*(4), 346-364.

Cai, B., Bo, X., Zhang, L., Boyce, J. K., Zhang, Y., & Lei, Y. (2016). Gearing carbon trading towards environmental co-benefits in China: Measurement model and policy implications. *Global Environmental Change*, *39*, 275-284.

CARB, (2018). Climate Adaptation Co-benefit Assessment Methodology. California Air Resources Board. Retrieved from https://ww3.arb.ca.gov/cc/capandtrade/auctionproceeds/final_adaptation_fillable.pdf?_ga=2.79623188.1438571363.1572871030-27490766.1572871030 (accessed 4 November 2019)

CARE, (2011). Flood proofing through raising homestead plinth level, SHOUHARDO II Program, CARE, Dhaka. Retrieved from http://www.carebangladesh.org/shouhardoII/reportStory/FloodProofing.pdf (Accessed 4 July 2019)

Carpenter, C. (2001). Businesses, green groups and the media: the role of non-governmental organizations in the climate change debate. *International Affairs*, *77*(2), 313-328.

Carraro, C. (2006). Incentives and institutions: a bottom-up approach to climate policy. University Ca'Foscari of Venice, Dept. of Economics Research Paper, (49/06).

Carter, T. R., Parry, M. L., Harasawa, H., & Nishioka, S. (1994). *IPCC Technical Guideline for Assessing Climate Change Impact and Adaptations.* Department of Geography, University College London.

Chakrabarty, S., & Islam, T. (2011). Financial Feasibility and eco-efficiency of the solar home systems (SHS) in Bangladesh. *Energy*, 36(8). pp. 4821-4827.

Chandel, SS, MN Naik, and R. Chandel, 2015. Review of solar photovoltaic water pumping system technology for irrigation and community drinking water supplies, *Renewable and Sustainable Energy Reviews* 49, 1084-99, https://doi.org/10.1016/j.rser.2015.04.083.

Chatterjee, K. & Huq, S. (2002). A report on the inter-regional conference on adaptation to climate change. *Mitigation and Adaptation Strategies for Global Change* 7, 403-406.

Chowdhury, A., Ganesh, P. S., & Salequzzaman, M.D. (2006). A conceptual framework for the sustainability assessment procedures of the shrimp aquaculture industry in coastal Bangladesh.*International Journal of Agricultural Resources, Governance and Ecology*, *5*(2/3), 162-184.

Conway, D., Nicholls, R. J., Brown, S., Tebboth, M. G., Adger, W. N., Ahmad, B., ... & Said, M. (2019). The need for bottom-up assessments of climate risks and adaptation in climate-sensitive regions. *Nature Climate Change*, *9*(7), 503-511.

Corell, E., & Betsill, M. M. (2001). A comparative look at NGO influence in international environmental negotiations: Desertification and climate change. *Global Environmental Politics, 1*(4), 86-107.

Creswell, J. W. (2009). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* (3rd ed.). Thousand Oaks, California: SAGE.

Dasgupta, S., Kamal, F.A., Khan, Z.H., Choudhury, S.,& Nishat, A. (2014). *River salinity and climate change: evidence from coastal Bangladesh*. Environment and Energy Team, The World Bank. Retrieved 10 January 2015, http://documents.worldbank.org/curated/en/522091468209055387/pdf/WPS6817.pdf

de Bruin, K., Dellink, R. B., Ruijs, A., Bolwidt, L., van Buuren, A., Graveland, J., ... & Tassone, V. C. (2009). Adapting to climate change in The Netherlands: an inventory of climate adaptation options and ranking of alternatives. *Climatic Change, 95*(1-2), 23-45.

de Murieta, E. S. (2020). Ancillary Benefits of Adaptation: An Overview. In *Ancillary Benefits of Climate Policy* (pp. 181-196). Springer, Cham.

de Oliveira, J. A. P. (2013). Learning how to align climate, environmental and development objectives in cities: lessons from the implementation of climate co-benefits initiatives in urban Asia. *Journal of Cleaner Production*, *58*, 7-14.

Dewan, C. (2012). Literature Review: review of the historical evaluation of policies and institutions of community based management in coastal Bangladesh. International Water Management Institute, Colombo.

Dewan, C., Mukherji, A., &Buisson, M. C. (2015). Evolution of water management in coastal Bangladesh: from temporary earthen embankments to depoliticized community-managed polders. *Water International 40*, 401–416.

Doria, M. D., Boyd, E., Tompkins, E. L., & Adger, W. N. (2009). Using expert elicitation to define successful adaptation to climate change. *Environmental Science and Policy12* (7), 810-819. Doi: 10.1016/j.envsci.2009.04.001

Doundoulakis, E., & Papaefthimiou, S. (2020). Ancillary benefits of climate policies in the shipping sector. In Ancillary Benefits of Climate Policy (pp. 257-276). Springer, Cham.

Dovie, D. B. K. (2019). Case for equity between Paris Climate agreement's Co-benefits and adaptation. *Science of the Total Environment, 656*, 732-739.

Dupuis, J. and Knoepfel, P. (2013). The adaptation policy paradox: the implementation deficit of policies framed as climate change adaptation. *Ecology and Society 18*(4), 31. Doi: 10.5751/ES-05965-180431.

Eckstein, D., Künzel, V., Schäfer, L., & Winges, M. (2019). Global Climate Risk Index 2020. *Bonn: Germanwatch*.

Eriksen, S., Aldunce, P., Bahinipati, C. S., Martins, R. D. A., Molefe, J. I., Nhemachena, C., ... & Ulsrud, K. (2011). When not every response to climate change is a good one: Identifying principles for sustainable adaptation. *Climate and Development, 3*(1), 7-20.

Eriksen, S., & Brown, K. (2011). Sustainable adaptation to climate change. *Climate and Development, 3*(1), 3-6.

Eriksen, S. and Lind, J., (2009). Adaptation as a political process: adjusting to drought and conflict in Kenya’s drylands. *Environmental Management*, 43. 817 – 835.

Eriksen, S. and O’Brien, K., 2007. Vulnerability, poverty and the need for sustainable adaptation measures. *Climate Policy*, 7. 337–352.

EU. (2016). Key policy issues in implementing and evaluating the EU adaptation strategy. Bottom-up Climate Adaptation Strategies towards a Sustainable Europe (BASE), Policy Brief, Issue 4, June 2016. European Union.

FAO-GIZ. (2018). The benefits and risks of solar powered irrigation – a global overview. Food and Agriculture Organization of the United Nations and Deutsche Gesellschaft für Internationale Zusammenarbeit, Retrieved from http://www.fao.org/3/i9047en/I9047EN.pdf (Accessed 29 September 2019)

Fedele, G., Donatti, C. I., Harvey, C. A., Hannah, L., & Hole, D. G. (2019). Transformative adaptation to climate change for sustainable social-ecological systems. *Environmental Science & Policy*, *101*, 116-125.

Fatemi, M., Okyere, S. A., Diko, S. K., Kita, M., Shimoda, M., & Matsubara, S. (2020). Physical Vulnerability and Local Responses to Flood Damage in Peri-Urban Areas of Dhaka, Bangladesh. *Sustainability*, *12*(10), 3957.

Fitzgerald, J. and Villarin, J. R.T. United States Environmental Protection Agency. Integrated Environmental Strategies (IES) Program. Presentation at 2005 International Conference on Atmosphere Protection. CGE Training Workshop on Mitigation Assessments, Seoul, Korea, September 2005. https://unfccc.int/files/national_reports/non-annex.../usepa.pps

Floater, G., Heeckt, C., Ulterino, M., Mackie, L., Rode, P., Bhardwaj, A., ... & Huxley, R. (2016). Co-benefits of urban climate action: a framework for cities. London School of Economics and Political Science. Retrieved from http://eprints.lse.ac.uk/68876/1/Cobenefits_Of_Urban_Climate_Action.pdf (Accessed 20 July 2019).

Füssel, H. M. (2007). Adaptation planning for climate change: concepts, assessment approaches, and key lessons. *Sustainability Science*, 2(2), 265-275.

Gao, S., & Jiang, P. (2019). Detecting and understanding co-benefits generated in tackling climate change and environmental degradation in China. *Environment, Development and Sustainability*, *22*, 4589-4618.

Garrett, R.D. and Latawiec, A.E. (2015). What are sustainability indicators for? In *Sustainability Indicators in Practice* (Ed) by A.E. Latawiec and D Agol, De Gruyter, Berlin 2015.

Gerring, J. (2008). Case selection for case-study analysis: Qualitative and quantitative techniques. In The Oxford handbook of political methodology by J. M. Box-Steffensmeier, H. E. Brady and D. Collier. Oxford University Press.

Gerring, J., & Cojocaru, L. (2016). Case-selection: A diversity of methods and criteria. *Sociological Methods & Research*, *45*, 392-423.

GOB. (2011). *Sector Development Plan (2011-2025)*, Water Supply and Sanitation Sector in Bangladesh, Government of Bangladesh, Dhaka.

Goco, J. A. (2005). Climate change governance and co-benefits. In Proceedings of the 15th Asia-Pacific Seminar on Climate Change. Overseas Environmental Cooperation Centre, Tokyo.

Granberg, M., & Glover, L. (2014). Adaptation and maladaptation in Australian national climate change policy. *Journal of Environmental Policy & Planning*, *16*(2), 147-159.

Gupta, A. D., Babel, M. S., Albert, X., & Mark, O. (2005). Water sector of Bangladesh in the context of integrated water resources management: A review. *International Journal of Water Resources Development 21*(2), 385-398.

Gupta, E. (2019). The impact of solar water pumps on energy-water-food nexus: Evidence from Rajasthan, India. *Energy Policy*, *129*, 598-609.

Gyawali, S., Acharaya, S. K., Koirala, R., Shrestha, B. B. (2017). Final evaluation report of CARE Nepal, Hariyo Ban Program. Kathmandu. Retrieved from https://www.careevaluations.org/wp-content/uploads/SWC_FinalEvaluationReport_HariyoBanProgram_26July2017.pdf (Accessed 7 November 2020)

Habiba, U., Shaw, R. and Takeuchi, Y. (2011). Chapter 2 Socioeconomic Impact of Droughtsin Bangladesh. In *Droughts in Asian Monsoon Region* (pp. 25-48). Emerald Group Publishing Limited.

Halady, I. R., & Rao, P. H. (2010). Does awareness to climate change lead to behavioral change? *Journal of Climate Change Strategies and Management* Vol. 2 No. 1, 6-22.

Halder, P. K., Paul, N., Joardder, M. U., & Sarker, M. (2015). Energy scarcity and potential of renewable energy in Bangladesh. *Renewable and Sustainable Energy Reviews, 51*, 1636-1649.

Hallegatte, S. (2009). Strategies to adapt to an uncertain climate change. *Global Environmental Change*, *19*(2), 240-247.

Halsnæs, K., & Verhagen, J. (2007). Development based climate change adaptation and mitigation-conceptual issues and lessons learned in studies in developing countries. *Mitigation and Adaptation Strategies for Global Change 12*(5), 665-684. Doi: 10.1007/s11027-007-9093-6

Hamilton, K., & Akbar, S. (2010). Assessing the environmental co-benefits of climate change actions. 2010 Environmental Strategy, The World Bank Group. Retrieved from https://pdfs.semanticscholar.org/049c/783514ee5c3893b5a227d41f4e44dd7323ab.pdf?_ga=2.60010472.490937978.1597902895-659061905.1597902895 (Accessed 20 August 2020)

Haque, M. M., Bremer, S., Aziz, S. B., & van der Sluijs, J. P. (2017a). A critical assessment of knowledge quality for climate adaptation in Sylhet Division, Bangladesh. *Climate Risk Management, 16*, 43-58.

Haque, U., Hashizume, M., Kolivras, K. N., Overgaard, H. J., Das, B. and Yamamoto, T. (2012). Reduced death rates from cyclones in Bangladesh: what more needs to be done? *Bulletin of the World Health Organization* 90, 150-156. Doi: 10.2471/BLT.11.088302

Haque, M. E., Islam, M. R., Islam, M. S., Haniu, H., & Akhter, M. S. (2017b). Life cycle cost and energy consumption behavior of submersible pumps using in the Barind area of Bangladesh. *Energy Procedia*, *110*, 479-485.

Harlan, S. L., & Ruddell, D. M. (2011). Climate change and health in cities: impacts of heat and air pollution and potential co-benefits from mitigation and adaptation. *Current Opinion in Environmental Sustainability*, *3*(3), 126-134.

Harmeling and Eckstein, D. (2012). *Global Climate Risk Index 2013: Who suffers most from extreme weather events?* Weather-related loss events in 2011 and 1992-2011. Briefing Paper. Bonn: Germanwatch.

Harun, M. A. Y. A., & Kabir, G. M. M. (2013). Evaluating pond sand filter as sustainable drinking water supplier in the Southwest coastal region of Bangladesh. *Applied Water Science*, *3*(1), 161–166.

Hasan, M. H., Kader, M. A., Shaon, M. T. I., Alam, M. I., & Billah, M. M. (2013). Performance on existing Pond Sand Filter (PSF) located at southern region of Bangladesh: a case study. *International Journal of Engineering and Technology, 3*(6), 600-607.

Hasanuzzaman, M., Al-Amin, A. Q., Khanam, S. and Hosenuzzaman, M. (2015). Photovoltaic Power Generation and Its Economic and Environmental Future in Bangladesh. *Journal of Renewable and Sustainable Energy*, *7*(1), 013108.

Hay, J., & Mimura, N. (2006). Supporting climate change vulnerability and adaptation assessments in the Asia-Pacific region: an example of sustainability science. *Sustainability Science*, *1*(1), 23-35.

Herrero, S. T., Ürge-Vorsatz, D., & Petrichenko, K. (2013). Fuel poverty alleviation as a co-benefit of climate investments: evidence from Hungary. In *European Council for an Energy Efficient Economy Summer Study (ECEEE) Summer Study Proceedings* (pp. 1605-1616).

Higgins, P.A.T. (2014). Climate Change Risk Management. An AMS Policy Program Study. The American Meteorological Society, Washington, DC.

Hossain, M. A., Hassan, M. S., Mottalib, M. A., & Hossain, M. (2015). Feasibility of solar pump for sustainable irrigation in Bangladesh. International Journal of Energy and Environmental Engineering, 6(2), 147-155.Huq, S. (2015 April 29). Politics of climate change: tracking climate finance. *The Daily Star*, Retrieved from http://m.thedailystar.net/op-ed/finance/tracking-climate-finance-77197

Huq, S. (2011). Adaptation laboratory: a global consortium converges on Bangladesh to learns about confronting long-term climate change, Action Research on Community Adaptation in Bangladesh (ARCAB), IIED Climate Change Group, London.

Huq, S., & Ayers, J. (2008). *Climate Change Impacts and Responses in Bangladesh.* European Parliament, Policy Department Economic and Scientific Policy. Brussels: European Parliament.

Huq, S. & Grubb, M. (2007). Preface. *Mitigation and Adaptation strategies for Global Change 12*, 645-649. Doi: 10.1007/s11027-007-9091-8

Huq, S., Yamin, F., Rahman, A., Chatterjee, A., Yang, X., Wade, S., ... & Chigwada, J. (2005). Linking climate adaptation and development: A synthesis of six case studies from Asia and Africa. *IDS Bulletin*, *36*(4), 117-122.

IDCOL. (2018). Renewable Energy: Solar Home System Program. Infrastructure Development Company Limited, Dhaka. Retrieved from http://idcol.org/home/solar (Accessed 25 December 2018)

IISD. (2001). A Reporting Service for Environment and Development Negotiations. *Earth Negotiations Bulletin, (12)*176. Manitoba: International Institute for Sustainable Development.

IISD. (2007). Creating Indicators of Sustainability, A social approach, Draft for Discussion, Manitoba. Retrieved from https://www.iisd.org/pdf/2007/igsd_creating_indicators.pdf (Accessed 13 July 2019)

IKI. (2018). Activating the co-benefits for a successful implementation of the Paris Agreement, COP24 briefing on key discussion items on the Paris Rulebook. Retrieved from https://seors.unfccc.int/applications/seors/attachments/get_attachment?code=5UK572NL9LPGFCU20VJFT48B1K4X8H7V (Accessed 19 March 2019).

IPCC. (2001) Climate Change 2001. Working Group II: Impacts, Adaptation and Vulnerability, Geneva: Intergovernmental Panel on Climate Change, https://archive.ipcc.ch/ipccreports/tar/wg2/index.php?idp=643.

IPCC. (2007). *Fourth Assessment Report (AR4).* Geneva: Intergovernmental Panel on Climate Change.

IPCC. (2011). *Summary for Policymakers.* In: IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen.

IPCC. (2013). *Climate Change 2013: The Physical Science Basis. Summary for Policymakers*. Contribution of Working Group I to the IPCC Fifth Assessment Report.

IPCC, (2014): Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32.

IPCC. (2018). Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. In Press.

Islam, S. N., & Gnauck, A. (2008). Mangrove wetland ecosystems in Ganges-Brahmaputra delta in Bangladesh. *Frontiers of Earth Science in China*, *2*(4), 439-448.

Islam, M. R., Jahan, C. S., Rahaman, M. F., & Mazumder, Q. H. (2020). Governance status in water management institutions in Barind Tract, Northwest Bangladesh: an assessment based on stakeholder's perception. *Sustainable Water Resources Management*, *6*(2), 1-14.

Islam, M. M., Sallu, S., Hubacek, K., & Paavola, J. (2014). Vulnerability of fishery-based livelihoods to the impacts of climate variability and change: insights from coastal Bangladesh. *Regional Environmental Change, 14*(1), 281-294.

Jahan, C. S., Mazumder, Q. H., Islam, A. T. M. M. and Adham, M. I. (2010). Impact ofirrigation in Barind area, NW Bangladesh—an evaluation based on the meteorologicalparameters and fluctuation trend in groundwater table. *Journal of the Geological Society of India, 76*(2), 134-142.

Jiang, P., Xu, B., Geng, Y., Dong, W., Chen, Y., & Xue, B. (2016). Assessing the environmental sustainability with a co-benefits approach: a study of industrial sector in Baoshan District in Shanghai. *Journal of Cleaner Production*, *114*, 114-123.

Jochem, E., & Madlener, R. (2003, December). The forgotten benefits of climate change mitigation: Innovation, technological leapfrogging, employment, and sustainable development. In Workshop on the Benefits of Climate Policy: Improving Information for Policy Makers.

Juhola, S., Glaas, E., Linnér, B. O., & Neset, T. S. (2016). Redefining maladaptation. *Environmental Science & Policy, 55*, 135-140.

Kahn, M. E. (2003). Two measures of progress in adapting to climate change. *Global Environmental Change, 13*(4), 307-312. Doi: 10.1016/S0959-3780(03)00052-9

Kamalapur, G. D., & Udaykumar, R. Y. (2011). Rural electrification in India and feasibility of Photovoltaic Solar Home System. *Electrical Power and Energy System.* 33. pp. 594-599.

Karim, M. F., & Mimura, N. (2008). Impacts of climate change and sea-level rise on cyclonic storm surge foods in Bangladesh. *Global Environmental Change, 18*(3), 490-500. Doi: 10.1016/j.gloenvcha.2008.05.002

Kanojia, C. (2019). Solar power to revolutionize Bangladesh irrigtiaon. The Financial Express, 23 March 2019. Retrieved from https://www.thefinancialexpress.com.bd/views/opinions/solar-power-to-revolutionise-bangladesh-irrigation-1552917511

Karlis, N. (2019). How a rural women's network in sub-Saharan Africa became a model for fighting the climate crisis, Salon, 28 September 2019. Retrieved from https://www.salon.com/2019/09/28/how-a-rural-womens-network-in-sub-saharan-africa-became-a-model-for-fighting-the-climate-crisis/ (Accessed 30 September 2019)

Kelley, LC, Gilbertson, E., Sheikh, A., Eppinger, S.D., and Dubowsky, S. (2010). On the feasibility of solar-powered irrigation, *Renewable and Sustainable Energy Reviews* 14, 2669-82, https://doi.org/10.1016/j.rser.2010.07.061.

Khan, T., Khanam, S. N., Rahman, M. H., & Rahman, S. M. (2019). Determinants of microfinance facility for installing solar home system (SHS) in rural Bangladesh. *Energy Policy*, *132*, 299-308.

Khew, Y. T. J., Jarzebski, M. P., Dyah, F., San Carlos, R., Gu, J., Esteban, M., ... & Akiyama, T. (2015). Assessment of social perception on the contribution of hard-infrastructure for tsunami mitigation to coastal community resilience after the 2010 tsunami: Greater Concepcion area, Chile. *International Journal of Disaster Risk Reduction*, *13*, 324-333.

Kieu, T. K., Singer, J., & Gannon, T. J. (2016). Education for sustainable development in Vietnam: Lessons learned from teacher education. *International Journal of Sustainability in Higher Education*, *17*(60), 853 – 874.

Kim, Y., Sohn, H-S., & Park, B. (2019). Make the village better: An evaluation of the Saemaul Zero Hunger Communities Project in Tanzania and Bangladesh, *World Development*, *124*, Doi.org/10.1016/j.worlddev.2019.104652.,

Klein, R. J., Huq, S., Denton, F., Downing, T. E., Richels, R. G., Robinson, J., & Toth, F. L. (2007). Inter-relationships between adaptation and mitigation. In M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. Linden, & C. E. Hanson, *Climate Change 2007: impacts, adaptation and vulnerability.* Contribution of working group II to the forth assessment report of the Intergovernmental Panel on Climate Change (pp. 745-777). Cambridge, UK: Cambridge University Press.

Klöck, C. & Fink, M. (2019): Dealing with climate change on small islands: Towards effective and sustainable adaptation? In: Klöck, C. & Fink, M. (eds.): Dealing with climate change on small islands: Towards effective and sustainable adaptation? (pp. 1–15). Göttingen: Göttingen University Press. https://doi.org/10.17875/gup2019-1209

Klotz, A. (2008). Case selection. In Qualitative Methods in International Relations (pp. 43-58). Palgrave Macmillan, London.

Komatsu, S., Kaneko, S., Shrestha, R. M., & Ghosh, P. P. (2011). Nonincome factors behind the purchase decision of solar home system in rural Bangladesh. *Energy for Sustainable Development*, 15(3). pp. 284-292.

Knittel, N. (2016). Mitigation: Co-Benefits and Interlinkages to Adaptation, Climate Policy Info Hub, 03 February 2016. Retrieved from http://climatepolicyinfohub.eu/mitigation-co-benefits-and-interlinkages-adaptation (Accessed 14 December 2018).

Kreft, S. and Eckstein, D. (2013). *Global Climate Risk Index 2014: Who suffers most from extreme weather events?* Weather-related loss events in 2012 and 1993-2012. Briefing Paper. Bonn: Germanwatch.

Kreft, S., Eckstein, D., Dorsch, L and Fischer, L. (2015). *Global Climate Risk Index 2016: Who suffers most from extreme weather events?* Weather-related loss events in 2014 and 1995-2014. Briefing Paper. Bonn: Germanwatch.

Krupnick, A., Burtraw, D., & Markandya, A. (2000). The ancillary benefits and costs of climate change mitigation: a conceptual framework. Ancillary benefits and costs of greenhouse gas mitigation, 53-93.

Kundzewicz, Z. W., Matczak, P., Otto, I. M., & Otto, P. E. (2020). From “atmosfear” to climate action. *Environmental Science & Policy, 105*, 75-83.

Kurata, M., Matsui, N., Ikemoto, Y., & Tsuboi, H. (2018). Do determinants of adopting solar home systems differ between households and micro-enterprises? Evidence from rural Bangladesh. *Renewable Energy, 129*, 309-316.

Kwan, S. C., & Hashim, J. H. (2016). A review on co-benefits of mass public transportation in climate change mitigation. *Sustainable Cities and Society, 22*, 11-18.

Lahimer, A. A., Alghoul, M. A., Yousif, F., Razykov, T. M., Amin, N., Sopian, K., (2013). Research and development aspects on decentralized electrification options for rural household. *Renewable and Sustainable Energy Reviews.* (24). pp. 314-324.

Laroche, M., Bergeron, J., & Barbaro-Forleo, G. (2001). Targeting consumers who are willing to pay more for environmentally friendly products. *Journal of Consumer Marketing*, *18*(6), 503 - 520.

Latawiec, A., & Agol, D. (2015). *Sustainability Indicators in Practice*. Walter de Gruyter GmbH & Co KG, pp 4,

Lavorel, S., Colloff, M. J., Locatelli, B., Prober, S. M., Bruley, E., & Nettier, B. (2018). Nature's contribution to adaptation in the French Alps. ESP.

Le, D., & Mori, A. (2017). Multi-level analysis of sustainable energy transition in Kenya: Role of exogenous actors. *International Journal of Energy Economics and Policy, 7*(5), 111-122.

Leszczynska, A. (2010). Manager's attitude towards environment. *Industrial Management & Data System*, *110*(8), 1234-1250.

Le Quéré, C., Jackson, R. B., Jones, M. W., Smith, A. J., Abernethy, S., Andrew, R. M., ... & Friedlingstein, P. (2020). Temporary reduction in daily global CO 2 emissions during the COVID-19 forced confinement. *Nature Climate Change,* 1-7.

Li, N., Shang, L., Yu, Z., & Jiang, Y. (2020). Estimation of agricultural greenhouse gases emission in interprovincial regions of China during 1996–2014. *Natural Hazards*, *100*(3), 1037-1058.

Lin, M. H. (2019, January). Integrated Decision Framework on UN SDGs and Climate Adaptation: SDG 6 in Taiwan. In Geophysical Research Abstracts (Vol. 21). EGU2019-12544.

Lo, K., & Broto, V. C. (2019). Co-benefits, contradictions, and multi-level governance of low-carbon experimentation: Leveraging solar energy for sustainable development in China. *Global Environmental Change, 59*, 101993.

Loennqvist, L., Huda, N., Kabir, N., Kaisari, R. Z., Khandker, M., & Chandra, S. S. (2010). *Shortcut to the frontline: supporting local NGOs on climate change in Bangladesh.* Occasional Papers Series No: 50. INTRAC and PRIP Trust.

Ma, G., Andrews-Speed, P., & Zhang, J. D. (2011). Study of Chinese consumer attitude on energy-saving houshold appliances and government policies: based on a questionnaire survey of residents in Chongqing, China. *Energy Procedia 5*, 445-451.

Mahmuduzzaman, M., Ahmed, Z.H., Nuruzzaman, A.K.M., Ahmed, F.R.S. (2014). Causes of salinity intrusion in coastal belt of Bangladesh. *International Journal of Plant Research 4* (4A), 8-13.

Mapplecroft. (2013). *Climate Change Vulnerability Index 2013.* Retrieved June 1, 2014 from https://www.maplecroft.com.

Markandya, A. & Rübbelke, T. D. G. (2004). Ancillary Benefits of Climate Policy/Sekundäre Nutzen der Klimapolitik. *Journal of Economics and Statistics* (Jahrbuecher fuer Nationaloekonomie und Statistik), 224(4), 488-503.

Marshall, M. N. (1996). Sampling for qualitative research. *Family Practice 13*(6), 522-525.

Martín, E. G., Giordano, R., Pagano, A., van der Keur, P., & Costa, M. M. (2020). Using a system thinking approach to assess the contribution of nature based solutions to sustainable development goals. *Science of The Total Environment*, *738*, 139693.

Mayrhofer, J. P., & Gupta, J. (2016). The science and politics of co-benefits in climate policy. *Environmental Science & Policy*, *57*, 22-30.

Mekhilef, S., SZ Faramarzi, R. Saidur, and Z. Salam, 2013. The application of solar technologies for sustainable development of agricultural sector, *Renewable and Sustainable Energy Reviews 18*, 583-94, https://doi.org/10.1016/j.rser.2012.10.049.

Mendelsohn, R. (2000). Efficient adaptation to climate change. *Climatic Change 45*(3-4), 583-600. Doi: 10.1023/A:1005507810350

Mendelsohn, R. (2006). The role of markets and governments in helping society adapt to a changing climate. *Climatic Change 78*(1), 203-215. Doi: 10.1007/s10584-006-9088-4

Minar, M. H., Hossain, M. B., & Shamsuddin, M. D. (2013). Climate change and coastal zone of Bangladesh: vulnerability, resilience and adaptability. *Middle-East Journal of Scientific Research*, *13*(1), 114-120.

Miyatsuka, A., & Zusman, E. (2009). Fact Sheet No. 1 What are Co-benefits?. Asian Co-benefits Partnership. Retrieved from https://pub.iges.or.jp/system/files/publication_documents/pub/nonpeer/2393/acp_factsheet_1_what_co-benefits.pdf (Accessed on 4 January 2019).

Mondal, M. A. H. and Denich, M. (2010). Assessment of Renewable Energy Resources Potential for Electricity Generation in Bangladesh. *Renewable and Sustainable Energy Reviews, 14*(8), pp. 2401-2413.

Mondal, A. H., & Klein, D. (2011). Impacts of solar home systems on social development in rural Bangladesh. *Energy for Sustainable Development*, 15(1). pp. 17-20.

Monroe L. S. & Wicander, R. (2009). *The Changing Earth: Exploring Geology and Evolution* (5th ed.). Belmont, CA: Brooks/Cole

MOEF. (2005). *National Adaptation Programme of Action.* The Ministry of Environment and Forest, Dhaka: The Government of Bangladesh.

MOEF. (2012). *Second National Communication of Bangladesh to the United Nations Framework Convention of Climate Change.* The Ministry of Environment and Forest, Dhaka: The Government of Bangladesh.

Morecroft, M. D., Duffield, S., Harley, M., Pearce-Higgins, J. W., Stevens, N., Watts, O., & Whitaker, J. (2019). Measuring the success of climate change adaptation and mitigation in terrestrial ecosystems. *Science, 366*(6471).

Mori, A. (2016). Environmental Policies in East Asia: Origins, Development, and Future. In Basic Studies in Environmental Knowledge, Technology, Evaluation, and Strategy (pp. 69-78). Springer, Tokyo.

Mori, A. (2018). Socio-technical and political economy perspectives in the Chinese energy transition. *Energy Research & Social Science*, *35*, 28-36.

Mori, A. (2019). Temporal dynamics of infrasystem transition: The case of electricity system transition in Japan. *Technological Forecasting and Social Change, 145*, 186-194.

Mori, A. (2020). Foreign actors, faster transitions? Co-evolution of complementarities, perspectives and sociotechnical systems in the case of Indonesia's electricity supply system. *Energy Research & Social Science, 69*, 101594.

Mori, A. and S. Im, 2017. How does access modality in multilateral climate funds affect vulnerability reduction?, Presented paper at the 7th Congress of the East Asian Association of Environmental and Resource Economics, Singapore.

Mori, A., Rahman, S. M., & Uddin, M. N. (2019). Climate Financing Through the Adaptation Fund: What Determines Fund Allocation? *The Journal of Environment & Development*, *28*(4), 366-385.

Moser, S. C., & Ekstrom, J. A. (2010). A framework to diagnose barriers to climate change adaptation. *Proceedings of the National Academy of Sciences*, 107(51), 22026-22031.

Mrkajic, V., Vukelic, D., & Mihajlov, A. (2015). Reduction of CO2 emission and non-environmental co-benefits of bicycle infrastructure provision: the case of the University of Novi Sad, Serbia. *Renewable and Sustainable Energy Reviews*, *49*, 232-242.

Munang, R., I. Thiaw, K. Alverso, M. Mumba, J. Liu, and M. Rivington, 2013. Climate change and ecosystem-based adaptation: A new pragmatic approach to buffering climate change impacts, *Current Opinion in Environmental Sustainability* 5: 67-71, https://doi.org/10.1016/j.cosust.2012.12.001.

Nainggolan, D., M. Termansen and M. Zandersen, 2014. Adaptation in agriculture, In: Markandya, A., I. Galarraga, and ES de Murieta (eds.), *Routledge Handbook of the Economics of Climate Change Adaptation*, Routledge, Oxon, 228-60.

Nalau, J., S. Becken, and B. Mackey, 2018. Ecosystem-based Adaptation: A review of the constraints, *Environmental Science & Policy* 89, 357-64, https://doi.org/10.1016/j.envsci.2018.08.014.

NZCCC. (2010). Climate change adaptation in New Zealand: Future scenarios and some sectoral perspectives. New Zealand Climate Change Centre. Nottage, R.A.C., Wratt, D.S., Bornman, J.F., Jones, K. (eds), Wellington, 136 p.

Nika, C. E., Gusmaroli, L., Ghafourian, M., Atanasova, N., Buttiglieri, G., & Katsou, E. (2020). Nature-based solutions as enablers of circularity in water systems: A review on assessment methodologies, tools and indicators. *Water Research*, *183*, 115988.

NOAA. (2020). Trends in atmospheric carbon dioxide. Global Monthly Mean CO_2. National Oceanic and Atmospheric Administration, Maryland, USA. Retrieved from https://www.esrl.noaa.gov/gmd/ccgg/trends/global.html (Accessed 24 July 2020).

Norton, A., Seddon, N., Agrawal, A., Shakya, C., Kaur, N., & Porras, I. (2020). Harnessing employment-based social assistance programmes to scale up nature-based climate action. *Philosophical Transactions of the Royal Society B*, *375*(1794), 20190127.

Noubondieu, S., Flammini, A., Bracco, S. 2018 Costs and benefits of solar irrigation systems in Senegal. Dakar, FAO. 28 pp. License: CC BY-NC-SA 3.0 IGO.

O'Brien, K., & Leichenko, R. (2007). Human security, vulnerability and sustainable adaptation. Human Development Report, 2008, 1-2. Retrieved from http://hdr.undp.org/sites/default/files/obrien_karen_and_leichenko_robin.pdf (Accessed 12 May 2019)

OECD (2000), Ancillary Benefits and Costs of Greenhouse Gas Mitigation. Proceedings of an IPCC Workshop co-sponsored by IPCC, OECD, RFF, Statistics Norway, USDoE, US EPA and WRI, held 27-29 March 2000 in Washington, DC. OECD, Paris

O'Garra, T., Mourato, S., & Pearson, P. (2005). Analysing awareness and acceptability of hydrozen vehicles: A London case study. *International Journal of Hydrogen Energy*, *30*, 649-659.

OpenStreetMap (n.d.). Open Street Map. Retrieved from https://www.openstreetmap.org/copyright (Accessed 7 December 2020)

Osbahr, H., Twyman, C., Adger, W. N., & Thomas, D. S. (2008). Effective livelihood adaptation to climate change disturbance: Scale dimensions of practice in Mozambique. *Geoforum*, *39*(6), 1951-1964. Doi: 10.1016/j.geoforum.2008.07.010

Ottinger, RL, P. Wang and KM Motel, 2016. Options for adaptation to climate change, In: Koh, KL, I Kelman, R. Kibugi, and RLE Osorio (eds.), *Adaptation to Climate Change: ASEAN and Comparative Experiences*, World Scientific, Singapore, 259-310.

Pathak, M., & Shukla, P. R. (2016). Co-benefits of low carbon passenger transport actions in Indian cities: Case study of Ahmedabad. *Transportation Research Part D: Transport and Environment*, *44*, 303-316.

Paprocki, K. (2018). Threatening dystopias: Development and adaptation regimes in Bangladesh. *Annals of the American Association of Geographers*, *108*(4), 955-973.

Paul, S. K., & Routray, J. K. (2011). Household response to cyclone and induced surge in coastal Bangladesh: coping strategies and explanatory variables. *Natural Hazards*, *57*(2), 477-499.

Penning-Rowsell, E. C., Sultana, P., & Thompson, P. M. (2012). The 'last resort'? Population movement in response to climate-related hazard in Bangladesh. *Environmental Science and Policy*, *27*(1), S44-S59. Doi: 10.1016/j.envsci.2012.03.009

Pizmony-Levy, O. (2019). Teachers in New York City Barred From Attending Climate Protest, by Barnard, A. in the New York Times, 19 September 2019. Retrieved from https://www.nytimes.com/2019/09/19/nyregion/youth-climate-strike-nyc.html (Accessed 23 September 2019)

Pringle, P., & Leiter, T. (2018). Pitfalls and potential of measuring climate change adaptation through adaptation metrics. Adaptation metrics: Perspectives on measuring, aggregating and comparing adaptation results, UNEP-DTU Partnership, Denmark, p 29.

Pullenkav, T. (2013). Solar water pumping for irrigation: Opportunities in Bihar, India, Deutche Gesellschaftfur Internationale Zusammenarbeit (GIZ) GmbH, Indo-German Energy Programme, http://www.igen-re.in/files/giz__2013__report_solar_water_pumping_for_irrigation_in_bihar.pdf, accessed 8 September 2019.

Rahman, S. M. (2019). Structural Analogy in Development and Climate Aid: The Case of Bangladesh. *Journal of Development Policy and Practice*, *4*(1), 89-116.

Rahaman, M. A., Bijoy, M. R., Chakraborty, T. R., Kayes, A. I., Rahman, M. A., & Leal Filho, W. (2020). Climate Information Services and Their Potential on Adaptation and Mitigation: Experiences from Flood Affected Regions in Bangladesh. In *Handbook of Climate Services* (pp. 481-501). Springer, Cham.

Rahman, M. H., & Alam, K. (2016). Forest Dependent Indigenous Communities' Perception and Adaptation to Climate Change through Local Knowledge in the Protected Area—A Bangladesh Case Study. *Climate, 4*(1), 12.

Rahman, M. M., Paatero, J. V., Poudyal, A., Lahdelma, R., (2013). Driving and hindering factors for rural electrification in developing countries: Lessons from Bangladesh. *Energy Policy* (2013). http://dx.doi.org/10.1016/j.enpol.2013.06.100i

Rahman, S., & Rahman, S. H. (2011). Indigenous coping capacities due to waterlogging, drinking water scarcity and sanitation at Koptaksho Basin, Bangladesh. *Bangladesh Journal of Environmental Research 9*, 7–16.

Rahman, S. M., & Ahmad, M. M. (2013). Solar home system in rural Bangladesh: Ornamentation or fact of development? *Energy Policy 63*, 348-354. Doi: 10.1016/j.enpol.2013.08.041

Rahman, S. M., & Ahmad, M. M. (2014). Climate finance in the Greater Mekong Subregion (GMS). *Development in Practice 24*(8). 960-974. Doi: 10.1080/09614524.2014.965131

Rahman, S. M., & Ahmad, M. M. (2016). Perception of local experts about accessibility to international climate funds: Case of Bangladesh. *The Journal of Developing Areas, 50*(3), 53-67.

Rahman, S. M., & Mori, A. (2020). Dissemination and perception of adaptation co-benefits: Insights from the coastal area of Bangladesh. *World Development Perspectives, 20,* 100247.

Rahman, S. M., Mori, A., Sultan-Ul-Islam, M., & Rahman, S. M. (2020). Integrating adaptation and mitigation in irrigation through diffusion of solar energy technology: a case from the northwest Bangladesh. In W. L. Filho, J. M. Luetz & D. Y. Ayal (Ed.) Handbook of Climate Change Management: Research, Leadership, Transformation (Forthcoming). Springer Nature, Cham.

Rahman, S. M., & Mori, A. (2020). *How does climate adaptation co-benefits help scale-up solar irrigation? A case of the Barind Tract, Bangladesh*. Manuscript Submitted for Publication.

Ramsey, S.; Subbia, A. R.; Bass, S. and Juergens, I. 2007, Livelihood adaptation to climate variability and change in drought- prone areas of Bangladesh, Asian Disaster Preparedness Center, Food and Agriculture Organization of the United Nations.

Rashid, M. A., & Hossain, M. I. (2019, February). Irrigation management system of BMDA: An innovative approach. In 2nd International Conference on Planning, Architecture & Civil Engineering, Rajshahi (pp. 7-9).

Rawlani, A. K., & Sovacool, B. K. (2011). Building responsiveness to climate change through community based adaptation in Bangladesh. *Mitigation and Adaptation Strategies for Global Change, 16*(8), 845-863. Doi: 10.1007/s11027-011-9298-6

REB. (2010). *At a Glance Solar Project of Rural Electrification Board*. Retrieved from Rural Electrification Board website, http://www.reb.gov.bd/index.php

Reif, C., & Osberghaus, D. (2020). Economic assessment of co-benefits of adaptation to climate change. In Ancillary Benefits of Climate Policy (pp. 197-212). Springer, Cham.

Riekkola, A. K., Ahlgren, E. O., & Söderholm, P. (2011). Ancillary benefits of climate policy in a small open economy: The case of Sweden. *Energy Policy, 39*(9), 4985-4998.

Robinson, J. M., & Breed, M. F. (2019). Green Prescriptions and Their Co-Benefits: Integrative Strategies for Public and Environmental Health. *Challenges, 10*(1), 9.

Roblin, S. (2016). Solar-powered irrigation: A solution to water management in agriculture?. *Renewable Energy Focus, 17*(5), 205-206.

Said, A. M., Ahmadun, F.-R., Paim, L. H., & Masud, J. (2003). Environmental concerns, knowledge and practices gap among Malaysian teachers. *International Journal of Sustainability in Higher Education, 4*(4), 305-313.

Samarasekara, R. S. M., Sasaki, J., Esteban, M., & Matsuda, H. (2017). Assessment of the co-benefits of structures in coastal areas for tsunami mitigation and improving community resilience in Sri Lanka. *International Journal of Disaster Risk Reduction, 23*, 80-92.

SANGRAM, (n.d.) Case Studies. SANGRAM, Barguna. Retrieved from http://sangram.ngo/case-studies/ (Accessed 3 June 2019)

SANGRAM, (n.d.) Adaptation with Alternative Livelihood Opprotunity (AALO), Barguna. Retrieved from https://sangram.ngo/aalo/ (Accessed 16 November 2020)

Saroar, M., & Routray, J. K. (2010). Adaptation in situ or retreat? A multivariate approach to explore the factors that guide the peoples' preference against the impacts of sea level rise in coastal Bangladesh. *Local Environment*, *15*(7), 663-686.

Schneider, A. A. (2020). An oasis for students: investigating the potential co-benefits of schoolyard redesign for climate adaptation. Master Thesis Series in Environmental Studies and Sustainability Science, Lund University, Sweden. Retrieved from https://lup.lub.lu.se/student-papers/search/publication/9011575 (Accessed 24 July 2020).

Scovronick, N., Budolfson, M., Dennig, F., Errickson, F., Fleurbaey, M., Peng, W., ... & Wagner, F. (2019). The impact of human health co-benefits on evaluations of global climate policy. *Nature Communications*, *10*(1), 1-12.

Seawright, J., & Gerring, J. (2008). Case selection techniques in case study research: A menu of qualitative and quantitative options. *Political Research Quarterly*, *61*(2), 294-308.

Senol, R,. 2012. An analysis of solar energy and irrigation systems in Turkey, *Energy Policy* 47, 478-86, https://doi.org/10.1016/j.enpol.2012.05.049.

Sethi, M. (2018). Co-benefits assessment tools and research gaps. In Mainstreaming climate co-benefits in Indian cities (pp. 47-73). Springer, Singapore.

Sethi, M. (2020). Climate co-benefits in rapidly urbanizing emerging economies: scientific and policy imperatives. In Ancillary Benefits of Climate Policy (pp. 301-324). Springer, Cham.

Shahid, S. (2012). Vulnerability of the power sector in Bangladesh to climate change and extreme weather events. *Regional Environmental Change, 12*(3), 595-606. Doi: 10.1007/s10113-011-0276-z

Shahid, S. (2008). Spatial and temporal characteristics of droughts in the western part of Bangladesh. *Hydrological Process*, *22*, 2235–2247. DOI: 10.1002/hyp.6820

Shakir, M. (2002). The selection of case studies: strategies and their applications to IS implementation case studies. *Research Letters in the Information and Mathematical Sciences*, *3*, 191-198.

Sharif, I., & Mithila, M. (2013). Rural electrification using PV: the success story of Bangladesh. *Energy Procedia*. 33. pp. 343-354.

Shrimali, G. & Rohra, S., (2012). India's solar mission: A review. *Renewable and Sustainable Energy Reviews.* 16. pp. 6317-6332.

Singer, J., Pham, H. T., & Hoang, H. (2014). Broadening stakeholder participation to improve outcomes for dam-forced resettlement in Vietnam. *Water resources and Rural Development*, *4*, 85-103.

Smith, A. (2013). The climate bonus: co-benefits of climate policy. Routledge.

Smit, B., & Pilifosova, O. (2003). Adaptation to climate change in the context of sustainable development and equity. *Sustainable Development*, *8*(9), 9.

Sontake, VC and Kalamkar, VR. (2016). Solar photovoltaic water pumping system—A comprehensive review, *Renewable and Sustainable Energy Reviews* 59, 1038–67, http://dx.doi.org/10.1016/j.rser.2016.01.021.

Sørup, H. J. D., Arnbjerg-Nielsen, K., Feilberg, M., Liu, L., Fryd, O., Ulbak, K. A., ... & Jensen, M. B. (2019). Sustainable climate change adaptation of urban water management in compliance with the UN SDGs. In 10th edition of the Novatech conference.

Sovacool, B. K., D'Agostino, A. L., Rawlani, A., & Meenawat, H. (2012a). Improving climate change adaptation in least developed Asia. *Environmental Science and Policy*, *21*, 112-125. Doi:10.1016/j.envsci.2012.04.009

Sovacool, B. K., D'Agostino, A. L., Meenawat, H., & Rawlani, A. (2012b). Expert views of climate change adaptation in least developed Asia. *Journal of Environmental Management, 97*, 78-88. Doi:10.1016/j.jenvman.2011.11.005

Spencer, B., Lawler, J., Lowe, C., Thompson, L., Hinckley, T., Kim, S. H., ... & Voss, J. (2017). Case studies in co-benefits approaches to climate change mitigation and adaptation. *Journal of Environmental Planning and Management, 60*(4), 647-667.

Spangenberg JH (2002). Environmental space and the prism of sustainability: frameworks for indicators measuring sustainable development. *Ecological Indicators, 2*(3), 295-309.

Spiggle, S. (1994). Analysis and interpretation of qualitative data in consumer research. *Journal of Consumer Research, 21*(3), 491-503.

Surminski, S., Tanner, T., & Surminski. (2016). Realising the 'Triple Dividend of Resilience'. Springer: Berlin.

Swanson, D.A., Hiley, J.C., Venema, H.D. and Grosshans, R. (2007). Indicators of Adaptive Capacity to Climate Change for Agriculture in the Prairie Region of Canada: An analysis based on Statistics Canada's Census of Agriculture. Working Paper for the Prairie Climate Resilience Project, Winnipeg: International Institute for Sustainable Development.

Tietenberg, T. (1996) Environment and natural resources economics. Addison Wesley, New York.

Tompkins, E. L., & Eakin, H. (2011). Managing private and public adaptation to climate change. *Global Environmental Change, 22*(11), 3-11. Doi: 10.1016/j.gloenvcha.2011.09.010

Trotter II, R. T. (2012). Qualitative research sample design and sample size: resolving and unresolved issues and inferential imperatives. *Preventive Medicine 55*(5), 398-400. Doi: 10.1016/j.ypmed.2012.07.003

Turner, R. K., Pearce, D., and Batman, I. (1994) Environmental economics. Harvester Wheatsheaf, New York.

Turner, W. R., Bradley, B. A., Estes, L. D., Hole, D. G., Oppenheimer, M. and Wilcove, D. S., 2010. Climate change: helping natural survive the human response. *Conservation Letters, 3*(5). 304 – 312.

Twidell, J. and Weir, T. (2015). Renewable energy resources. London: Routledge.

UNDP-GEF. (2004). *Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures.* Cambridge: Cambridge University Press.

UNDP-UNEP. (2014). *Bangladesh whole-of-government approach to climate finance.* Retrieved from http://www.climatefinance-developmenteffectiveness.org

UNDP-GEF. (2004). Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures. Cambridge: Cambridge University Press.

UNEP-GEF. (2012). *Technology Needs Assessment Report-Bangladesh,* Retrieved from United Nations Framework Convention on Climate Change website, http://unfccc.int

UNFCCC. (1995). United Nations Framework Convention on Climate Change. Retrieved July 18, 2012, from Documents of the Conference of the Parties at its First Session, Report of the Global Environmental Facility to the COP: http://unfccc.int/cop5/resource/cop1.html

UNFCCC. (2007). Climate Change: impacts, vulnerabilities and adaptation in developing countries. Bonn: United Nations Framework Convention on Climate Change.

UNFCCC. (2018). Report of the Conference of the Parties on its twenty-third session, held in Bonn from 6-8 November 2017. United Nations Framework Convention on Climate Change. Retrieved from https://unfccc.int/sites/default/files/resource/docs/2017/cop23/eng/11a01.pdf (Accessed 19 March 2019).

UNFCCC (2009). Potential costs and benefits of adaptation options: A review of existing literature. Technical Paper. FCCC/TP/2009/2, 7 December 2009. United Nations Framework Convention on Climate Change. Retrieved from https://unfccc.int/resource/docs/2009/tp/02.pdf (Accessed 22 June 2020).

UNFCCC. (2019). Clean Development Project Registry. Retrieved from https://cdm.unfccc.int/Projects/projsearch.html (accessed 25 September 2019)

UNOCHA. (2019). Relief Web, UN Office for the Coordination of Humanitarian Affairs. Retrieved from https://reliefweb.int/map/bangladesh/bangladesh-national-reference-map-24-jan-2019 (accessed 6 November 2020).

Urmee, T., & Harries, D. (2011). Determinants of the success and sustainability of Bangladesh's SHS program. *Renewable Energy, 36*(11), 2822-2830. Doi: 10.1016/j.renene.2011.04.021.

Van Oijstaeijen, W., Van Passel, S., & Cools, J. (2020). Urban green infrastructure: A review on valuation toolkits from an urban planning perspective. *Journal of Environmental Management*, *267*, 110603.

VijayaVenkataRaman, S., Iniyan, S., & Goic, R. (2012). A review of climate change, mitigation and adaptation. *Renewable and Sustainable Energy Review*, *16*(1), 878-897. Doi:10.1016/j.rser.2011.09.009

Wamsler, C., & Brink, E. (2015). The role of individual adaptive practice for sustainable adaptation. *International Journal of Disaster Resilience in the Built Environment, 6*(1), 6-29.

Whitmarsh, L. (2009). Behavioural response to climate change: Asymmetry of intensions and impacts. *Journal of Environmental Psychology, 29*(1), 13-23. Doi: 10.1016/j.jenvp.2008.05.003

Williams, C., Fenton, A., & Huq, S. (2015). Knowledge and adaptive capacity. *Nature Climate Change*, *5*(2), 82-83.

Wise, R. M., Butler, J. R. A., Suadnya, W., Puspadi, K., Suharto, I., & Skewes, T. D. (2016). How climate compatible are livelihood adaptation strategies and development programs in rural Indonesia?. *Climate Risk Management*, *12*, 100-114.

Wijayatunga, P. D. C., and Attalage, R. A., (2005). Socio-economic impact of solar home systems in rural Sri Lanka: a case study. *Energy for Sustainable Development.* 11(2). pp. 5-9.

World Bank. (2009). *Convenient Solution to an Inconvenient Truth: Ecosystem-based Approaches to Climate Change.* Environment Department. Washington DC: World Bank.

World Bank. (2010). *Economics of Adaptation to Climate Change: Bangladesh.* Washington DC: World Bank.

World Bank. (2011). *Bangladesh: lighting up rural communities.* Retrieved June 05, 2012, from The World Bank website, http://go.worldbank.org/3DX5GJ26B0

Wu, J., Zhang, H., Pan, Y., Krause-Jensen, D., He, Z., Fan, W., ... & Rivkin, R. B. (2020). Opportunities for blue carbon strategies in China. *Ocean & Coastal Management, 194*, 105241.

Yedla, S., & Park, H. S. (2009). Co-benefit as an approach to align climate change concerns with national development objectives: solid waste management. *Journal of Material Cycles and Waste Management*, *11*(2), 123-129.

Yalew, A., Hirte, G., Lotze-Campen, H., & Tscharaktschiew, S. (2018). Climate Change, Agriculture, and Economic Development in Ethiopia. *Sustainability*, 10(10), 3464.

Yokota, H., Tanabe, K., Sezaki, M., Akiyoshi, Y., Miyata, T., Kawahara, K., ... & Ahmad, S. A. (2001). Arsenic contamination of ground and pond water and water purification system using pond water in Bangladesh. *Engineering Geology*, *60*(1-4), 323-331.

Ziervogel, G., Shale, M., & Du, M. (2010). Climate change adaptation in a developing country context: The case of urban water supply in Cape Town. *Climate and Development*, *2*(2), 94-110.

Zsoka, A. (2008). Consistency and 'awareness gaps' in the environmental behavior of Hungarian companies. *Journal of Cleaner Production*, *16*, 322-329.

Appendix 1a: Assessment Methodology of Climate Adaptation Co-benefits

Sl.	Measures	Assessment (Y/N)
Potential measures for extreme **heat** effects moderation		
1	Is the project planting trees that will provide shade to buildings, homes, sidewalks, streets, or parking lots?	☐Yes ☐No ☐N/A
2	Is the project enhancing insulation of homes?	☐Yes ☐No ☐N/A
3	Is the project installing cool roofs?	☐Yes ☐No ☐N/A
4	Is the project reducing electrical grid demand and household costs associated with cooling?	☐Yes ☐No ☐N/A
5	Is the project preventing conversion of agricultural lands (croplands, rangelands, or pasturelands) or natural land cover (trees, grasslands, shrublands, watersheds, or wetlands) to pavement or buildings?	☐Yes ☐No ☐N/A
6	Is the project adding permeable land cover?	☐Yes ☐No ☐N/A
7	Is the project replacing agricultural lands (croplands, rangelands, or pasturelands) or natural land cover (trees, grasslands, shrublands, watersheds, or wetlands) with pavement or buildings? (negative co-benefit)	☐Yes ☐No ☐N/A
Potential measures for **drought** effects moderation		
1	Is the project setting up an ongoing mechanism to conserve water?	☐Yes ☐No ☐N/A
2	Is the project promoting improved soil health, soil quality, or soil stability?	☐Yes ☐No ☐N/A
3	Is the project restoring wetlands, watersheds, or riparian buffers?	☐Yes ☐No ☐N/A
4	Is the project planting native, drought-tolerant vegetation?	☐Yes ☐No ☐N/A
5	Is the project changing permeable surfaces to paved surfaces? (negative co-benefit)	☐Yes ☐No ☐N/A
6	Is the project increasing water use? (negative co-benefit)	☐Yes ☐No ☐N/A
Potential measures for **sea level rise and inland flooding** adaptation		
1	Does the project include floodplain restoration or protection?	☐Yes ☐No ☐N/A
2	Does the project include forest/tree restoration or protection in a flood-prone or flood hazard area?	☐Yes ☐No ☐N/A
3	Does the project include improved soil health in a flood-prone or flood hazard area?	☐Yes ☐No ☐N/A
4	Does the project include rainwater capture and/or infiltration systems as part of urban green efforts in a flood-prone or flood hazard area?	☐Yes ☐No ☐N/A
5	Does the project include additional infrastructure, including natural infrastructure, to protect against flooding in a flood-prone or flood hazard area?	☐Yes ☐No ☐N/A
6	Is the project mitigating the effects of sea level rise/flooding in a region at risk for sea level rise/flooding?	☐Yes ☐No ☐N/A
7	Is the project developing buildings or structures in floodplains? (negative co-benefit)	☐Yes ☐No ☐N/A

Potential measures for **agricultural productivity and conservation**		
1	Is the project conserving Prime Farmland, Farmland of Statewide Importance, Unique Farmland, Grazing Land, or Farmland of Local Importance?	☐Yes ☐No ☐N/A
2	Is the project promoting improved soil health, soil quality, or soil stability?	☐Yes ☐No ☐N/A
3	Is the project reducing on-farm water consumption?	☐Yes ☐No ☐N/A
4	Is the project converting Prime Farmland, Farmland of Statewide Importance, Unique Farmland, Grazing Land, or Farmland of Local Importance to urban or other development? (negative co-benefit)	☐Yes ☐No ☐N/A
Potential measures for **species habitat**		
1	Is the project restoring or conserving habitat that contains Species of Greatest Conservation Need, including threatened or endangered species?	☐Yes ☐No ☐N/A
2	Is the project restoring or conserving historical habitat for Species of Greatest Conservation Need, including threatened or endangered species?	☐Yes ☐No ☐N/A
3	Is the project constructing or conserving wildlife corridors and/or habitat connectivity?	☐Yes ☐No ☐N/A
4	Is the project disturbing wetlands, waterways, tidelands, or wildlife corridors? (negative co-benefit)	☐Yes ☐No ☐N/A
5	Is the project developing land, or otherwise disturbing habitat, that contains threatened or endangered species? (negative co-benefit)	☐Yes ☐No ☐N/A
Potential measures for **wildfire mitigation**		
1	Does the project involve fuels management work to maintain ecosystem health in a high priority landscape?	☐Yes ☐No ☐N/A
2	Does the project involve rehabilitation work in a high priority landscape impacted by wildfire?	☐Yes ☐No ☐N/A
3	Does the project involve fire hazard prevention work to mitigate wildfire threats to communities?	☐Yes ☐No ☐N/A
4	Is the project implementing other types of forest or other ecosystem management treatments to reduce wildfire intensity or reduce potential impacts of wildfires?	☐Yes ☐No ☐N/A
5	Is the project implementing other fire mitigation or prevention measures for non-forested habitats that may be impacted by wildfire?	☐Yes ☐No ☐N/A
6	Does the project involve new construction in a high priority landscape for reducing or preventing wildfire threats? (negative co-benefit)	☐Yes ☐No ☐N/A

Source: CARB, 2018.

Appendix 1b: Filled-in Index for Co-benefits from Solar Irrigation in Godagari

Sl.	Measures	Assessment (Y/N)
Potential measures for extreme **heat** effects moderation		
1	Is the project planting trees that will provide shade to buildings, homes, sidewalks, streets, or parking lots?	☐ Yes ☐ No ☑ N/A
2	Is the project enhancing insulation of homes?	☐ Yes ☐ No ☑ N/A
3	Is the project installing cool roofs?	☐ Yes ☐ No ☑ N/A
4	Is the project reducing electrical grid demand and household costs associated with cooling?	☑ Yes ☐ No ☐ N/A
5	Is the project preventing conversion of agricultural lands (croplands, rangelands, or pasturelands) or natural land cover (trees, grasslands, shrublands, watersheds, or wetlands) to pavement or buildings?	☑ Yes ☐ No ☐ N/A
6	Is the project adding permeable land cover?	☑ Yes ☐ No ☐ N/A
7	Is the project replacing agricultural lands (croplands, rangelands, or pasturelands) or natural land cover (trees, grasslands, shrublands, watersheds, or wetlands) with pavement or buildings? (negative co-benefit)	☑ Yes ☐ No ☐ N/A
Potential measures for **drought** effects moderation		
1	Is the project setting up an ongoing mechanism to conserve water?	☑ Yes ☐ No ☐ N/A
2	Is the project promoting improved soil health, soil quality, or soil stability?	☑ Yes ☐ No ☐ N/A
3	Is the project restoring wetlands, watersheds, or riparian buffers?	☑ Yes ☐ No ☐ N/A
4	Is the project planting native, drought-tolerant vegetation?	☐ Yes ☐ No ☑ N/A
5	Is the project changing permeable surfaces to paved surfaces? (negative co-benefit)	☑ Yes ☐ No ☐ N/A
6	Is the project increasing water use? (negative co-benefit)	☑ Yes ☐ No ☐ N/A
Potential measures for **sea level rise and inland flooding** adaptation		
1	Does the project include floodplain restoration or protection?	☐ Yes ☐ No ☑ N/A
2	Does the project include forest/tree restoration or protection in a flood-prone or flood hazard area?	☐ Yes ☐ No ☑ N/A
3	Does the project include improved soil health in a flood-prone or flood hazard area?	☐ Yes ☐ No ☑ N/A
4	Does the project include rainwater capture and/or infiltration systems as part of urban green efforts in a flood-prone or flood hazard area?	☐ Yes ☐ No ☑ N/A
5	Does the project include additional infrastructure, including natural infrastructure, to protect against flooding in a flood-prone or flood hazard area?	☐ Yes ☐ No ☑ N/A
6	Is the project mitigating the effects of sea level rise/flooding in a region at risk for sea level rise/flooding?	☐ Yes ☐ No ☑ N/A
7	Is the project developing buildings or structures in floodplains? (negative co-benefit)	☐ Yes ☐ No ☑ N/A

Potential measures for **agricultural productivity and conservation**		
1	Is the project conserving Prime Farmland, Farmland of Statewide Importance, Unique Farmland, Grazing Land, or Farmland of Local Importance?	☑ Yes ☐ No ☐ N/A
2	Is the project promoting improved soil health, soil quality, or soil stability?	☑ Yes ☐ No ☐ N/A
3	Is the project reducing on-farm water consumption?	☐Yes ☑ No ☐N/A
4	Is the project converting Prime Farmland, Farmland of Statewide Importance, Unique Farmland, Grazing Land, or Farmland of Local Importance to urban or other development? (negative co-benefit)	☐Yes ☑ No ☐N/A
Potential measures for **species habitat**		
1	Is the project restoring or conserving habitat that contains Species of Greatest Conservation Need, including threatened or endangered species?	☑ Yes ☐ No ☐ N/A
2	Is the project restoring or conserving historical habitat for Species of Greatest Conservation Need, including threatened or endangered species?	☐ Yes ☐ No ☑ N/A
3	Is the project constructing or conserving wildlife corridors and/or habitat connectivity?	☑ Yes ☐No ☐N/A
4	Is the project disturbing wetlands, waterways, tidelands, or wildlife corridors? (negative co-benefit)	☑ Yes ☐ No ☐ N/A
5	Is the project developing land, or otherwise disturbing habitat, that contains threatened or endangered species? (negative co-benefit)	☑ Yes ☐ No ☐ N/A
Potential measures for **wildfire mitigation**		
1	Does the project involve fuels management work to maintain ecosystem health in a high priority landscape?	☐ Yes ☐ No ☑ N/A
2	Does the project involve rehabilitation work in a high priority landscape impacted by wildfire?	☐ Yes ☐ No ☑ N/A
3	Does the project involve fire hazard prevention work to mitigate wildfire threats to communities?	☐ Yes ☐ No ☑ N/A
4	Is the project implementing other types of forest or other ecosystem management treatments to reduce wildfire intensity or reduce potential impacts of wildfires?	☐ Yes ☐ No ☑ N/A
5	Is the project implementing other fire mitigation or prevention measures for non-forested habitats that may be impacted by wildfire?	☐ Yes ☐ No ☑ N/A
6	Does the project involve new construction in a high priority landscape for reducing or preventing wildfire threats? (negative co-benefit)	☐ Yes ☐ No ☑ N/A

Source: CARB, 2018.

Appendix 1c: Filled-in Index for Co-benefits from Homestead Plinth Raise in Barguna Sadar

Sl.	Measures	Assessment (Y/N)
Potential measures for extreme **heat** effects moderation		
1	Is the project planting trees that will provide shade to buildings, homes, sidewalks, streets, or parking lots?	☐ Yes ☐ No ☑ N/A
2	Is the project enhancing insulation of homes?	☐ Yes ☐ No ☑ N/A
3	Is the project installing cool roofs?	☐ Yes ☐ No ☑ N/A
4	Is the project reducing electrical grid demand and household costs associated with cooling?	☐ Yes ☐ No ☑ N/A
5	Is the project preventing conversion of agricultural lands (croplands, rangelands, or pasturelands) or natural land cover (trees, grasslands, shrublands, watersheds, or wetlands) to pavement or buildings?	☐ Yes ☐ No ☑ N/A
6	Is the project adding permeable land cover?	☐ Yes ☐ No ☑ N/A
7	Is the project replacing agricultural lands (croplands, rangelands, or pasturelands) or natural land cover (trees, grasslands, shrublands, watersheds, or wetlands) with pavement or buildings? (negative co-benefit)	☐ Yes ☐ No ☑ N/A
Potential measures for **drought** effects moderation		
1	Is the project setting up an ongoing mechanism to conserve water?	☐ Yes ☐ No ☑ N/A
2	Is the project promoting improved soil health, soil quality, or soil stability?	☐ Yes ☐ No ☑ N/A
3	Is the project restoring wetlands, watersheds, or riparian buffers?	☐ Yes ☐ No ☑ N/A
4	Is the project planting native, drought-tolerant vegetation?	☐ Yes ☐ No ☑ N/A
5	Is the project changing permeable surfaces to paved surfaces? (negative co-benefit)	☐ Yes ☐ No ☑ N/A
6	Is the project increasing water use? (negative co-benefit)	☐ Yes ☐ No ☑ N/A
Potential measures for **sea level rise and inland flooding** adaptation		
1	Does the project include floodplain restoration or protection?	☐ Yes ☐ No ☑ N/A
2	Does the project include forest/tree restoration or protection in a flood-prone or flood hazard area?	☐ Yes ☐ No ☑ N/A
3	Does the project include improved soil health in a flood-prone or flood hazard area?	☐ Yes ☐ No ☑ N/A
4	Does the project include rainwater capture and/or infiltration systems as part of urban green efforts in a flood-prone or flood hazard area?	☐ Yes ☐ No ☑ N/A
5	Does the project include additional infrastructure, including natural infrastructure, to protect against flooding in a flood-prone or flood hazard area?	☐ Yes ☐ No ☑ N/A
6	Is the project mitigating the effects of sea level rise/flooding in a region at risk for sea level rise/flooding?	☑ Yes ☐ No ☐ N/A
7	Is the project developing buildings or structures in floodplains?	☑ Yes ☐ No ☐ N/A

	(negative co-benefit)	
Potential measures for **agricultural productivity and conservation**		
1	Is the project conserving Prime Farmland, Farmland of Statewide Importance, Unique Farmland, Grazing Land, or Farmland of Local Importance?	☐ Yes ☐ No ☑ N/A
2	Is the project promoting improved soil health, soil quality, or soil stability?	☐ Yes ☐ No ☑ N/A
3	Is the project reducing on-farm water consumption?	☐ Yes ☐ No ☑ N/A
4	Is the project converting Prime Farmland, Farmland of Statewide Importance, Unique Farmland, Grazing Land, or Farmland of Local Importance to urban or other development? (negative co-benefit)	☐ Yes ☐ No ☑ N/A
Potential measures for **species habitat**		
1	Is the project restoring or conserving habitat that contains Species of Greatest Conservation Need, including threatened or endangered species?	☐ Yes ☐ No ☑ N/A
2	Is the project restoring or conserving historical habitat for Species of Greatest Conservation Need, including threatened or endangered species?	☐ Yes ☐ No ☑ N/A
3	Is the project constructing or conserving wildlife corridors and/or habitat connectivity?	☑ Yes ☐ No ☐ N/A
4	Is the project disturbing wetlands, waterways, tidelands, or wildlife corridors? (negative co-benefit)	☐ Yes ☐ No ☑ N/A
5	Is the project developing land, or otherwise disturbing habitat, that contains threatened or endangered species? (negative co-benefit)	☐ Yes ☐ No ☑ N/A
Potential measures for **wildfire mitigation**		
1	Does the project involve fuels management work to maintain ecosystem health in a high priority landscape?	☐ Yes ☐ No ☑ N/A
2	Does the project involve rehabilitation work in a high priority landscape impacted by wildfire?	☐ Yes ☐ No ☑ N/A
3	Does the project involve fire hazard prevention work to mitigate wildfire threats to communities?	☐ Yes ☐ No ☑ N/A
4	Is the project implementing other types of forest or other ecosystem management treatments to reduce wildfire intensity or reduce potential impacts of wildfires?	☐ Yes ☐ No ☑ N/A
5	Is the project implementing other fire mitigation or prevention measures for non-forested habitats that may be impacted by wildfire?	☐ Yes ☐ No ☑ N/A
6	Does the project involve new construction in a high priority landscape for reducing or preventing wildfire threats? (negative co-benefit)	☐ Yes ☐ No ☑ N/A

Source: CARB, 2018.

Appendix 1d: Filled-in Index for Co-benefits from Pond Sand Filter in Barguna Sadar

Sl.	Measures	Assessment (Y/N)
Potential measures for extreme **heat** effects moderation		
1	Is the project planting trees that will provide shade to buildings, homes, sidewalks, streets, or parking lots?	☐ Yes ☐ No ☑ N/A
2	Is the project enhancing insulation of homes?	☐ Yes ☐ No ☑ N/A
3	Is the project installing cool roofs?	☐ Yes ☐ No ☑ N/A
4	Is the project reducing electrical grid demand and household costs associated with cooling?	☐ Yes ☐ No ☑ N/A
5	Is the project preventing conversion of agricultural lands (croplands, rangelands, or pasturelands) or natural land cover (trees, grasslands, shrublands, watersheds, or wetlands) to pavement or buildings?	☐ Yes ☐ No ☑ N/A
6	Is the project adding permeable land cover?	☐ Yes ☐ No ☑ N/A
7	Is the project replacing agricultural lands (croplands, rangelands, or pasturelands) or natural land cover (trees, grasslands, shrublands, watersheds, or wetlands) with pavement or buildings? (negative co-benefit)	☑ Yes ☐ No ☐ N/A
Potential measures for **drought** effects moderation		
1	Is the project setting up an ongoing mechanism to conserve water?	☑ Yes ☐ No ☐ N/A
2	Is the project promoting improved soil health, soil quality, or soil stability?	☐ Yes ☐ No ☑ N/A
3	Is the project restoring wetlands, watersheds, or riparian buffers?	☐ Yes ☐ No ☑ N/A
4	Is the project planting native, drought-tolerant vegetation?	☐ Yes ☐ No ☑ N/A
5	Is the project changing permeable surfaces to paved surfaces? (negative co-benefit)	☑ Yes ☐ No ☐ N/A
6	Is the project increasing water use? (negative co-benefit)	☐ Yes ☐ No ☑ N/A
Potential measures for **sea level rise and inland flooding** adaptation		
1	Does the project include floodplain restoration or protection?	☐ Yes ☐ No ☑ N/A
2	Does the project include forest/tree restoration or protection in a flood-prone or flood hazard area?	☐ Yes ☐ No ☑ N/A
3	Does the project include improved soil health in a flood-prone or flood hazard area?	☐ Yes ☐ No ☑ N/A
4	Does the project include rainwater capture and/or infiltration systems as part of urban green efforts in a flood-prone or flood hazard area?	☑ Yes ☐ No ☐ N/A
5	Does the project include additional infrastructure, including natural infrastructure, to protect against flooding in a flood-prone or flood hazard area?	☐ Yes ☐ No ☑ N/A
6	Is the project mitigating the effects of sea level rise/flooding in a region at risk for sea level rise/flooding?	☐ Yes ☐ No ☑ N/A
7	Is the project developing buildings or structures in floodplains? (negative co-benefit)	☑ Yes ☐ No ☐ N/A

Potential measures for **agricultural productivity and conservation**		
1	Is the project conserving Prime Farmland, Farmland of Statewide Importance, Unique Farmland, Grazing Land, or Farmland of Local Importance?	☐ Yes ☐ No ☑ N/A
2	Is the project promoting improved soil health, soil quality, or soil stability?	☐ Yes ☐ No ☑ N/A
3	Is the project reducing on-farm water consumption?	☐ Yes ☐ No ☑ N/A
4	Is the project converting Prime Farmland, Farmland of Statewide Importance, Unique Farmland, Grazing Land, or Farmland of Local Importance to urban or other development? (negative co-benefit)	☐ Yes ☐ No ☑ N/A
Potential measures for **species habitat**		
1	Is the project restoring or conserving habitat that contains Species of Greatest Conservation Need, including threatened or endangered species?	☐ Yes ☐ No ☑ N/A
2	Is the project restoring or conserving historical habitat for Species of Greatest Conservation Need, including threatened or endangered species?	☐ Yes ☐ No ☑ N/A
3	Is the project constructing or conserving wildlife corridors and/or habitat connectivity?	☐ Yes ☐ No ☑ N/A
4	Is the project disturbing wetlands, waterways, tidelands, or wildlife corridors? (negative co-benefit)	☐ Yes ☐ No ☑ N/A
5	Is the project developing land, or otherwise disturbing habitat, that contains threatened or endangered species? (negative co-benefit)	☐ Yes ☐ No ☑ N/A
Potential measures for **wildfire mitigation**		
1	Does the project involve fuels management work to maintain ecosystem health in a high priority landscape?	☐ Yes ☐ No ☑ N/A
2	Does the project involve rehabilitation work in a high priority landscape impacted by wildfire?	☐ Yes ☐ No ☑ N/A
3	Does the project involve fire hazard prevention work to mitigate wildfire threats to communities?	☐ Yes ☐ No ☑ N/A
4	Is the project implementing other types of forest or other ecosystem management treatments to reduce wildfire intensity or reduce potential impacts of wildfires?	☐ Yes ☐ No ☑ N/A
5	Is the project implementing other fire mitigation or prevention measures for non-forested habitats that may be impacted by wildfire?	☐ Yes ☐ No ☑ N/A
6	Does the project involve new construction in a high priority landscape for reducing or preventing wildfire threats? (negative co-benefit)	☐ Yes ☐ No ☑ N/A

Source: CARB, 2018.

Appendix 2: Literature survey protocol

Table 2a: SCOPUS search results for Adaptation co-benefit related literature (as of 10 September 2020)

Sl.	Key Words	Exclusion/Inclusion Criteria	Number of Documents
1	Adaptation co-benefit	No criteria	239
2	Adaptation co-benefit	Exclude medicine; Limits to English language; Limits to journal	156
3	Adaptation W/2 co-benefit	No criteria	36
4	Adaptation PRE/2 co-benefit	No criteria	25
5	"Adaptation co-benefit"	No criteria	10
6 (2+3+4+5)	Total with duplication	-	227
7	Duplicate entries	-	58
8 (6-7)	After removal of duplication	-	169
9	Number of literature found related to any extent	Manual investigation of each abstract*	90

* Exclusion criteria: articles directly related to one or multiple issues: fishery, aquatic construction, health, animal health, mitigation (emission), agricultural emission, waste, mining, hydrodynamic model, agro-meteorology, specific agro-product, tourism, business entities, small and medium enterprises; articles from book chapter, conference, symposium, seminar, congress; articles with religious philosophy.

Table 2b: SCOPUS search results for sustainable adaptation related literature (as of 10 September 2020)

Sl.	Key Words	Exclusion/Inclusion Criteria	Number of Documents
1	Sustainable adaptation	No criteria	9124
2	Sustainable adaptation	Exclusion criteria**	200* (3285)
3	"Sustainable adaptation"	No criteria	221
4	Sustainable W/2 adaptation	No criteria	341
5	Sustainable PRE/2 adaptation	No criteria	579
6 (2+3+4+5)	Total number of articles	-	1341
7	Duplicate entries	-	606
8 (6 – 7)	After removal of duplication	-	735
9	Number of literature found related to any extent	Manual investigation of each abstract***	112

* Highly cited first 200 articles

**TITLE-ABS-KEY (sustainable AND adaptation) AND (EXCLUDE (SUBJAREA , "MEDI") OR EXCLUDE (SUBJAREA , "BIOC") OR EXCLUDE (SUBJAREA , "MATH") OR EXCLUDE (SUBJAREA , "DECI") OR EXCLUDE (SUBJAREA , "IMMU") OR EXCLUDE (SUBJAREA , "MATE") OR EXCLUDE (SUBJAREA , "CENG") OR EXCLUDE (SUBJAREA , "PHYS") OR EXCLUDE (SUBJAREA , "CHEM") OR EXCLUDE (SUBJAREA , "NURS") OR EXCLUDE (SUBJAREA , "VETE") OR EXCLUDE (SUBJAREA , "HEAL") OR EXCLUDE (SUBJAREA , "PHAR") OR EXCLUDE (SUBJAREA , "NEUR") OR EXCLUDE (SUBJAREA , "DENT") OR EXCLUDE (SUBJAREA , "Undefined")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2013) OR LIMIT-TO (PUBYEAR , 2012) OR LIMIT-TO (PUBYEAR , 2011)) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (SRCTYPE , "j"))

******* Exclusion criteria: articles directly related to one or multiple issues: fishery, aquatic construction, health, animal health, mitigation (emission), agricultural emission, waste, mining, hydrodynamic model, agro-meteorology, specific agro-product, tourism, business entities, small and medium enterprises; articles from book chapter, conference, symposium, seminar, congress; articles with religious philosophy.

Appendix 3: Focus Group Discussion Protocol

The standard protocol was applied.

1. Welcome message and introduction: This focus group discussion is designed to assess stakeholders' perception, thoughts and feelings about adaptation measures implemented in the region.
    a. Anonymity: Despite being taped, the discussion by the participants would remain anonymous.
    b. Ground rules: The basic rule followed is that only one person speaks at a time.

2. Guiding questions:
    a. What are the core benefits you are enjoying from the adaptation interventions in your region?
    b. How do you know about the benefits?
    c. What are some other benefits (co-benefits), which you did not know before, you observe and/or enjoy from the adaptation interventions?
    d. What are some any negative benefits (harms) from the interventions you are practicing?
    e. Did you have any idea about the possible benefits from the interventions before it took place? And how did you learn it?
    f. Did the implementing entity (NGO and government in respective cases) share about benefits and co-benefits of adaptation intervention before the intervention was being implemented? Why and how?
    g. How do you assess the information about adaptation co-benefits to influence you actions in operation and maintenance of the adaptation intervention?

3. Concluding question:
    a. How do you assess if the adaptation interventions are sustainable?

4. Conclusion:
    a. Thanking the participants.
    b. Distribution of a packet of snacks for the participants.

Appendix 4: In-depth Interview

Date (dd/mm/yy)	Interview number

This interview aims to identify how vulnerability and resilience to climate change are affected by various adaptation interventions implemented in the coastal/drought prone area of Bangladesh. This study also aims to identify various co-benefits from adaptation interventions in the area.

What is your current position?

What is your current place of work or institution?

1. To the best of your knowledge, what are the various adaptation interventions planned and implemented in the region?
2. In your opinion, how do you evaluate the success of such interventions in reducing vulnerability of the community people?
3. In your opinion, how have the interventions enhanced resilience of the community people where the intervention took place?
4. What is your suggestion about some potential adaptation measures those may be undertaken to increase resilience and to reduce vulnerability of the community people?
5. In your opinion, what are the adaptation co-benefits (both positive and negative) from the interventions you are familiar with?
6. Does the government or NGO plan and prepare enough projects in order to reduce vulnerability of the region?
7. In your opinion, how do you evaluate the adaptation interventions undertaken by NGOs and civil society organizations (CSOs)?
8. May you please share your views about donors who have invested in the region in various adaptation projects?
9. Do the project implementers have a policy for a regionally balanced selection of projects, for example, one safe drinking facility in each community?
10. In your opinion, how do adaptation interventions affect employment of individual in a community?
11. In your opinion, how do the attitude and behavior of individual change with the adaptation interventions compared with the status individual possesses without the interventions before?
12. What is your opinion about the quantity/number of co-benefits available from the adaptation interventions?
13. Does the project implementer/sponsor/donor communicate about the co-benefits before the implementation of the project? Please explain.
14. Do you think informed co-benefits would encourage beneficiaries become (more) pro-active towards adaptation intervention?

Thank you!