Coping with the Floods - Evaluation of Adaptation Technologies for Agriculture in Bangladesh

Sebastian Forneck

Md. Fuad Hassan

Florent Noulekoun

Gabriel Ponzoni Frey

November, 2015

Interdisciplinary Term Paper

ZEF Doctoral Studies Program

Abstract

As a measure to adapt to flooding in agricultural areas, different technologies have been introduced or enhanced in the Southern and North-Eastern parts of Bangladesh. While there is detailed knowledge about the impact floods have on the society and the environment, very few studies have investigated the effects adaptation technologies for flood management have on agriculture. In a complex system of people, production and employment, and nature, many of the common technologies may create new problems, while trying to fix old ones. This study aims to (a) identify the most common adaptation technologies, (b) elaborately discuss two of these technologies, and (c) evaluate the suitability of each of these technologies, assessing their influence on the social, economic, and ecological dimensions of the affected areas. A literature review was conducted to gather the needed information on the relevant aspects relating to adaptation technologies for flood management in the agricultural setting of Bangladesh. The findings, together with the results of a partial Multi Criteria Analysis (MCA), were used to analyse and prioritize the investigated technologies. *Floating Agriculture*, *Structural Barriers against Water Intrusion*, *Water and Salinity Tolerant Varieties*, *Flood Control, Drainage and Irrigation* (FDCI) schemes, and *Capacity Building and Awareness Creation* were the five identified technologies for flood management. It became evident, that the most suitable technologies aim to enable people to adjust to the floods and use them to an advantage for agricultural practices instead of cutting the flood water out of the agricultural fields. Through the process of prioritization, *Floating Agriculture*, *Water and Salinity Tolerant Varieties*, and *Capacity Building and Awareness Creation* were ranked to be the most suitable adaptation technologies for flood management in the study area. We therefore conclude that more investment in these adaptive measures is reasonable. To further elaborate on the suitability, the scope of the Multi Criteria Analysis should be widened in future studies to include more detailed information about the social, economic, and ecological impact of adaptation technologies on agriculture.

Keywords: flood, agriculture, adaptation technology, Multi Criteria Analysis

Table of Contents

Acronyms and Abbreviations

ADB	Asian Development Bank
APFM	Associated Programme on Flood Management
APK	Adaptation Knowledge Platform
BADC	Bangladesh Agriculture Development Corporation
BBS	Bangladesh Bureau of Statistics
BCAS	Bangladesh Centre for Advanced Studies
BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
DEA	Department of Agricultural Extension
FAO	Food and Agriculture Organization of the United Nations
FAP	Flood Action Plan
FEC	French Engineering Consortium
FDCI	Flood Drainage, Control and Irrigation
ft	Feet
GMB	Ganges, Brahmaputra and Meghna rivers
IFM	Integrated Flood Management
IUCN	International Union for Conservation of Nature
IWRM	Integrated Water Resource Management
MoEF	Ministry of Environment and Forests
NARS	National Agricultural Research System
NGO	Non Governmental Organisation
UNFCCC	United Nations Framework Convention on Climate Change
UNISDR	United Nations International Strategy for Disaster Reduction

1 Introduction

1.1 Background and justification

Bangladesh is a very densely populated country. Situated on the delta of three large rivers - the Brahmaputra, also known as Jamuna in Bangladesh; the Ganges or Ganga; and Meghna - the country is mostly found on low altitudes (MoEF, 2005; Hofer and Messerli, 2006). The vast network of rivers makes it prone to floods every year. These floods are primarily caused by rainfall in the monsoon season, between July and October (Hofer and Messerli, 2006). Recurrent flood events affect 20 to 30% of the country's area and are responsible for increasing the fertility of the land in low-lying areas (Venton and Majumder, 2013; BWDB, 2014).

Although these recurrent floods are not new and are part of farmers' life (Hofer and Messerli, 2006; Younus, 2012; Rahman and Rahman, 2015), Bangladesh's geographical setting puts the country under high natural disaster risk. Besides river flooding that is common in the country, coastal floods are another flood variant. When the rivers' output decreases in winter, high tides bring sea water inland and increase the salinity in the soil and in freshwater (Rabbani *et al.*, 2010; Hofer and Messerli, 2006). The many tropical cyclones that originate from The Bay of Bengal also lead to salinity intrusion, aside from destruction (AKP, 2010; Rabbani *et al.*, 2010; Venton and Majumder, 2013).

The intensity and regularity of these flooding events have been increasing under climate change and variability (change in the hydrological cycles, sea level rise, increased water temperatures) over the last decades, and this trend is expected to continue for the next decades in Bangladesh (Karim and Mimura, 2008; Hofer and Messerli, 2006). Such events have left more than 60% of the land under water for at least some period of the year in the past (Webster, 2013). These severe floods resulted in the death of more than 1000 people in 1998 and have been negatively impacting agricultural production (BBS, 2014; Southgate *et al.*, 2013; Rahman and Rahman, 2015).

Bangladesh indeed depends a lot on agriculture. Farming occupies about 70% of the available land and employs about 45% of the labour force (World Bank, 2014; Hassan and Das, 2015). Rice is the most important crop in the country and makes Bangladesh one of the top ten producers of rice in the world (FAOSTAT, 2015). Other harvests like jute, wheat, sugarcane and vegetables also have their relevance (Ortiz, 1994; Hofer and Messerli, 2006). Furthermore, even though the economy of the country is very rural, the importance of the agricultural sector in the GDP has been dropping over the years (Asaduzzaman, 2009; Younus, 2014), as other sectors develop and the population is becoming more urban (World Bank, 2014; Brammer, 2010).

Still, the majority (67%) of the population lives in rural areas (World Bank, 2014), and most of them rely on a subsistence type of agriculture characterized by very low productivity (Hassan and Das, 2015; Turner and Ali, 1996). The growth of the Bangladeshi population and the related increase in food demand further burden land resources (Alexander *et al.*, 1998) and the already low-productive agricultural system. In addition to its low productivity, agriculture is directly affected by the essence of the flooding event and its regularity and harshness (Younus, 2014). For example, in 2007 extreme floods yielded the loss of more than 300.000 tons of rice (BBS, 2014). Moreover, as approximately 30% of the total arable lands of Bangladesh is on coastal areas (Haque, 2006), a rise of the sea level will probably mean that farmers will have to abandon their lands or shift their productions (Ortiz, 1994). These high and more extensive flood events threaten the agriculture sector and are expected to lead to food insecurity (Asaduzzaman, 2009; MoEF, 2005). Therefore, farmers' adjustment mechanisms and their cropping decision behaviour are important determinants for coping with floods in Bangladesh (Younus, 2014).

Technological adaptations and strategies have been employed to reduce the impact of flood on agriculture, like the use of flood and salinity resistant crop varieties (Normile, 2008) or the use of floating agriculture (UNFCCC, 2006). Although technological adaptations may indeed mitigate the effects of floods on agriculture, mal-adaptation practices and inappropriateness can actually generate more losses and increase vulnerability (UNFCCC, 2014; Rahman and Rahman, 2015). As an example, coastal embankments have been used in Bangladesh for years and have improved the soil fertility in low-lying areas. However, inadequate drainage infrastructure along an embankment can produce its failure (Thompson and Sultana, 1996) and make coastal areas in Bangladesh more susceptible (Agrawala *et al.*, 2003).

Several research works have been conducted on flood hazards, and human and agricultural adjustments processes to flood in Bangladesh (Thompson and Sultana, 1996; Hofer and Messerli, 2006; Karim and Mimura, 2008; Younus, 2012; Younus and Harvey, 2014). Various flood issues have also been studied under the project for "Flood-control drainage and flood-control drainage and irrigation" jointly initiated by the Flood Action Plan (FAP), a French engineering consortium (FEC), and the Bangladesh Water Development Board (BWDB) (Younus, 2014). However, to date, few studies have looked into the impact of flood technological adaptations on the agricultural system or the suitability of such technologies to local conditions, which may be one of the reasons for technological adaption failure (Trærup and Bakkegaard, 2015).

In light of the increasing trend of flood hazards, which require appropriate adjustment and adaptation measures, this study seeks to answer the following arisen questions: (i) What are the existing adaptation technologies for flood management in agriculture in Bangladesh? (ii) What are their social, economic, and ecological impacts on the agricultural system of Bangladesh? and (iii) how suitable are they for flood management in Bangladesh?

1.2 Objectives

The main objective of this study is to evaluate the impacts and suitability of adaptation technologies for flood management in agriculture in Bangladesh. The specific objectives of the study are:

- To identify and document the existing adaptation technologies for flood management in Agricultural sector in Bangladesh
- To assess the social, economic, and ecological impacts of particular adaptation technologies for flood management on the agricultural system in Bangladesh
- To assess the suitability of these adaptation technologies for flood management in Bangladesh

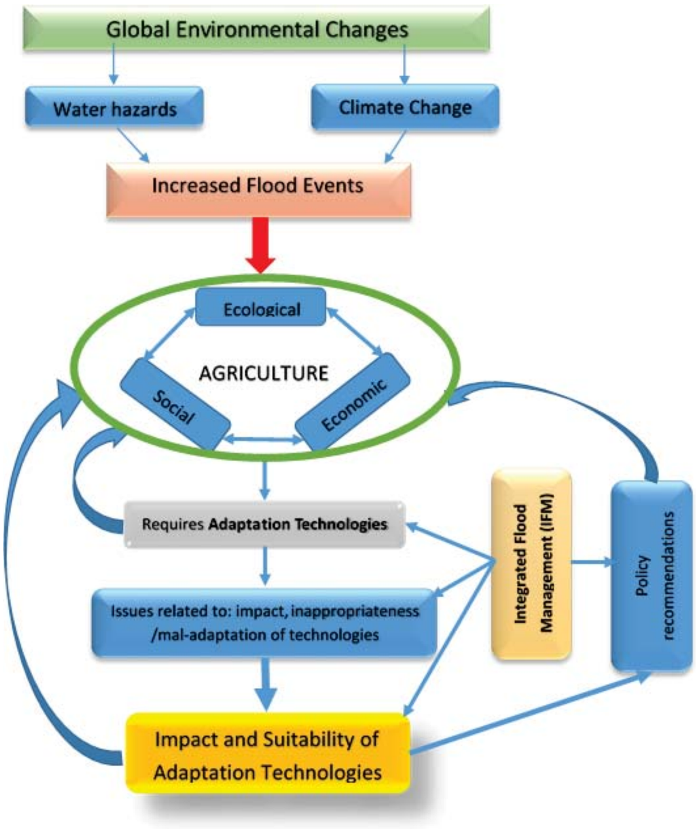
2 Conceptual Framework

To achieve our objectives, we first proposed a conceptual framework (Figure 1). Due to global environmental changes such as climate change (increase in temperature and rainfall variability) and increased water hazards (cyclone, water surges), there is an increasing trend of flood events (UNFCCC, 2006; Rabbani *et al.*, 2010). This is translated by the change in the frequency of occurrence and scope of floods over the last decades (UNFCCC, 2006; Younus, 2014). These extreme flood events have severely impacted the agricultural sector, affecting the three main pillars of the agricultural system (social, economic, and ecological). There have been decreased agricultural productivity, changing social behaviour, loss of species richness, increased water logging, land loss etc. in some flood-prone countries such as Bangladesh (Irfanullah *et al.*, 2011; Hofer and Messerli, 2006; Agrawala *et al.*, 2003; Ahmed *et al.*, 2013). These harmful consequences of flood increase the vulnerability of communities and affect their livelihood (Hofer and Messerli, 2006). Therefore, there is an urgent need to design adequate and adaptive measures and strategies for flood management in the agricultural system.

Technologies are a basic component for adaptation (ADB, 2014). Following the definition of the UNFCCC (2005), adaptation technologies can be defined as technologies that are used "in order to reduce the vulnerability, or enhance the resilience, of a natural or human system to the impact of climate change". Technological adaptation is a complex process that requires consideration of political, economic, social, and ecological context (UNFCCC, 2014). Particularly in the agricultural sector, technological adaptation may base on the selection of technologies that help increase productivity, ensure food security, and enhance resilience (UNFCCC, 2014). This necessitates a holistic and integrative approach, which matches the goals of technological adaption and the different above-mentioned dimensions.

In the context of flood management, one holistic approach that aims to reduce flood hazards by minimizing the loss of life, preserving the environment, and ensuring an economic development, is Integrated Flood Management (IFM) (APFM, 2009).

Figure 1: Conceptual framework for technological adaptation for flood management in the agricultural system in Bangladesh



IFM rooted from the broader concept of Integrated Water Resource Management (IWRM). IFM represents a paradigm shift from the traditional fragmentary approach on flood management to a more integrative management option at a river basin level, and accounts for climate change and variability (APFM, 2007; 2009).

One of the key elements of IFM approach is to "adopt a best mix of strategies" (APFM, 2009). This element implies that the identification of a strategy or combination of strategies (combination of technology options) to be suitable in a particular context of flood management depends on the climate, the basin characteristics, and the socioeconomic conditions in the region (APFM, 2009).

Considering the fact that adaptation technologies may be inappropriate to the local context, in which they are used, or mal-adaption practices lead to their ineffectiveness creating new damages or hazards (Agrawala *et al.*, 2003; UNFCCC, 2014; Rahman and Rahman, 2015), there is a need to assess the impact and the suitability of adaptation technologies for flood management to enhance communities' resilience and reduce vulnerability to floods.

Hence, relying on the technology suitability assessment section of IFM and accounting for the prevailing technology adaptation problems for flood management in Bangladesh, this study was designed. The main aim of the study is to assess the impact (positive or negative) of these technologies on the agricultural sector and the suitability (or prioritisation of the existing and implemented adaptation technologies) of the adaptation technologies. Deriving from the findings policy recommendations and actions can be formulated in order to avoid future inherent flood management problems related to technological adaptation, and, at the same time, to help communities build resilience against floods and flood damages.

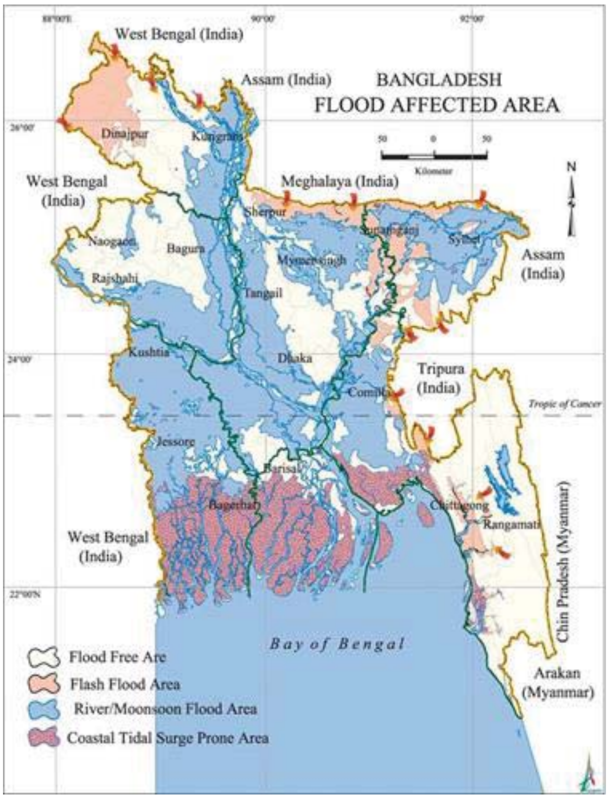
3 Material and Methods

3.1 Study area description

Bangladesh is situated in the Bay of Bengal, on the Ganges, Brahmaputra and Meghna rivers (GMB) delta. The country has three defined seasons: the winter or dry season, between November and February; the summer, following from March to June; and the monsoon or wet season, from July to October (Hofer and Messerli, 2006). In winter the temperatures in the south are usually warmer than in the north and in the monsoon season the western regions are warmer than the eastern ones (Agrawala *et al.*, 2003).

The mean annual precipitation in the country is 2456mm and most of it (72%) falls in the monsoon season. The rainfall patterns are not homogeneous, and the southeast and northeast of the country receive most of that rainfall (Ahasan *et al.*, 2010). The altitude in the country is not higher than 60 meters above sea level and more than 60% of the country is under 5 meters of elevation (BWDB, 2014; Venton and Majumder, 2013). Also, the country is reticulated by a mesh of more than 400 rivers (BWDB, 2014).

Figure 2: Flood Affected Areas in Bangladesh



Source: http://en.banglapedia.org/images/0/06/FloodAffectedArea.jpg

The occurrence of flood due to increasing water level in the rivers is the most common feature in this country (Figure 2). These floods are natural events, and more frequent in some northern and southern areas of the country (Hossain, 2003). On the other side, the southern parts of Bangladesh are also vastly affected by flooding events, especially coastal flooding. With these in mind, this study focus on the southern part of Bangladesh, some other parts under the GMB (Ganges, Brahmaputra and Meghna rivers) delta, as well as the northern belts (Haor areas). Haors are basin like structures in the wetlands. In Bangladesh the majority of the haors are located in the North-east part (Alam *et al.*, 2010).

Most of the districts in our study belong to Ganges Tidal Floodplain (South), Sylhet Basin (Northeast), and Surma Kusiyara Floodplain (Northeast). The land types in these regions vary from medium low to heavy silt clay loam and grey colour (Quddus, 2009). Farmers practice different cultivation systems in the flood affected areas, where they mostly grow rice, wheat, mustard, potato, and other types of vegetables (FAO, 2001). In the South, most of the agricultural land is utilized for cultivating transplanted *aman* rice, *aus* rice, vegetables, and fisheries including shrimp, and rearing livestock (FAO, 2014).

3.2 Methods

In order to fulfil the objectives of the study different methods were applied. First of all, an extensive literature review was carried out to identify and document the existing adaptation technologies for flood management in the study area. For this review, information from a wide selection of available published literature on various adaptation technologies used for flood management in Bangladesh were thoroughly studied. Internet search using the most common and relevant search engines (Google, Google Scholar, Web of Science, Science gateway etc.) was performed. The websites of both local and international organisations intervening in the domain of flood and disaster management such as FAO, BRAC, BUET, BWDB and BCAS were consulted as well. Reviewed literature comprised peer-reviewed scientific articles, books, and grey literature including official reports of the governmental and non-governmental, local and international organizations.

Second of all, based on the output from the literature review, two of the identified adaptation technologies were purposively selected and thoroughly discussed to showcase the impacts of technological adaptation for flood management on the agricultural sector in the study areas. These technologies were considered because of the availability of data on them and their different approaches of managing the floods. The analysis was based on the theoretical framework focusing on the trade-offs between the technologies and different pillars of the agricultural system (Figure 1).

Finally, a “partial Multi Criteria Analysis (MCA)” was undertaken to identify the most suitable adaptation technologies (prioritization) for flood management in the study area. This MCA analysis was partial because local stakeholders (local community members and experts) could not be involved in the process. According to Trærup and Bakkegaard (2015), MCA involves several stages including mainly:

1. **Identification of the adaptation technologies**: this was achieved through an extensive literature review, which enabled the selection of five technologies (Table 1), and the elaboration of a technological factsheet (TFS) for each of them (Annex 1). The TFS, which describes each technology, was used as a means to familiarize experts with the technology options during the process of technology performance evaluation (step 3);
2. **Selection of the criteria for prioritizing the adaptation technologies**: this was fulfilled based on an extensive literature review coupled with the use of the MCA guidance document by Trærup and Bakkegaard (2015), and the screening of the criteria through a working group meeting among experts. Nine criteria (Table1, Annex 2) covering social, political, institutional, economic, and environmental dimensions were selected. The selected criteria were independent from each other or mutually exclusive. All criteria were assigned a numerical form on a scale of 0-100 and formulated in positive terms (Table1, Annex 2).
3. **Ranking of the technologies**: each technology’s performance was evaluated against each of the criteria through a decision matrix (Table 4, Annex 2). For this purpose, an individual expert scoring sheet (Annex 2) was made and handed out to all experts. The scoring scale in this study was from 0 to 100, using 0 as the least preferred technology and 100 as the most preferred technology (Table 2, Annex 2). The average score was calculated and used. Results were presented in forms of radar graph, standardizing the scores in a scale of 0 to 1.
4. **Assignment of weight to the criteria**: after scoring each technology against each criterion, the scores are not yet comparable because stakeholders may consider on criterion more important than another (Trærup and Bakkegaard, 2015). Therefore, to include experts’ preference and make the criteria comparable, they were assigned weights (in %) based on their relative importance (Haque *et al.*, 2010; Trærup and Bakkegaard, 2015). Thus, during the process of technology performance evaluation, experts were also provided with a criteria weighting table (Table 3, Annex 2) to weight the criteria. The total sum of the assigned weights equalled 100% and the average weight for each criterion was calculated and used (Table 3, Annex 2).
5. **Combination of weights and scores**: based on the outputs from the technology performance evaluation (scores) and the weighing of the criteria (weights) the total weighted score of each technology option was calculated. It represents the overall performance of each technology considering all criteria on the same relative scale (Trærup and Bakkegaard, 2015).

To compute the total weighted score in this study, the relative score of each criterion was multiplied by its corresponding weight.

6. **Examination of the results**: according to their total weighted scores obtained from step 5, technologies were ranked. This resulted in a technology ranking list where the most suitable/preferred technology was the one with the highest total relative weighted score.

In total, nine experts, chosen from ZEF senior and junior researchers, participated in the process of technology scoring and criteria weighing. Experts' evaluation was mainly based on their qualitative judgement. Experts with social, economic, and environmental background were selected due to the selected criteria, which combine the three dimensions, and also to reduce the bias that could eventually arise from the scoring and weighing process owing to individual expert field. In addition, local expertise and experience were considered as four of the experts have worked in Bangladesh for many years and two out of the four are Bangladeshi. Therefore, the experts, by their knowledge and experience on floods and agriculture, are assumed to be able to understand the most crucial aspects of the given issue and rate the adaption technologies accordingly.

4 Results and Discussion

4.1 Existing adaptation technologies for flood management

Adaptation technologies can be broadly divided into two categories: Hard and soft technologies. Hard technologies refer to equipment and infrastructure, whereas soft technology includes management practices and institutional arrangements (Christiansen *et al.*, 2011).

In Bangladesh different kinds of adaptation technologies for flood management are widely implemented in regard to agriculture (Table 1): the use of *Water and Salinity Tolerant Varieties*; *Structural Barriers against Water Intrusion*; *Flood Control*, *Drainage and Irrigation* (FCDI) schemes; Floating Agriculture; and Capacity building and Awareness Creation (Hossain *et al.*, 2006; Al-Emran *et al.*, 2014; Talukder and Shamsuddin, 2012; Asaduzzaman, 2004; Mallick *et al.*, 2005; Agrawala *et al.*, 2003)

One adaption technology used in Bangladesh is **Floating Agriculture**, also known as floating gardening. This kind of soil-less agriculture is a form of hydroponics. Being a traditional cultivation system, Floating Agriculture was already being practiced in southern Bangladesh more than two hundred years ago (Irfanullah *et al.*, 2005). Floating beds of rotting aqua weeds are used as a nutrient for crops and vegetables. Since these beds are able to float on the water, they also provide the needed "land" for this kind of agriculture (Hutton *et al.*, 2015). Floating Agriculture, as a culturally embedded adaption technology to live with the floods instead of controlling the floods, will be elaborately discussed in session 4.2.1..

Structural Barriers against Water Intrusion includes dams, dykes, embankments, and other artificial constructions. The technology helps to hold back river- and seawater, and protect areas at risk from being damaged from inundation or strong waves (UNFCCC, 2006). Starting from ancient times, when farmers used earthen embankments to protect their fields, the local variations became part of the cultural landscape of Bangladesh (Rahman and Kabir, 2013). Since the use of *Structural Barriers against Water Intrusion* has come under harsh criticism lately (see e.g. Islam, 2001; Hossain and Sakai, 2008), this kind of technological adaptation will be under review in the following part of this paper (4.2.2).

Water and Salinity Tolerant Varieties include all kinds of crops or vegetables that are able to cope with salinity and extreme moisture caused by salt water intrusion or river flooding. Two of the most popular varieties of rice, *aus* and *aman*, are a good example of how this improvement works.

Table 1. Brief description of existing adaptation technologies for flood management in Bangladesh

Adaptation technologies	**Brief description**	**Nature of the technology**		**Type of the technology**	**State of the technology in Bangladesh**
		Modern	Traditional		
Floating Agriculture/Gardening	With the help of floating beds created from aquatic weed, which serves as nutrients and as soil-surrogate, crops and vegetables are able to grow on the water surface. Floating agriculture thereby allows agriculture even during flooding periods, providing sustainable food security for local communities.[7,12]	The similar technology is used in modern times, becoming more popular since the 1990s and spread to other regions like the north-east from 2005 on.[12,13]	Floating agriculture is practiced since centuries in local communities. Experts assume that the technology was developed around 1400 BC.[14,17]	Hard	It is used by local communities in South and North-East Bangladesh[12]
Structural Barriers against Water Intrusion	The technology includes dams, dikes, embankments, and other artificial constructions. It aims to protect lives, crop, lands, and livestock at a particular area from flooding. In Bangladesh most structural barriers against water intrusion are embankments.[3]	First embankment projects were launched in the 1960s, which lead to the introduction of larger scale dams and barrages.[6]	Local earthen embankments exists since centuries. The first coastal embankments were built in 17th century.[18]	Hard	The technology is implemented nationwide by government agencies, which is also responsible for the maintenance.[9,11]
Water and Salinity Tolerant Varieties	The technology includes salinity-resistant crops like salt-resistant wheat, water-resistant varieties of rice like *aman*, and vegetables as a general alternative to vulnerable crops. With these varieties food security can be significantly raised in flood-prone areas.[19]	First introduced in the 1970's, these varieties of rice had poor resistance to pests. A second generation was improved in matters of pest-resilience in the 1980's, and from 1990 on, a third generation was brought in, which provided a higher yield.[10]	Farmers have been selecting the varieties resistant to flooding/salinity over time, but no estimation on time of introduction exists.[8]	Hard	Widely adopted and implemented by local farmers.[10]
Flood Control, Drainage and Irrigation schemes (FCDI)	The technology redirects water and drains vulnerable and flood-affected areas by using for example irrigation canals or afforestation (biodrainage). It increases the area of land free of flooding, reduces the negative impact of abnormal floods, and, especially through irrigation, increases the yield of agricultural production.[4,22]	The institutionalized projects started at a similar time as modern embankment projects, meaning the early 1960s. Recently, policy makers started focussing on irrigation systems rather than on FDC schemes.[9,16]	Water regulating embankments, drainage systems like excavation or dredging of silting rivers to unclog waterways, and irrigation systems exist since centuries in different areas of Bangladesh.[2,15]	Hard	The technology is widely implemented in flood-prone areas, but its maintenance needs to be reinforced.[3,4,5]
Capacity Building and Awareness Creation	The technology includes long-term weather forecasts, awareness creation, capacity building, early warning systems and the usage of indigenous knowledge for all of the above mentioned. It helps to anticipate and handle flood events more efficiently in order to minimize damage to lives and livestock. It also helps farmers to adjust their cropping system to periods of flood occurrence, thereby sustaining crop yields.[2]	In modern times, mass media - like TV, radio, or newspapers -, hydro-meteorological data, education in schools and through art, and notifications on poster, rickshaws, or brochures have become part of this technology.[1]	Traditionally, local warning systems like flood markers on trees or assignment of flood watchmen were common variations of this technology.[21]	Soft	The technology is implemented, but needs to be more accessible, especially in remote areas. Based upon modern communication systems, the technology is mostly used by public institutions.[20]

Sources: [1]ADPC, 2004; [2]Agrawala *et al.*, 2003; [3]Al-Emran *et al.*, 2014; [4]Ali, 2002; [5]BWDB, 1997; [6]Choudhury *et al.*, 2004; [7]Haq *et al.*, 2004; [8]Hofer and Messerli, 2006; [9]Hossain, 2003; [10]Hossain *et al.*, 2006; [11]Hossain and Sakai, 2008; [12]Irfanullah *et al.*, 2011; [13]Irfanullah, 2013; [14]Islam and Atkins, 2007; [15]Kabir and Faisal 1999; [16]Mirza and Ericksen, 1996; [17]Pantanella *et al.*, 2011; [18]Rahman and Kabir, 2013; [19]Rasid, 1993; [20]Sarker and Hasan, 2011; [21]Schware, 1982; [22]Talukder and Shamsuddin, 2012.

During pre-monsoon and in higher areas with shallow water *aus* rice is used as the less water resistant crop, whereas in the low lying areas of the Ganges-Brahmaputra floodplains and during monsoon *aman* as the water-resistant variety is planted (Rasid, 1993).

Physical structures, such as embankments and drainage canals, are used to redirect water and help to drain vulnerable areas, meaning to control the flooding (Agrawala *et al.*, 2003; Talukder and Shamsuddin, 2012). The same principle is also applied through a variety of irrigation systems to reduce the amount of water in a particular area. These flood management options are gathered under ***Flood Control, Drainage and Irrigation*** (FCDI) schemes. The technology aims to make more land inaccessible for flood water, thereby reducing the average water level in a particular area and reducing extreme flooding to a common level people are capable to cope with (Islam, 2001).

The last category of adaptation technology is ***Capacity Building and Awareness Creation***. This technology includes education on flood-related issues, weather and crop forecasts, as well as early warning systems (Agrawala *et al.*, 2003). Since preparation for flooding also includes protective measures for the livestock, this technology is directly and indirectly linked to agriculture (Mallick *et al.*, 2005). *Capacity Building and Awareness Creation* can be implemented on the national level through media, but also on the local level by school education or advertising on walls or rickshaws (ADPC, 2004).

Other characteristics of the above described adaptation technologies can be found on Table 1.

Although all named technologies will be rated for their singular capability towards particular issues, it has to be kept in mind that they are also interconnected. *Capacity Building and Awareness Creation* can provide knowledge dissemination for successful Floating Agriculture. Embankments protect against water intrusion and regulate water at the same time. Therefore, following the idea of integrated flood management (APFM, 2009), not only the different technologies have to be analysed each for itself, as done in this paper, but also the synergies between them should be considered.

4.2 Social, economic, and ecological impacts of Floating Agriculture and Structural Barriers against Water Intrusion for flood management on the agricultural system

4.2.1 Floating Agriculture

- **Description**

Floating Agriculture is one of the oldest practices of cultivating agricultural crops in Bangladesh that utilizes the areas which are inundated for long periods of time. This type of technology allows agriculture under flooding conditions (Zhu *et al.*, 2010). It involves planting crops on soil-less floating rafts or beds. Historically, these rafts were made of composted organic material, including water hyacinth (an invasive weed in wetlands), algae, straw, herbs, and waterwort (ADB, 2014). Under waterlogged situation, these types of beds can float on the surface of the water and enable cultivation in such drowned areas (Zhu *et al.*, 2010). This technique is related to hydroponics and is known as Baria, vasoman chash, or dhap in Bangladesh. This practice has been used for centuries in Bangladesh and will continue over the coming ones. Currently, in many places it has become associated with new technologies (redesigns of the floating beds) which contributes in its potential growth (Islam and Atkins, 2007).

In the monsoon season, some of the southwestern areas of Bangladesh that are adjacent to coastal banks such as Bagerhat, Gopalgonj, Khulna, Barisal, Jhalkathi, and Jessore remain swamped for a longer time periods. In such circumstances, Floating Agriculture is adopted and practiced by the people of these areas (Asaduzzaman, 2004). In southern Bangladesh, where the practice originated, it is concentrated in seedling agribusiness. Recently, it has been widely promoted by NGOs as an adaptation option, mainly for providing direct seasonal benefits (such as household nutrition) to the poorest and most vulnerable populations (Irfanullah, 2013).

Floating Agriculture needs a regular source of freshwater to work best, like lakes along the coast and river areas. This technology adapts well where heavy monsoons hit and flooding is likely. The most important requirements for an efficient operation of floating gardens is a sufficient source of construction materials (for example, mature water hyacinth), the continuous supply of stationary water, and a functional market for the farmer to sell the harvest (Irfanullah, 2013). It is mentionable that this practice is not suitable to heavily salty water because salinity intrusion inhibit its production as well as the adoption (Islam and Atkins, 2007; Irfanullah, 2013).

In the floating beds different types of vegetables such as cowpea coriander, ladies finger, wax gourd, taro, Chinese amaranth, pumpkin, Spinach, eggplant, hyacinth bean, tomato, and also some spices like ginger, chili, turmeric are cultivated (Haq *et al.*, 2004).

- **Advantages**

Floating Agriculture can be extremely effective, especially in minimizing crop damage from flooding. Farmers can use raft garden beds to cultivate a wide range of vegetables for food and income during times when other activities are impossible because of inundation. This low-technology production system has the potential to improve productivity per unit of land with little or no chemical fertilization. (Islam and Atkins, 2007; Pantanella *et al.*, 2011; Sterrett, 2011).

By allowing a continuous cultivation during flooding periods through the floating beds, the technology helps spare land which would otherwise be lost by inundation, thereby increasing the total cultivable area and communities' resilience. Though Floating Agriculture requires no external fertilizer input, the productivity from the system is 10 fold greater than the one from the conventional agricultural system (Haq *et al.*, 2004).

Floating garden is environmentally friendly as it enables the efficient use of water hyacinth which ultimately helps keep the water clean, decrease mosquito outbreaks, and creates opportunity for fishery (Saha, 2010). The use of floating rafts as organic residue after crop harvest is another intrinsic benefit from practicing Floating Agriculture (Asaduzzaman, 2004; Saha, 2010).

Pavel *et al.* (2012) estimated the cost and benefit of 30 floating gardens considering the mean expenditure and return. Their findings revealed that the 0.26 years net return (NR) and benefit cost ratio (BCR) varied depending on the floating bed sizes. It was also observed from their study that for standard (14 × 4 × 3 ft) sizes bed, the estimated NR (USD 111.55) and BCR (USD 3.67) are higher than for other size of beds. According to the findings of Pavel *et al.* (2012), there is a positive relationship between net return and the bed sizes of floating garden. Therefore, the technology generates additional revenue and helps alleviate poverty (Saha, 2010).

In addition, this system also creates employment opportunities, as it is quite labour intensive (Haq *et al.*, 2004), thereby reducing labour migration to urban areas, since it provides jobs in rural areas (Chowdhury and Moore, 2015). The participation of both men and women in the practice increases gender equity, empowers women, and leads to capacity building and additional social interactions of women (Chowdhury and Moore, 2015; Islam and Atkins, 2007). Being a traditional way of agriculture, the use of floating gardens also helps preserve local knowledge and cultural practices (Chowdhury and Moore, 2015; Irfanullah *et al.*, 2011). Through the empowerment of women to participate in agricultural and farming practices based on commonly shared knowledge, the community becomes more cohesive and this social cohesion can be used for collective actions, for example in matters of environmental protection (Chowdhury and Moore, 2015). In comparison to the people who do not practice Floating Agriculture in the flood prone areas, those who implement the technology have a better economical standard of living (Saha, 2010). Floating Agriculture is beneficial to poor, marginal, and landless farmers as it ensures better food security by enhancing their supporting capacity (Irfanullah *et al.*, 2011).

- **Disadvantages**

The low availability of an adequate mix of plant material for bed creation is one of the major barrier to the rapid scale-up of this technology is (UNFCCC, 2006). Another barrier cited by Islam and Atkins (2007) is the need for frequent transportation to get products to markets, because of the short production cycle and a lack of refrigerated storage for harvested crops. In Bangladesh, the absence of formal regulation for Floating Agriculture can result in aggressive tactics from the local elite and politically powerful to capture areas suitable for the technology (Islam and Atkins, 2007). In addition, conflict arises within the community regarding the rights of cultivation on khas or common property areas. In the absence of proper governmental monitor the powerful political individuals try to absorb most of the common areas for cultivation (Islam and Atkins, 2007).

4.2.2 Structural Barriers against Water Intrusion

- **Description**

The introduction of structured barrier projects against water intrusion in the 1960s marked a turning point in the coping with floods. From arranging the lives around flooding, barriers like embankments shifted the focus to the prevention of flooding (Ehlert, 2012; Islam, 2001). Instead of coping with the conditions created by floated lands, the water was kept out of the agricultural areas. In 2003, embankments of a combined length of over 10.000 km regulated the stream of floods in Bangladesh (Al-Emran *et al.*, 2014; Islam, 2000). As Annex 3 shows, embankments are widely distributed all around Bangladesh and represent one of the most common technologies for flood management.

Besides protecting the fields from water intrusion, the embankments themselves became a part of the rural infrastructure of Bangladesh. They are used as roads as well as potential places for settlement, especially for poor, landless people (Islam, 2000).

- **Advantages**

Embankments and other kinds of barriers are mainly built to protect the lives and livelihood of farmers. Crops like rice can be planted without the risk of losing it to flooding and production can be continuously performed all year long. Coming with a higher productivity, new jobs are also created. More labourers are needed on the fields, no unemployment during the rainy season, and the embankment construction and maintenance offer job opportunities (Huu, 2012). The new kind of agriculture, now providing land for cattle and depending on artificial nutrition, raised the need for fertilizer and animal fodder. To cover this need new jobs are created, also providing additional employment (*ibid*.). Since the embankments are used as rural roads and therefore improve the connections of one place to another - first and foremost between urban and rural areas - distribution of goods became more profitable and created jobs in the transportation sector (*ibid*.). Besides protecting against severe dangers of flooding like drowning, some studies also show a decline of harmful diseases in the protected areas. Myaux, Chakraborty, and de Francisco's study (1997), for example, assumes a correlation between the existence of an embankment and the reduction of child mortality through diarrhoea.

Beside the economic and protective advantages, embankments, being a traditional adaptation technology against floods, have become part of the culturally shaped landscape of Bangladesh (Rahman and Kabir, 2013).

- **Disadvantages**

It was already mentioned earlier, that structural barriers have been criticized during the last decades, in regard to problems caused by this kind of technology. First and foremost embankments do not solve the flood problem in general (Islam, 2001). They are mere protections against the symptoms, but they do not affect the source. They are also, especially the earthen ones, no permanent solution against flooding. The embankments are vulnerable to rain and flood water, and have to be repaired regularly and maintained constantly (Hossain and Sakai, 2008). But not only natural causes are damaging the barriers. Human activities like the use of embankments as roads or places to settle and for agriculture or cattle grazing, the partial damaging for irrigation purposes, and the poor design of structure in general harm the functionality of embankments (Islam, 2000).

Floods are also perceived as an integral element of the everyday life of people in Bangladesh. Historically shaped by its positive and negative aspects, floods have become part of what Husserl calls the Lebenswelt or everyday lifeworld (translation by author), the “primal, unquestioned, and self-evident basis of all acting and thinking” (Flick *et al.*, 2000: 110, translated by the author). The absence of floods therefore highly affects the historically grown social and cultural background of communities, therefore floods cannot be measured only by their physical impact (Ehlert, 2012). Therefore, depending on the particular community or area, perception of floods might differ significantly, up to accepting the damage extreme flooding causes as god’s will and therefore refusing all adaptive measures to lower vulnerability (Grothmann and Patt, 2005). Local stakeholders broadly distinguished in normal (“barsha”) and abnormal (“bonna”) floods (Paul, 1997; Zaman, 1993; Rasid, 1993; Hofer and Messerli, 2006). The first kind is usually seen as a source for soil fertility and therefore positively connoted, whereas the latter represents a threat to life and livelihood, and therefore is perceived negatively. The local perspective on floods is not only different depending on the area, also the perspectives of external experts, politicians, or journalists differ from the perceptions of farmers. Farmers see flooding as part of their daily life, whereas engineers tend to problematize floods and to look for solutions. Politicians tend to have a macroscopic-international view, and journalists dramatize to catch the attention of their readers (Hofer and Messerli, 2006). Given this variation of different perceptions, building structures to cut off flooding can cause major problems on the local scale.

Another problem relates to the security of the people living inside of the embankments. Although being created to protect the inhabitants, the erosion of structural barriers can create severe danger to local stakeholders (Hossain and Sakai, 2008; Islam, 2001; Huu, 2012). Sudden breaches, caused by human interference or natural erosion through rain or flood water, can break the embankment, and lead to a loss of human lives and livelihood due to extreme water intrusion (Hossain and Sakai, 2008). But even if the embankment remains intact, the flood water has to be directed somewhere. Through limiting the space for floods to spread, the floods become even more intense at the remaining vulnerable places, causing dangerous flash flood from otherwise normal flooding (Choudhury *et al.*, 2004; Huu, 2012; Hossain and Sakai, 2008).

Embankments can also create social inequality between the stakeholders. Although the construction of embankments creates jobs for poor people temporarily, it also harms small farmers, since only wealthy farmers can finance the needed fertilizer for low water agriculture (Huu, 2012). Due to the reduced soil fertility resulting from lack of natural fertilizer through river-inundation (Myaux *et al.*, 1997; Hossain and Sakai, 2008; Huu, 2012; Islam, 2001), expensive artificial fertilizer cannot be just seen as a bonus to raise productivity, but as a mandatory requirement to practice the new way of agriculture. Beside with the additional costs for fertilizer, the fertilizer pollutes the ground, and subsequently the food and groundwater (Huu, 2012). Former methods of farming including floods reduced the need for artificial fertilizer significantly due to the river-inundation. The absence of the cleaning of regular flooding as well let the fertilizer remain in the fields and even more pollute the ground water (Myaux *et al.*, 1997).

Also with introducing new kinds of agriculture, new technologies like harvesting instruments are needed to maintain or raise the production (Myaux *et al.*, 1997). Again wealthy farmer are more likely to be able to effort these new technologies. So, even if small scale farmers produce more crops, they are worse off in relation to their richer competitors.

Social conflict in matters of land use can rise in case of leaking or intentionally cut embankments, since shrimp farmers rely on water ponds, while agricultural farmers need dry fields to produce their crops (Rahman and Rahman, 2015). These maladaptation of embankments also leads to pollution of water by salt or eroded dirt (Rahman and Rahman, 2015). The lack of flooding water can rise problems relating to hygiene and sanitation, since the natural "flushing" of floods is prevented as well (Hossain and Sakai, 2008).

Embankments also force farmers to abandon the traditional farming methods they and their family followed for decades (Zaman, 1993). Therefore, these barriers do not only shift the patterns of production, but also have a huge impact on the culture, and change the everyday lifeworld of farmers significantly. One of these impacted traditional farming methods is fishery. In the agricultural areas, in which floods leave wild fish resources as a side product (Ehlert, 2012), and even more for fisherman, who rely only on this source of income, embankments harm local stakeholders. Water is usually directed towards water reservoirs. These reservoirs are often controlled by powerful stakeholder, who have the ability to include, but also exclude others from having access to the resource (Andreasen, 2011). Because of this or other reasons like the distance to the next water pond, many small fishermen cannot proceed with their traditional lifestyle (Myaux *et al.*, 1997). Not only from an economic and social perspective have embankments created challenges regarding this matter. Due to the limited space for fishes in the new water ponds, embankments always contribute to a decline of fish populations (Ehlert, 2012; Huu, 2012).

Just like fishermen, agricultural farmers suffer under a, arguable smaller, amount of lost land for farming purposes. Embankments have to be built at a particular spot and these spots can hardly be used for agricultural practices afterwards (Myaux *et al.*, 1997). Beside economic loss using embankments for agricultural practices would erode the embankments and therefore lead to problems mentioned earlier.

One of the major economic disadvantages of embankments are the costs. In comparison to other adaptive technologies huge amounts of money have to be spend on structural barriers to construct, repair, maintain, and monitor (Hossain and Sakai, 2008). Taking the 1998 extreme flooding as an example, the repair costs for structural barriers were about 143 million USD. Since the erosion of embankments is an ongoing process, the investment vanishes after several years and the continuous maintenance costs create additional debt for the state of Bangladesh (Islam, 2001).

Some of these problems can be fixed while still sticking to embankments as a flood management option. In comparison to cordon-embankments, which completely isolate the field from water intrusion, variations can be used, which regulate the income of water (Islam, 2001). So, water can still be used as fertilizer, help with sanitary and pollution issues, preserving the cultural landscape to a degree, while on the other hand weakening the impact of abnormal floods. Also, vegetation can be used to prevent eroding of earthen embankments (Islam, 2000).

But even with those adjustments and variations, many disadvantages still prevail, why many scientist like Islam (2001) start following the open approach to flood, meaning open even additional areas to flooding, so that the height and therefore the impact of the flood is decreased.

4.3 Adaptation technologies and their suitability for flood management in the agricultural sector

4.3.1 Adaptation technology performance

The mean scores in the Table 2 showed the performance of each technology evaluated against each criterion. The scores varied according to both the technology and the criterion against which it is evaluated. While *Floating Agriculture* involved the least direct costs for the implementation and maintenance for flood management (71.44), *Water and Salinity Tolerant Varieties* was the most accepted technology for flood management in the study areas (74.44). Results also showed that *Capacity Building* and *Awareness Creation* was the most effective option to increase resilience against flood damages (73.89).

Table 2: Mean score of each technology evaluated against each criteria; values in parenthesis represent the standard deviation (SD); (N*=9)

Criteria No	**Criteria**	**Floating agriculture**	**Structural barriers against water intrusion**	**Water and salinity tolerant varieties**	**Flood Control, Drainage and Irrigation (FCDI) schemes**	**Capacity building and awareness creation**
1	Ease of implementation	60.56 (27.21)	51.11 (13.87)	69.44 (12.1)	50 (13.92)	61.56 (22.09)
2	Use and maintenance	68.33 (26.46)	50.56 (17.04)	69.44 (18.45)	46.56 (12.12)	66.33 (25.86)
3	Direct costs for the implementation and maintenance of the adaptation technology	71.44 (26.2)	34.33 (17.22)	67.22 (11.49)	47.67 (17.44)	59 (22.15)
4	Improving farmers income	68.89 (23.15)	51.89 (17.74)	66.67 (17.32)	59.11 (13.07)	57.11 (18.41)
5	Contribution of the technology to protect against floods (to what extent the technology will help build resilience against flood damages)	58.22 (31.66)	53.89 (24.34)	58.33 (24.49)	73.67 (12.59)	73.89 (16.91)
6	Enhancement of ecological condition (protection of environmental resources)	68.44 (24.53)	41.11 (22.61)	45.67 (17.44)	51.67 (20.46)	42.22 (22.93)
7	Contribution of the technology to social and sustainable development (benefit to society and people well-being)	67.22 (23.2)	54.44 (25.91)	65.67 (18.1)	54.44 (18.62)	68.89 (16.35)
8	Degree of Community Acceptance	65 (25.12)	52.11 (23.93)	74.44 (19.28)	60.89 (10.11)	70.33 (19.81)
9	Coherence of the technology with national development policy and priority; political acceptance for the adaptation technology	62.56 (27.64)	67.22 (16.98)	72.78 (17.16)	71.33 (19.9)	67.11 (26.39)

Furthermore, the performance of each technology on a given criterion differed from one technology to another as visually shown in Figure 3. However, there exists some level of disagreement in expert scores among technologies as portrayed by the relatively higher variation (SD) in the scores assigned to *Floating Agriculture* compared to other technologies (Table 2).

4.3.2 Criteria weighting

The mean weight assigned to each criterion is shown in Table 3. Overall, the average weight of the criteria ranged between 6 and 16%. The criterion *contribution of the technology to protect against floods* had the highest average weight (15.7%). This is likely due to the fact that this study is about flood management and the overarching goal is to protect vulnerable people against its damages. Moreover, the least average weight (6.5%) was assigned to the criterion *coherence of the technology with national development policy and priority; political acceptance for the adaptation technology* pointing out the lower relative importance of this criterion compared to the others from the experts' point of view, as translated by its relatively small standard deviation.

Table 3: Mean weight assigned to the criteria based on their relative importance in the case of flood management in Bangladesh; values in parenthesis represent the standard deviation (SD) (N*=9)

Criteria	**Weight (%)**
Ease of implementation	12.8 (7.3)
Use and maintenance	9.7 (2.5)
Direct costs for the implementation and maintenance of the adaptation technology	11.4 (6)
Improving farmers income	11.0 (3.7)
Contribution of the technology to protect against floods (to what extent the technology will help build resilience against flood damages)	15.7 (3.5)
Enhancement of ecological condition (protection of environmental resources)	9.4 (4.5)
Contribution of the technology to social and sustainable development (benefit to society and people well-being)	12.1 (3.7)
Degree of Community Acceptance	11.5 (3.3)
Coherence of the technology with national development policy and priority; political acceptance for the adaptation technology	6.5 (2.9)
Total	100

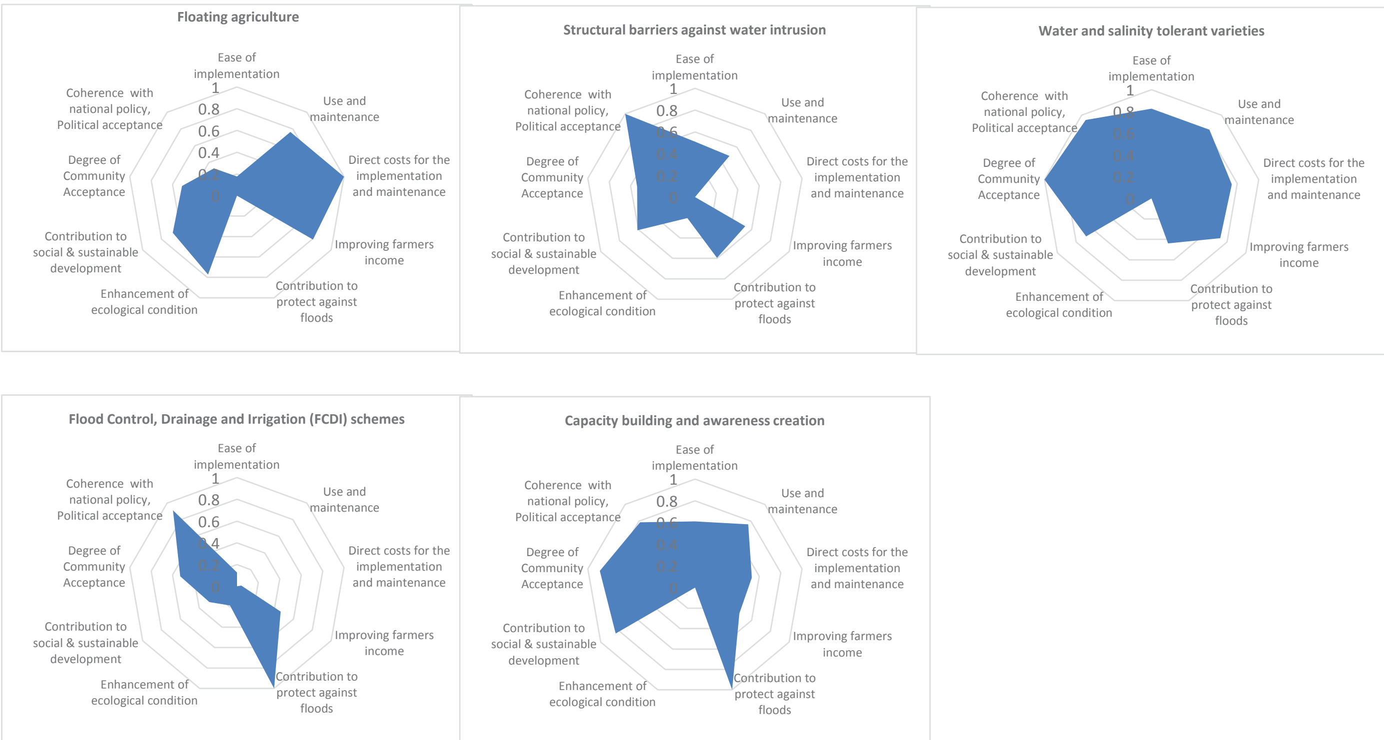
4.3.3 Prioritisation of adaptation technologies

According to the total weighted score, the top three priority adaptation technology for flood management in the study area are, in order of importance: *Floating Agriculture*, *Water and Salinity Tolerant Varieties*, and *Capacity Building and Awareness Creation* (Table 4). It should be noted that the former two technologies were assigned a very similar total weighted score, closely followed by the third one. The least preferred technology was *Structural Barriers against Water Intrusion*.

4.3.4 Suitability of the adaptation technologies in agricultural sector

From the different steps of MCA ranging from the evaluation of the technology performance to the combination of technology scores and criterion weights, the most suitable technologies for flood management in Southern and North-eastern Bangladesh are *Floating Agriculture*, *Water and Salinity Tolerant Varieties*, and *Capacity Building and Awareness Creation*. This appears very interesting as the implementation of the *Floating Agriculture* is widely adopted by communities in the study areas (Irfanullah *et al.*, 2011; Chowdhury and Moore, 2015). Besides, results showed that *Floating Agriculture* is assumed to have a low direct implementation and maintenance cost (Figure 3). The use of the improved crop varieties, ranked to be the most accepted technology by communities in the study area (Figure 3), is a mechanism employed by farmers to adjust to flooding and sustain productivity during flood periods (Rasid, 1993; Hossain *et al.*, 2006).

Figure 3: Radar graphs showing the standardized scores of each adaptation technology against each selected criterion



Capacity Building and Awareness Creation, achieved by both local and modern means, helps protect and prevent flood damages (Agrawala *et al.*, 2003; Sarker and Hasan, 2011), and is apparently the most effective in reducing vulnerability to flood (Figure 3).

However, the result of the prioritization process shows an aggregative figure of the suitability of adaptation technologies because the process of MCA used in this study was partial and limited to the judgment of a number of experts, out of which few have local experience. In addition, the broad scope of the study area did not allow a site-specific result which could improve the accuracy of the findings.

Results from Table 2 and 3 pointed out that the process of technology scoring and weight assignment to criteria is subjective as stakeholders may have different preferences. Therefore, as suggested by different scholars (Haque *et al.*, 2010; Trærup and Bakkegaard, 2015), a sensitivity analysis is required to incorporate the uncertainty that could be linked to stakeholders' preferences or arise from different scenarios. This analysis, which assesses how sensitive is the result to the variation of criteria weights or technology scores, was not performed under this study.

Referring to the requirements of strategies' adoption under the IFM approach (APFM, 2009), it is important to mention that a mix of two or more technologies might be more suitable and effective in dealing with floods than the mere use of a single one.

Table 4: Ranking list of the suitability of adaptation technology options for flood management in the agricultural sector in Southern and North-Eastern Bangladesh

Technology options	**Total weighted score**	**Rank**
Floating agriculture	65.29	1
Water and salinity tolerant varieties	65.25	2
Capacity building and awareness creation	63.61	3
Flood Control, Drainage and Irrigation (FCDI) schemes	57.44	4
Structural barriers against water intrusion	50.29	5

5 Conclusions, Outlook, and Recommendations

Five adaptation technologies were identified for flood management in Southern and North-Eastern Bangladesh, namely *Floating Agriculture*, *Structural Barriers against Water Intrusion*, *Water and Salinity Tolerant Varieties*, *Flood Control*, *Drainage and Irrigation* (FCDI) schemes, and Capability Building and Awareness creation. Two of them, *Floating Agriculture* and *Structural Barriers against Water Intrusion* were discussed in more detail to show their impacts on the agricultural sector.

Floating Agriculture, a traditional agriculture system mostly used in water logged area in Bangladesh, appeared to give higher agricultural yield. The practice is economically viable as it involves less production cost and higher returns. Besides its economic importance, communities in Bangladesh widely adopted this technique because it is part of their tradition and culture. Therefore, *Floating Agriculture* can help farmers to increase their income, generate employment opportunities for both men and women, and overall reduce poverty in the flood prone and wet land areas of Bangladesh. However, land property right, lack of technical knowledge and weak transportation infrastructure inhibit its rapid spread and implementation.

The second adaptation technology, which was discussed in detail, was *Structural Barriers against Water Intrusion*. These barriers in Bangladesh were usually embankments and identified one of the most common measure against flooding, spread all over Bangladesh. Embankments, if built properly, help raise the yield and protect the lives and livelihood of farmers. But, especially if maladapted or damaged, structural barriers can also create great ecological, economic, and social harm to the area protected by the embankments and even other places.

The partial MCA enabled the identification of *Floating Agriculture*, *Water and Salinity Tolerant Varieties*, and *Capacity Building and Awareness Creation* as the most suitable technologies for flood management in the study area. This adaptive framework integrated multidimensional criteria (social, politic, economic, and environmental) and experts' preferences in the process of prioritizing the five adaptation technologies used for flood management. If fully completed, by involving most of the stakeholders and their preferences, the prioritisation of technologies could serve as decision making platform for policy makers. The latter could help decide the most immediate technology option to be implemented for flood management since not all the measures can be undertaken at the same time.

Based on the results of this study, we recommend the following:

- The dissemination and scaling-up of the practice of *Floating Agriculture* along with the required technical assistance by the Department of Agricultural Extension (DAE) or local NGOs;
- Government may also take steps to ensure the security and rights of smallholder farmers in practicing *Floating Agriculture* in the public or government areas;
- The avoidance of the construction of new embankments because the unforeseen consequences negatively affect farmers' livelihood, and their benefits are rather small in comparison to the disadvantages;
- The redesign of existing barriers to be regulative instead of cutting off completely the water to reduce the probability of dangerous flash floods and allow additional opportunities for farming and fertilizing;
- Considering this study as starting point, further research including most of the local stakeholders and a specific site should be carried out to complete and extent the scope of the MCA process, in order to improve the reliability of the findings. To this end, the integration of sensitivity analysis, climate change scenarios, and vulnerably framework to the MCA process are suggested;
- Further research to investigate ways of including in the MCA approach a frame that considers various options of combining adaptation technologies should also be carried out.

6 Limitations

We acknowledge that the time limitation restricted our literature review. Moreover, the limit on the number of pages meant we had to reduce the description of technologies and the use of figures. Both the time and space restrictions also compelled us to select just two of the technologies for in-depth description.

For the MCA, we could only base our criteria on the literature review, as collecting field data was not possible. This also meant that no local stakeholders, for example farmers and experts, were able to participate in the process, a step very important for the results of the MCA (Trærup and Bakkegaard, 2015). Thus, we called it a partial MCA, and we discussed the results accordingly.

7 Acknowledgements

We would like to kindly thank our tutors at ZEF during the entire research process, namely the Senior Researchers Dr. Daniel Callo-Concha, Dr. Saravanan Subramanian, Dr. Djiby Racine Thiam, and Dr. Bernhard Tischbein. Their comments, suggestions, and promptness in helping and filling out the Technical Fact Sheets (TFS) were of great importance. A special thanks to our colleagues Till Ludwig and Monirul Hassan, who lent us their expertise on Bangladesh.

8 References

Adaptation Knowledge Platform (AKP). 2010. "Scoping Assessment on Climate Change Adaptation in Bangladesh." Bangkok: Regional Climate Change Adaptation Knowledge Platform for Asia. http://www.climateadapt.asia/upload/publications/files/4d81c35109ddfScoping_Assessment_on_Climate_Change_Adaptation_in_Bangladesh.pdf, accessed October 26, 2015.

Agrawala, S., T. Ota, A. U. Ahmed, J. Smith, and M. van Aalst. 2003. "Development and Climate Change in Bangladesh: Focus on coastal flooding and the Sundarbans." OECD, Paris.

Ahasan, M. N., M. A. M. Chowdhary, and D. A. Quadir. 2010 "Variability and trends of Summer Monsoon rainfall over Bangladesh." Journal of Hydrology and Meteorology 7 (1): 1–17.

Ahmed, F., M. Y. Rafii, M. R. Ismail, A. S. Juraimi, H. A. Rahim, R. Asfaliza, and M. A. Latif. 2012. "Waterlogging tolerance of crops: breeding, mechanism of tolerance, molecular approaches, and future prospects." BioMed research international (2013): 1–10.

Alam, M. S., M. A. Quayum, and M. A. Islam. (2010), "Crop Production in the Haor Areas of Bangladesh: Insights from Farm Level Survey." The Agriculturists 8 (2): 88–97.

Al-Emran, S., A. Jahan, G. M. A. Mahdi, and S. Chakma. 2014. "Vulnerability and Coping Strategies of Floods in Bangladesh Agriculture." ASA University Review 8 (2): 50–69.

Alexander, M. J., M. S. Rashid, S. D. Shamsuddin, and M. S. Alam. 1998. "Flood Control, Drainage and Irrigation Projects in Bangladesh and their Impacts on Soils: An empirical study." Land Degradation and Development, 9 (3): 233–246.

Ali, M. L.. 2002. "An Integrated Approach for the Improvement of Flood Control and Drainage Schemes in the Coastal Belt of Bangladesh". Wageningen University. The Netherlands.

Andreasen, H. M.. 2011. "Struggling to Survive, or Adapting for the Future: Understanding Climate Change Problems, Responses and Capacities from the Perspective of Farmers, Fishermen and Workers in Rural Bangladesh." Roskilde University. Roskilde, Denmark.

Asaduzzaman, M. 2004. "Floating Agriculture in the flood-prone or submerged areas in Bangladesh (Southern regions of Bangladesh)." Asia-Pacific Environmental Innovation Strategies (APEIS), Research on Innovative and Strategic Policy Options (RIPSO), Good Practice Inventory. http://enviroscope.iges.or.jp/contents/APEIS/RISPO/inventory/db/pdf/0146.pdf, accessed November 12, 2015.

Asaduzzaman, M.. 2009. "Getting Agriculture Moving Again: Strategic Options for Post-HYV Agriculture in Bangladesh." DFID, Bangladesh.

Asian Development Bank (ADB), 2014. "Technologies to support climate change adaptation in Developing Asia." Mandaluyong City, Philippines: Asian Development Bank. ISBN 978-92-9254-803-2.

Asian Disaster Preparedness Centre (ADPC). 2004. "Channels of Communication - a Challenge: Public Awareness for Flood Preparedness in Bangladesh." http://www.alnap.org/resource/7554, accessed November 27, 2015.

Associated Programme on Flood Management (APFM). 2007. "Economic Aspects of Integrated Flood Management". APFM Technical Document No. 5, Flood Management Policy Series. World Meteorological Organization (WMO), No. 1010.

Associated Programme on Flood Management (APFM). 2009. "Integrated Flood Management: Concept Paper". World Meteorological Organization (WMO), No. 1047.

Bangladesh Bureau of Statistics (BBS). 2014. "Yearbook of Agricultural Statistics-2012, Planning Division." Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka. http://www.bbs.gov.bd/WebTestApplication/userfiles/Image/LatestReports/AgriYearbook-2012.pdf, accessed October 26, 2015.

Bangladesh Water Development Board (BWDB). 1997. "Water Management in Flood Control and Drainage System in Bangladesh". System Rehabilitation Project, Technical Report No. 50, Dhaka, Bangladesh.

Bangladesh Water Development Board (BWDB). 2014. "Annual Flood Report 2014." Flood Forecasting and Warning Centre. http://www.ffwc.gov.bd/images/annual14.pdf, accessed 26 October 26, 2015.

Brammer, H.. 2010. "After the Bangladesh Flood Action Plan: Looking to the future." Environmental Hazards, 9 (1): 118–130.

Choudhury N. Y., A. Paul., and B.K. Paul. 2004. "Impact of Costal Embankment on the Flash Flood in Bangladesh: A Case Study." Applied Geography 24 (3): 241–258. doi:10.1016/j.apgeog.2004.04.001.

Chowdhury R. B., and G. A. Moore. 2015. "Floating Agriculture: A Potential Cleaner Production Technique for Climate Change Adaptation and Sustainable Community Development in Bangladesh." Journal of Cleaner Production. doi:10.1016/j.jclepro.2015.10.060. Http://www.sciencedirect.com/science/article/pii/S0959652615015279, accessed November 27, 2015.

Christiansen L., A. Olhoff, and S. Trærup (Eds.). 2011. "Technologies for Adaptation: Perspectives and Practical Experiences." Roskilde, Demark: UNEP Risø Centre Roskilde. https://ipcc-wg2.gov/njlite_download2.php?id=11174, accessed November 27, 2015.

Ehlert, J.. 2012. Beautiful Floods – Environmental Knowledge and Agrarian Change in the Mekong Delta, Vietnam. Vienna, Austria: LIT Verlag.

FAO, 2001. "Early Warning, Prevention, Preparedness and Management of Disasters in Food and Agriculture", Organization of the United Nations Regional Office for Asia and the Pacific, Conference in Chiangmai, Thailand.

FAO, 2014. "Towards Sustainable Agriculture and Improved Food Security & Nutrition." http://www.fao.org/3/a-i4236e.pdf, accessed on November 20, 2015.

FAOSTAT. 2015. "Database of the Food and Agriculture Organization of the United Nations." http://faostat.external.fao.org, accessed November 25, 2015.

Flick, U., E. von Kardorff, and I. Steinke (Eds.). 2000. Qualitative Forschung. Hamburg, Germany: Rowohlt Taschenbuch Verlag

Grothmann, T., and A. Patt. 2005. "Adaptive Capacity and Human Cognition: The Process of Individual Adaptation to Climate Change." Global Environmental Change 15 (3): 199–213. doi:10.1016/j.gloenvcha.2005.01.002.

Haq, A. H. M. R., T. K. Ghosal, and Ghosh, P.. 2004. "Cultivating wetlands in Bangladesh." Leisa Magazine 20 (4): 18–20. http://waswc.soil.gd.cn/subjects/wetlands/Cultivating%20wetlands%20in%20Bangladesh,%20a%20Leisa%20paper%20070831.pdf, accessed on November 05, 2015.

Haque, S. A.. 2006. "Salinity problems and crop production in coastal regions of Bangladesh." Pakistan Journal of Botany, 38 (5): 1359–1365.

Haque, N. A., S. Grafakos, and M. Huijsman. 2010. "Assessment of adaptation measures against flooding in the city of Dhaka, Bangladesh." IHS working paper 25.

Hassan, A. W. R., and A. K. Das. 2015. "Social Issues: Occupation Change and Food Security in Bangladesh." In Food Security and Disaster Risk Reductions in Bangladesh, edited by U. Habiba, M. A. Abedin, A. W. R. Hassan, and R. Shaw, 53–63. Japan: Springer. doi:10.1007/978-4-431-55411-0_4

Hofer, T., and B. Messerli. 2006. Floods in Bangladesh: history, dynamics and rethinking the role of the Himalayas. Tokyo, Japan: United Nations University Press.

Hossain, A. N. H. A.. 2003. "Integrated Flood Management Case Study - Bangladesh: Flood Management." http://www.alnap.org/resource/9430, accessed November 27, 2015.

Hossain, M., M. L. Bose and B. A. A. Mustafi. 2006. "Adoption and productivity impact of modern rice varieties in Bangladesh." The Developing Economies 44 (2): 149–166.

Hossain, M. Z., and T. Sakai. 2008. "Severity of Flood Embankments in Bangladesh and Its Remedial Approach." CIGR Ejournal, 2008. http://agris.fao.org/agris-search/search.do?recordID=US201301545317, accessed November 27, 2015.

Hutton, C. W., C. T. Hill, and M. J. Clark. 2015. Modified Sustainable Livelihoods Framework (MSLF): A tool for monitoring and assessing GIAHS sites. Southampton, UK: University of Southampton.

Huu, P. C.. 2012. Floods and Farmers – Politics, Economics and Environmental Impacts of Dyke Construction in the Mekong Delta/ Vietnam. Vienna, Austria: LIT Verlag.

Irfanullah, H. M., A. Nishat, and R. Ahmed. 2005. "Baira: The Floating Gardens for Sustainable Livelihood." IUCN-The World Conservation Union, Bangladesh Country Office.

Irfanullah, H. Md.. 2013. "Floating Gardening: A Local Lad Becoming a Climate Celebrity?" Clean Slate 88: 26–27.

Irfanullah, H. Md., Md. A. K. Azad, Md. Kamruzzaman, and Md. A. Wahed. 2011. "Floating Gardening in Bangladesh: A Means to Rebuild Lives after Devastating Flood." Indian Journal of Traditional Knowledge 10 (1): 31–38.

Islam, M. N.. 2000. "Embankment Erosion Control: Towards Cheap and Simple Practical Solutions for Bangladesh." 2nd International Conference on Vetiver (ICV2): 307–321. http://prvn.rdpb.go.th/files/CP-3-1.PDF, accessed November 27, 2015.

Islam, N.. 2001. "The Open Approach to Flood Control: The Way to the Future in Bangladesh." Futures 33 (8–9): 783–802. doi:10.1016/S0016-3287(01)00019-2.

Islam, T., and P. Atkins. 2007. "Indigenous Floating Cultivation: A Sustainable Agricultural Practice in the Wetlands of Bangladesh." Development in Practice 17 (1): 130–136.

Kabir, M. R., and I. M. Faisal. 1999. "Indigenous practice for water harvesting in Bangladesh." in Proceedings of the Regional Workshop on Traditional Water Harvesting System, Tehran, Iran. http://www.uap-bd.edu/ce/tech_bulletinn&journal/TechBull/KabirSir.pdf, accessed November 27, 2015.

Karim, M. F., and N. Mimura. 2008. "Impacts of climate change and sea-level rise on cyclonic storm surge floods in Bangladesh." Global Environmental Change 18: 490–500. doi:10.1016/j.gloenvcha.2008.05.002

Mallick, D. L., A. Rahman, M. Alam, A. S. Md. Juel, A. N. Ahmad, and S. S. Alam. 2005. "Case Study 3: Bangladesh Floods in Bangladesh: A Shift from Disaster Management Towards Disaster Preparedness." IDS Bulletin 36 (4): 53–70. doi:10.1111/j.1759-5436.2005.tb00234.x.

Ministry of Environment and Forests (MoEF). 2005. National Adaptation Programme of Action (NAPA). Final report. Dhaka, Bangladesh. http://unfccc.int/resource/docs/napa/ban01.pdf, accessed October 26, 2015.

Mirza, M. Q., and N. J. Ericksen. 1996. “Impact of Water Control Projects on Fisheries Resources in Bangladesh.” Environmental Management 20 (4): 523–539.

Myaux, J. A., M. Ali, J. Chakraborty, and A. de Francisco. 1997. “Flood Control Embankments Contribute to the Improvement of the Health Status of Children in Rural Bangladesh.” Bulletin of the World Health Organization 75 (6): 533–539.

Normile, D.. 2008. “Reinventing Rice to Feed the World.” Science 321: 330–333.

Ortiz, C. A. C.. 1994. “Sea-Level Rise and Its Impact on Bangladesh.” Ocean & Coastal Management 23: 249–270.

Pantanella E., M. Cardarelli, P. P. Danieli, A. MacNiven, and G. Colla. 2011. “Integrated Aquaculture - Floating Agriculture: Is It a Valid Strategy to Raise Livelihood.” Acta Horticulturae 921: 79–86. doi:10.17660/ActaHortic.2011.921.9.

Paul, B. K.. 1997. “Flood Research in Bangladesh in Retrospect and Prospect: A Review.” Geoforum 28 (2): 121–131. doi:10.1016/S0016-7185(97)00004-3.

Pavel, M. A. A., M. A. Chowdhury, and M. A. A. Mamun. 2014. “Economic evaluation of floating gardening as a means of adapting to climate change in Bangladesh.” International Journal of Environmental Studies 71 (3): 261–269. doi:10.1080/00207233.2014.911406.

Quddus, M. A.. (2009). “Crop production growth in different agro-ecological zones of Bangladesh.” Journal of the Bangladesh Agricultural University 7 (2): 351–360.

Rabbani, G., A. A. Rahman, and N. Islam. 2010. “Climate Change and Sea Level Rise: Issues and Challenges for Coastal Communities in the Indian Ocean Region.” In Coastal Zones and Climate Change, edited by D. Michel, and A. Pandya, 17–29. Washington, DC, USA: The Henry L. Stimson Centre.

Rahman T., and K. H. Kabir. 2013. “Effects of Embankments on the Habitation of the Southwestern Coastal Region of Bangladesh.” Asian Journal of Environment and Disaster Management, 5 (1): 65–80. doi:10.3850/S179392402013001774.

Rahman, M. A., and S. Rahman. 2015. “Natural and traditional defense mechanisms to reduce climate risks in coastal zones of Bangladesh.” Weather and Climate Extremes 7: 84–95.

Rasid, H.. 1993. “Preventing Flooding or Regulating Flood Levels?: Case Studies on Perception of Flood Alleviation in Bangladesh.” Natural Hazards 8 (1): 39–57. doi:10.1007/BF00596234.

Saha, S. K.. (2010). “Soilless Cultivation for Landless People: An Alternative Livelihood Practice through Indigenous Hydroponic Agriculture in Flood-prone Bangladesh.” Beppu: Ritsumeikan Asia Pacific University.

Sarker, P., and M. Hasan. 2011. “ICTs and Environmental Sustainability: Mapping National Policy Contexts – Bangladesh Baseline Study,” http://idl-bnc.idrc.ca/dspace/handle/10625/49323, accessed November 27, 2015.

Schware, R.. 1982. “Official and Folk Flood Warning Systems: An Assessment.” Environmental Management 6 (3): 209–216. doi:10.1007/BF01866884.

Southgate, R.J., C. Roth, J. Schneider, P. Shi, T. Onishi, D. Wenger, W. Amman, I. Ogallo, J. Beddington, and V. Murray. 2013. “Using Science for Disaster Risk Reduction.” UNISDR Scientific and technical advisory Group. http://preventionweb.net/go/32609, accessed October 27, 2015.

Sterrett, C.. 2011. “Review of Climate Change Adaptation Practices in South Asia.” Oxfam Policy and Practice: Climate Change and Resilience 7 (4): 65–164. http://www.oxfam.org/en/grow/policy/review-climate-change-adaptation-practices-south-asia, accessed on November 25, 2015.

Talukder, B., and D. Shamsuddin. 2012. “Environmental Impacts of Flood Control Drainage and Irrigation (FCDI) Projects in a Non-Irrigated Area of Bangladesh: A Case Study.” Journal of Transdisciplinary Environmental Studies 11 (2): 17–36.

Thompson, P. M., and P. Sultana. 1996. “Distributional and Social Impacts of Flood Control in Bangladesh.” The Geographical Journal 162 (1): 1–13.

Trærup, S., and R. K. Bakkegaard. 2015. “Evaluating and prioritizing technologies for adaptation to climate change. A hands on guidance to multi criteria analysis (MCA) and the identification and assessment of related criteria.” UNEP DTU Partnership, Copenhagen.

Turner, B. L., and A. S. Ali. 1996. “Induced intensification: Agricultural change in Bangladesh with implications for Malthus and Boserup.” Proceedings of the National Academy of Sciences, 93 (25): 14984-14991.

UNFCCC. 2005. “Report on the seminar on the development and transfer of technologies for adaptation to climate change”. United Nations Framework Convention on Climate Change, Subsidiary Body for Scientific and Technological Advice. Bonn, Germany.

UNFCCC. 2006. “Technologies for adaptation to climate change.” United Nations Framework Convention on Climate Change. Bonn, Germany. http://unfccc.int/resource/docs/publications/tech_for_adaptation_06.pdf, accessed November 25, 2015.

UNFCCC. 2014. “Technologies for Adaptation in the Agriculture Sector”. TEC Brief #4. United Nations Framework Convention on Climate Change. Bonn, Germany.

Venton, C. C., and S. Majumder. 2013. “The Economics of Early Response and Resilience: Lessons from Bangladesh.” Government of the United Kingdom, Department for International Development. London. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/226156/TEERR_Bangladesh_Report.pdf, accessed November 25, 2015.

Webster P. J.. 2013. “Improve weather forecasts for the developing world.” Nature 493, 17–19. doi:10.1038/493017a.

World Bank. 2014. World Development Indicators Online (WDI) database. World Bank Development indicators. http://data.worldbank.org, accessed on November 24, 2015.

Younus, M. A. F.. 2012. “Autonomous Crop Adaptation Processes to Extreme Floods: A Case Study in Bangladesh.” In Water and Climate: Policy Implementation Challenges: Proceedings of the 2nd Practical Responses to Climate Change Conference, edited by K. A. Daniell, 124–131. Barton, A.C.T.: Engineers Australia.

Younus, M. A. F.. 2014. “Flood Vulnerability And Adaptation To Climate Change In Bangladesh: A Review.” Journal of Environmental Assessment Policy and Management 16 (3): 1450024.

Younus, M., and N. Harvey. 2014. “Economic Consequences of Failed Autonomous Adaptation to Extreme Floods: A Case Study from Bangladesh.” Local Economy 29 (1): 20–35.

Zaman, M. Q. 1993. “Rivers of Life: Living with Floods in Bangladesh.” Asian Survey 33 (10): 985–996. doi:10.2307/2645097.

Zhu, X., M. M. Linham, and R.J. Nicholls. 2010. Technologies for Climate Change Adaptation: Coastal erosion and flooding. TNA Guidebook Series. UNEP/GEF. New Delhi, India: Magnum Custom Publishing.

9 Annexes

9.1 Annex 1: Technology Fact Sheet (TFS)

Technology	
Technology characteristics	
Introduction	
Technology characteristics/highlights	
Institutional and organizational requirements	
Operation and maintenance	
Endorsement by experts	
Adequacy for flood management	
Scale/Size of beneficiaries group	
Disadvantages	
Capital costs	
Cost to implement the adaptation technology	
Development impacts, direct and indirect benefits	
Reduction of vulnerability to flood events, indirect	
Environmental benefits, indirect	
Local context	
Opportunities and Barriers	
Market potential	
Status	
Timeframe	
Acceptability to local stakeholders	

9.2 Annex 2: Individual Expert Scoring Sheet for Technology Suitability Assessment in the frame of the study entitled: "*Coping with the Floods - Evaluation on Adaptation Technologies for Agriculture in Bangladesh*"

In order to identify the most suitable adaptation technologies (prioritization) for flood management in Bangladesh, a "partial Multi Criteria Analysis (MCA)" was undertaken. This MCA analysis was partial because local stakeholders (local communities and experts) could not be involved in the process.

MCA involves several stages including mainly: the identification of the adaptation technologies and the criteria, the ranking of the technologies and the assignment of weigh to the criteria. The two latter stages are achieved through the reliance on well knowledgeable experts for the evaluation of the technologies.

This individual expert scoring sheet was elaborated to kindly request expert to evaluate the adaptation technologies selected in the frame of this study based mainly on their judgement. It also serves as guidelines for accompanying experts throughout the scoring process. Based on the selected criteria categories along with their scoring scale (Table 1), the ranking scores table (Table 2) and their knowledge, experts are required to assign a given score to each technology in the decision matrix for MCA (Table 4). In the decision matrix, each row describes a technology option and each column describes the performance score of the options against each criterion. Besides, some more details are provided on the identification and assessment of the criteria in Table 1 and Fig.1 (exhaustive information are found in the paper "Evaluating and prioritizing technologies for adaptation to climate change, pp 16-28" which will be shared as attachment). Technology fact sheets (TFS), which briefly describe each technology, will be circulated to all experts for familiarization with the technology options (in attachment). Furthermore, experts are requested to assign weight to each criterion based on their own judgement of the relative importance of the criterion in this very specific context of flood management in Bangladesh (Table 3). The sum of all weights should total 100%.
Thank you so much for spending your time and filled out the 2 major tables (3 and 4).

Table 1. Criteria for MCA for prioritization of adaptation technologies for flood management in agriculture sector in Bangladesh

Criteria category	Criteria	Scoring scale	More details
Institutional and Implementation barriers	Ease of implementation	0: very difficult to 100: very easy	Expertise requirement; time of implementation, labour power
	Use and maintenance	0: very difficult to 100: very easy	Availability of equipment and technical assistance, Skill requirement
Economic	Costs: Direct costs for the implementation and maintenance of the adaptation technology	0: very high to 100: very low	Capital cost per unit of technology (for the supply of salinity-tolerant varieties); cost of installation
	Improving farmers income	0: very low to 100: very high	Changes in damages to value of economic activity
Environmental / Ecological	Contribution of the technology to protect against floods (to what extent the technology will help build resilience against flood damages)	0: very low to 100: very high	Biodiversity protection (number of ha protected, number of local seed variety, quality of natural habitats)
	Enhancement of ecological condition (protection of environmental resources)	0: very low to 100: very high	Reduced soil erosion, runoff; Reduced area of land lost or degraded due to inundation and salinity; Water and air quality
Social	Contribution of the technology to social and sustainable development (benefit to society and people well-being)	0: very low to 100: very high	Reducing poverty (no. of jobs created, no. of hh with access to clean water, changes in asset wealth); Reduction in inequity, degree of community acceptance
	Degree of Community Acceptance	0: very low to 100: very high	Influenced by impact on tradition and culture, and perceptions of community members -> Effect on the "Lebenswelt"
Political	Coherence of the technology with national development policy and priority; political acceptance for the adaptation technology	0: very low to 100: very high	Degree of coherence with national adaptation plan and development goals, Number of laws and regulations supporting technology

Table 2: Ranking scores for the performance of each technology in the matrix

Score	General description
0	Used when information on a technology does not apply to the particular criteria
1-20	Extremely weak performance; strongly unfavourable
21-40	Poor performance, major improvement needed
41-60	At an acceptable or above level
61-80	Very favourable performance, but still needing improvement
81-100	Clearly outstanding performance which is way above the norm

Table 3: Weighing of the criteria based on their relative importance in the case of flood management in Bangladesh*

No.	Criterion	Weight (%)
1	Ease of implementation	
2	Use and maintenance	
3	Costs: Direct costs for the implementation and maintenance of the adaptation technology	
4	Improving farmers income	
5	Contribution of the technology to protect against floods (to what extent the technology will help build resilience against flood damages)	
6	Enhancement of ecological condition (protection of environmental resources)	
7	Contribution of the technology to social and sustainable development (benefit to society and people well-being)	
8	Degree of Community Acceptance	
9	Coherence of the technology with national development policy and priority; political acceptance for the adaptation technology	
	Total	**100**

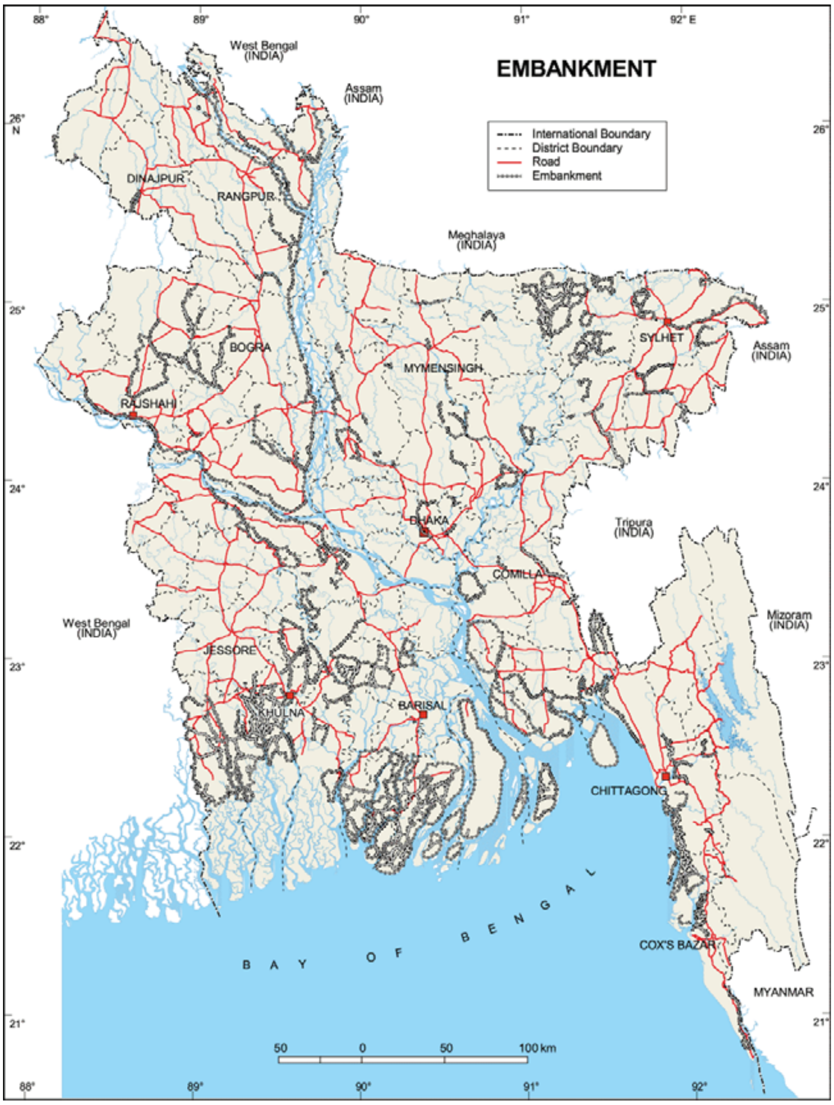
*The weight assignment exercise should be based on the expert judgement of the importance of each criterion

Table 4. Decision matrix for MCA*

Technologies/Criteria	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6	Criterion 7	Criterion 8	Criterion 9
Floating agriculture/gardening									
Structural barriers against water intrusion									
Flood and salinity tolerant varieties									
Flood Control, Drainage and Irrigation (FCDI) schemes									
Capacity building and planning for flood occurrence and variability									

*Based on the ranking scores for the performance of each technology (table 2) and their quantitative expert judgement, experts are requested to assign a given score to each technology

9.3 Annex 3: Embankments in Bangladesh



Source: http://www.bpedia.org/