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Analyzing the Sufficiency of Adaptation Options in Combating Climate Vulnerability in Bangladesh

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Authors' contributions

This work was carried out in collaboration between both authors. Author MRK managed the literature searches, structured the article, designed framework and wrote the first draft of the manuscript. Author MEBA grammatically corrected and edited this article. Both authors read and approved the final manuscript.

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ABSTRACT

Adaptation comprises one of the pertinent issues related to climate vulnerable countries like Bangladesh. Bangladesh is particularly vulnerable to the adverse effects of climate change with its manifestations being felt every year in the form of various natural disasters such as cyclones, floods, riverbank erosions, droughts, and salinity as a result of global warming. Predications indicate Bangladesh as the most vulnerable country in the world susceptible to climate change related disasters in the 21st century. This article therefore aims at providing an analysis on climate change vulnerability and fifteen (15) climate adaptation options adopted locally in the disaster prone areas of Bangladesh. The climate policy of Bangladesh is aimed at developing stable climate change strategies in order to achieve the sustainable development goal which forms a great of the vision 2021. The Government of Bangladesh together with some NGOs have committed to implementing different external climate change adaptation programmes. However, their climate adaptation strategies have been applied on a limited scale. Furthermore, the adaptive capacity of the indigenous practice is not strong enough to cope with shocks in the long run; especially natural disasters. Additionally, migration of affected people from disaster prone areas

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has been identified as an option not viable enough to sustain their livelihoods. Various initiatives (government including some NGO bodies) have been undertaken on the part of with the objective of motivating farmers to adopt new technological change. Some of them include: the introduction of flood and drought tolerance crop varieties. However, the extent to which farmers perceived these tolerant crop varieties was limited resulting in their poor adoption; as a result of poor knowledge, lack of input support and low information access. This report further suggests the need to determine the effectiveness of different adaption practices that were undertaken to combat climate change. In addition, a suggested framework consisting of the models of vulnerability, adaptation techniques and strategies to effectively diffuse climate change sensitive knowledge, skill and practices would be relevant for different stakeholders involved in the climate change debate to implement further climate change policies in Bangladesh.

Keywords: Climate vulnerability; adaptation options; sufficiency; Bangladesh.

1. INTRODUCTION

Bangladesh usually termed 'the land of rivers' is made up of a low-lying flat topography. It is frequently cited as one of the most climate vulnerable countries in the world [1,2,3]. The country is situated at the interface of two geographical conditions, with the Himalayas to the north and the Bay of Bengal to the south. This peculiar geographical location has resulted in its increased vulnerability to disasters, particularly, the southern region which is most likely to experience devastating coastal cyclones, and the northwest region which suffers from the recurrence of droughts [4]. As such, global warming is expected to increase the intensity and frequency of natural disasters in the next century [5].

According to the predictions set out by the IPCC [6], the global temperatures are expected to rise between 1.8℃ and 4.0℃ towards the last decade of the 21st century. In a similar way, forecasts indicate that sea levels in Bangladesh will rise to 10 cm, 20 cm and 1.0 m by the years 2020, 2050, and 2100 and are expected to cause respective loses of 2%, 4% and17.5% in the total land mass. Predictions of the Organization of Economic Cooperation and Development [7] indicate that a one meter rise in sea level would inundate the coastal region which comprises 18% of total land mass of Bangladesh. Additionally, low levels of rainfall, high temperatures and high evaporation rates in hottest season increases the vulnerability of the north-western region to severe drought [8]. On the other hand, the occurrence of severe flood is caused by precipitation during rainy season. The end result of these recurrent floods is felt through the dangerous riverbank erosion. Salinity in the coastal region is caused by the back water effect of the Bay of Bengal [1].

Bangladesh faces at least one major disaster in every year and has lost on average 3.02% of its GDP per year over the last 10 years. As such, it has recorded the highest disaster mortality rate in the world [9]. Bangladesh has been ranked 1st position within the context of tropical cyclone vulnerability, and is the 6th flood prone country in the world causing an average of 200 deaths per year [10]. Tropical cyclones attack the country on an average every three years due to increasing the sea surface temperature. It occurs with high wind speeds over 150 kilometers per hour and causes storms which surge up to 7 meters high [4,10]. Rising global temperatures lead to rising sea levels which in effect causes a back water effect. The back water flow from the Bay of Bengal to coastal river causes salinity invasion into the crop fields. Statistics indicate that approximately 2.8 million hectares of the country's coastal soil has been already affected by salinity triggered bythe back water effect [1].

Although the normal rainfall is often considered as blessing for agriculture in Bangladesh, but excessive rainfall seems disastrous. This coupled with the low-lying topography affects majority of the river basin area of the country which constantly suffers from the incidence of flood. The high magnitude floods inundate large areas and cause devastating damages of properties, as well as rising deaths of children and women [1]. The flooded areas at different times varied between 31% to 85% of the total land of Bangladesh [9,10]. During the last decade, devastating floods occurred in 2007, with inundated 32,000 square kilometers of land areas. Its damages were felt in the destruction of 85,000 houses, crop damages amounting to almost 1.3 million acres and the death of 649 people. The total loss in the 2007 flooding is estimated to amount to over $ 1.0 billion [10].

During the peak of rainy season, most of the rivers regions normally overflow resulting in massive erosion. River bank erosion affects millions of people each year, and destroys homestead, infrastructures, standing crops and farmland. About 5% of the country is directly affected by erosion, with its immediate impact being the displacement of people. A household suffered riverbank erosion 2.33 times in the lifetime of its members, meanwhile some other families experienced displacements 4-5 times or more [1]. Immediate shelter is established to nearby flood embankments, most of which are densely populated due to the consequence of continuous erosion [11]. Displaced people are only capable of staying in temporary constructed dormitories made out of bamboo and straw. The main areas of migration for the affected people due to erosions include nearby cities or the capital city with the aim of finding options to sustain their livelihood [1].

Low levels of precipitation, high temperatures and high evaporation rates make the north-western region more vulnerable to severe drought [8]. The occurrence of droughts in Bangladesh is a seasonal problem which affects the northwestern region due to low rainfall patterns. Its consequences are felt in poor agricultural crop yields which turn cause hardship to poor laborers and eventually unemployment leading to periods of seasonal food crisis locally referred to as *Monga* [10]. Rice production losses due to droughts in 1997 totalled about 1 million tons and valued at around $US 500 million [5]. In addition, predictions show that within the next two decades, moderately drought prone areas will be developed into severe drought affected areas [5].

The largest threat to the ecology and biodiversity of Bangladesh to come will be global climate disruption due to the buildup of human-generated activities. People around the world are beginning to address the problem by reducing their carbon footprint through less consumption and better technology. But unsustainable human population growth can overwhelm those efforts, leading us to conclude that we not only need smaller footprints, but fewer feet.

1.1 Socio-economic Impacts of Climate Change in Different Sectors of Bangladesh

Climate change impacts have far reaching socio-economic effects on different sectors in Bangladesh. Natural disasters especially in the form of cyclones, storm surge, destructive floods, and river bank erosion damage key socio-economic infrastructures such as: embankments, schools, hospitals, religious and cultural monuments [1]. Between the years 1970 and 1991, tropical cyclones occurred causing deaths of approximately 500, 000 and 138, 000, respectively [4,10]. Sudden failures in the riverbank have been damaging standing crops and floating crop lands with saline water [12]. During cyclones or floods, the management of water becomes particularly difficult on the part of the affected people. Shortage of safe water is seen as an acute problem, especially in coastal region due to salinity. Drinking water containing saline salt leads to health hazards. On the other hand, floods cause the outbreak of epidemic water borne diseases such as: diarrhea, malaria, cholera, dengue fever, which account for the majority of children's deaths. [13].

Women, children and old-aged people are most likely to be become more vulnerable to natural disaster. Women face specific constraints during natural hazards like inadequate access to basic services such as: shelter relocation, extra burden for water and fuel collection, and increased intensity of violence [14]. There are limited movements for Women, children and old-aged group during disasters which eventually increase deaths amongst them. Also, due to natural disasters, women lose property rights following the deaths of their fathers or husbands. The families of households headed by women are most vulnerable after disaster because of their low economic status and social power. Majority of the women face skin borne diseases and reproductive health-related problems because of prolonged exposure to dirty water. Women in salinity prone areas are frequently suffering from miscarriages because of drinking saline water [15].

Approximately 15.18 million of farm households and over 47.5% people in the country directly depend on agriculture, which engages approximately 60% of the total labor force [16]. Agriculture is extremely vulnerable to water stress, changing rainfall patterns, increased flood intensity, and salinity in coastal areas. Every year, perennial trees, standing crops and livestock are destroyed by floods and riverbank erosion. Rainfall and temperature fluctuations increase the disease-pest infestation in the most field crops. About 25% of food grains are lost in fields and storages because of severe pest

attacks [5]. According to IPCC predictions, rice production in Bangladesh could fall by 8% and wheat by 32% by 2050 due to water scarcity, which could lead to serious food insecurity in the future [10,17].

1.2 National Climate Change Strategy and Action Plan

The Government of Bangladesh has published the Bangladesh Climate Change Strategy and Action Plan (BCCSAP)-2009 in consultation with civil society, NGOs, research organizations, the private sector and the development partners. This plan is illustrated in Table 1.

Basically, the BCCSAP is the expansion and revised version of the National Adaptation Programme of Actions (NAPA) which was published in 2005. The BCCSAP is composed of 44 program interventions under six pillars including: 1) Food security, social protection and health; 2) Comprehensive disaster management; 3) Infrastructural9development; 4) Research and knowledge management; 5) Mitigation and low carbon development; and 6) Capacity building and institutional development. The core programmes to be implemented under each pillar have been presented in Table 1 [10]. The five year plan was approved in 2011 to with the aim of achieving the BCCSAP placed a lot of emphasis on mainstreaming and strengthening adaption to climate change [5]. The main aim of the BCCSAP is to build the capacity against the challenges of climate change as part of the achievement of the country's great vision 2021. The climate change unit of government is responsible for the coordination in facilitating the adaptation works with all stakeholders such as the people in general, the NGOs, the civil society, the private sectors and the international actors in a systematic manner [10].

1.3 Global Overview of Climate Adaptation Options

Coping includes the use of existing resources to attain different desired goals during and immediately after unusual and adverse situations of a hazardous event. The strengthening of coping capacities including preventive measures is a crucial aspect of adaptation and resilience to a natural hazard [18]. Adaptation describes the actions and adjustments taken in order to maintain the capacity in dealing with stresses of current and future external changes [18,19]. While adaptive capacities are the preconditions that enable actions and adjustments of the adaptation process [18]. The vulnerability and adaptive capacity of particular individuals rely on the cognitive factors (e.g. ability to perceive the risks posed or unwillingness to accept the need to act in response) and normative factors (e.g. social or cultural norms or beliefs that may limit adaptation) [19,20,21].

There are various types of obstacles that hinder the success of climate change adaptation. These barriers include: physical, ecological, technological, financial, informational, cognitive and socio-cultural elements. Additional financial resources are necessary for proper monitoring and forecasting natural disasters. Organization and institutional responses are also indispensable to promote the adaptive capacity [22]. A change of behavioral attitude is necessary to climate change adaptation. More so, it is difficult to improve the adaptive capacity without a comprehensive understanding of the situations, in which decisions about adaptation are undertaken [23].

Table 1. National climate change strategy and action plan

BCCSAP six pillars	Specific programmes
1. Food security, social protection and health	Resistance cropping system, safe housing, health care , creation of employment opportunities
2. Comprehensive disaster management	Community based adaptation, Early warning, Partnership between GOs and NGOs
3. Infrastructures development	Cyclone shelter establishment, Embankment development
4. Research and knowledge management	Hydrology system development, New technology generation particularly resistance crop variety
5. Mitigation and low carbon development	Social forestry, Coastal green belt by tree plantation, Integrated Pest Management (IPM)
6. Capacity building and institutional change	Education and training, Human capacity building

Source: MoEF, 2009 [10]

An integrated approach such as Community Based Adaptation (CBA) is very relevant and valuable to climate vulnerable communities. Community based participation coupled with collective action build adaptive capacity and resilience against a rapidly changing climate. CBA focuses on local decision making processes involved in designing the adaptation strategies and approaches [24]. Top-down approaches are not effective adaptation options in a community. In Bangladesh, although the guidelines of National Adaptation Plans of Actions (NAPA) addresses bottom-up participatory approaches, they often fail to include community people in the policy making process and in implementing the adaptation options [25].

Kurukulasuriya and Rosenthal [26] summarized the typology of adaptation options to climate change to include:- a) Technological innovation developments, for instance: flood-drought resistant crops, short duration crops, livestock feeds and hydrological system improvement; b) Insurance and income generating responses such as: credit schemes, flood insurance schemes for crops or livestock and creating employment opportunities; c) Farm pattern adjustments such as: crop and livestock diversification, changing land use pattern and timing of operations; d) Institutional changes including: price policy adjustments, removal or placement of subsidies, and improvements in local agricultural markets. Farmers' adaptive capacity is determined by wealth, human capital, material resources, infrastructure, information and technology. Institutional adjustment in production technology (planting date shifting, crop resistance, crop rotation, rainwater harvesting), government policy, insurance schemes and international trade are good examples of adaptation options in agriculture [27]. Agrawal [18] focused on the group adaptation strategies in the context of environmental risks. These adaptation options can be classified into five analytical adaptation options and their combinations which include: mobility, storage, diversification, communal pooling, and exchange. Effectiveness of these strategies is a functional part of the institutional and social contexts in which they are perceived.

Temporal migration is a good alternative option for the people who lose their homesteads and crop land due to riverbank erosion. In Bangladesh, about 81% of respondents migrated to distant city places in search jobs in order to cope with losses incurred from disasters. The Rest of the respondents could not migrate because of their inability to finance migration and transportation costs. These non- migrants relocated their houses in a nearby area immediately after relief of disaster [28]. Infrastructural development in the form of shelter or embankment plays a crucial role for the pre-disaster adaptation. However, lack of awareness contributed to peoples' limited access to shelter facilities. As such, different types of awareness programs provided in schools, homes and communities can contribute to adaptation and assisting children during disasters [29]. In addition, Mass media platforms such as: radio and television also play a significant role especially in getting weather related forecasts [30]. Mobile phones are also very popular devices for transferring weather related information amongst community people [31].

2. METHODS AND OBJECTIVES

The general objective of this article was to formulate and disseminate appropriate climate adaptation policies for different stakeholders in Bangladesh in order to promote sustainable climate change management strategies. In order to fulfill the general objective, the specific objectives of the article were as: a) to carry out a review about the previous climatic hazards and their socio-economic impact in Bangladesh, b) To explore different adaptation options carried out locally in order to combat natural disasters, c) To formulate a discussion on the potential and problem of the climate different climate adaptation options, and d) To provide a framework composed of climate vulnerability, vulnerable groups, adaptation techniques and strategies for future policy implication. In order to facilitate the attainment of the above objectives, the information provided in this article was gathered through an extensive review of relevant and existing literature.

3. CLIMATE CHANGE ADAPTATION OPTIONS IN BANGLADESH

In Bangladesh, fifteen (15) climate adaptation options have been analyzed to promote a sustainable climate change adaptation strategy and these strategies are based on three categories (Table 2). Infrastructure development is one of the six key preventive adaptation measures of the BCCSAP-2009 a typical example of this includes, a cyclone shelter, which is a building composed of concrete with two sided triangle shapes facing the wind. Railings

on both sides help people climb upstairs when in instances of very strong wind. It also contains separate rooms for males and females with inclusive toilets in the downward area of the building. About 700-1000 people can take refuge in a typical cyclone shelter with the building costing approximately 50,000 £. Earlier, a typical shelter was used only for single purposes. This is unlike the case recently where, the shelters built are meant for multi-purpose use including: local government offices, schools or health centers. According to government estimates, before hitting cyclone Sidr in 2007, 1.5 million people took refuge in different cyclone shelters. As a result of these shelters, limited number of deaths (3500) occurred as compared to the 1991 cyclone situation where in 140, 000 deaths were recorded [10]. Paul et al. [30] stated that there were about 3976 emergency cyclone centre in Bangladesh during cyclone *Sidr* occurrence in 2007. However, cyclone shelters are still limited in many regions with distances situated far away from the residences. As a result, most of the people were not able to reach their points of the shelter during cyclone hazards [32]. During the attack of cyclone *Sid r*in 2007, about 20% of people took refuge in cyclone shelters while approximately 12% of people used markets, schools and mosques as their points of shelter. The remaining people (approximately 70%) possessed no means of shelter and used nothing for their shelter purpose [30].

The external interventions strategy for pre-disaster management is done by early warnings or forecasting. Cooperative Assistance and Relief Everywhere (CARE) has been implementing Char Livelihood Programmes (CLP) as community based early warning systems with the aim of creating awareness to the island *(char*) communities of northern Bangladesh, these programs have been introduced since 2010.More than 60% of households in the communities received announcements as early warning signals of flood incidence. Majority of households received early warning information from local government (52%) and the media (39%). So, the CARE programme has created stronger awareness to the islands (*char*) with respect to pre-flood forecasting [33]. Nevertheless, the transmission of early warning systems of flash flooding, which is controlled by opening the barrage of upstream India is often hampered by the lack of inter country coordination for forecasting.

Bangladesh is a low lying country crisscrossed with more than 800 rivers. Every year, monsoon floods submerge houses and schools and wash away roads, which in turn increase the rates of primary children drop outs because of closed the school activities for 3 to 4 months. Some prominent figures involved in setting climate adaptation strategies include: floating boat school started in 1998 through a non-government organization (Shidhulai Swanirvar Sangstha) with the financial support of Bill and Melinda Gates Foundation and the United Nations Children Emergency Fund (UNICEF) aimed at facilitating school reach to students. The mobile floating school provides primary education based on the curriculum of government schools. There were about 1,600 children receiving education under floating schools, whose libraries are composed of 1,500 books, 4 solar-powered computers including a wide range of teaching materials. The schools provide services to around 90,000 families covering an area of more than 300 miles.

Table 2. Category-wise climate change adaptation options

Categories	Specific adaptation options
Adaptation options by external interventions	Establishing multi-purpose cyclone shelters
	Forecasting or early warning system
	Floating boat school in flood prone Riverine area
	Lifting household above flood level
	Providing community based ring or tube-well
	Supplying cooking stove
	Establishing solar panel
Indigenous adaptation techniques	Keeping household necessary items on *Muchan*
	Storage of dry food and pure water
	Protecting river erosion by piled sand bag
	Shifting home nearby place
	People migration to city for livelihood earnings
Agricultural adaptation	Floating vegetables garden
	Sandbar pumpkin cultivation
	Tolerance or resistance crop cultivation

The organization now carries on only 54 school boats [34]. In spite of this, the pertinent question arises on whether these school boats are too limited to provide primary education for the whole flooded area. Notwithstanding, there is limited literature evidence, concerning the maintenance and future sustainability of these school boats.

Sona Mollar Dangi is small village island comprising of 26 households with approximately 250 people in Padma riverbank of Bangladesh. Life was very happy before incidence of the disastrous flood in 1998 which caused the entire village to be flooded under water for a few weeks, prompting the people to migrate to high ground in distant places. After water removal, the people continued to live there even after osing everything. The years 2004 and 2008 witnessed the occurrence of floods, whereby the houses of the villages were washed away. The community people felt the need to mobilize themselves and perform some sort of collective action. Faridpur Development Agency (FDA), an NGO provided support financially and technically through trainings on how to construct households and raise them above flood levels. These support enable the community people to managed and raise all households above the flood level of 1998 by 1.5 feet. It also restores the safety of households and barns from floods; which reduces them from moving in the event of floods [10].

Another example of Lifting households above flood levels could be reflected within the household of Mrs. Ambia, a member of Village Disaster Management Committee (VDMC) of GangacharaUpazila under Rangpur district, Bangladesh. Her family consists of six members including: 3 children below 8 years and an old aged mother-in-law. Her husband works on a daily wage basis and migrates to the capital city during off-seasons. She plays the role of the family head in the absence of her husband. In comparison to other houses in the community, her home is located in the low lying area of the community. As a result, she was compelled to move into a safe area during the period of floods every year, which to her seemed very insecure and a burden especially during the night alongside her children, old mother-in-law, household materials and livestock (poultry or goats). Her home was selected to be raised above flood level in a collaborative group meeting of VDMC. She mentioned that her homestead area was lifted up to a height of 4 feet in June 2014 with a total cost of BDT 11200/- funded by the core project of the NGO-Rangpur Dinajpur Rural service (RDRS). She also added that, during the June-July 2015 flooding in her village, her house remained safe from the flooded water. Nevertheless, this external initiative does not provide facilities to all households of the community [35].

There is a lack of electricity connection in the rural areas of Bangladesh due to their remoteness and less developed areas coupled with high rates of poverty. Remote people by the riverside faced several problems in the dark of night while the community floated abruptly. Some of these problems included: i) the fear of snakes, ii) insecurity of young girls and women, ii) difficulties encountered moving to safer places on the part of: children, old persons, and disabled or ill people. Activities like the establishment of solar panel cells in highly raised household have been considered an option for the remote communities to overcome their problems related to night time flooding. Another advantage is the source of renewable energy with no emission of green house gasses [35]. But this external intervention covers very few households ranging from 1-2% of the rural communities.

The lack of pure water is an acute problem during flood occurrences About 2 to 4 community rings or tube-wells have been considered as another coping option, in order to enable the people's ability to collect pure water especially during water logging conditions; this is because, these rings or tube-wells are established in maintaining the raised places out of the flooding level. Another problem come upon in the flood affected area is the difficulty faced in the cooking and storage of food. This is as a result of because the people's usage traditional cooking stoves which are most liable to the damages of flood water. Consequently, the external agency developed stable cooking stove options (*locally called Bondhu Chula*) composed of concrete and cement with less likelihood of being damaged by water. Another advantage of this cooking stove is its ease of mobility.

Flood affected people make *muchan* or *pataton* (local name) in order to save their household assets against heavy floods. *Muchan* is an additional chamber attached to the roof of the house whereby water cannot reach. Most of the households (84-94%) used this technique to save household items while only 6-16% households moved to safer places or shelter [28]. This indigenous technique is suitable for short

term flooding. Riverbank erosion is a crucial post-flood problem in Bangladesh. Approximately 30-40% people of the country live close to riverbank and char/islands. These people are most vulnerable to river bank erosion due to unstable embankment. Generally, people utilize their local indigenous knowledge to adapt to the river bank erosion. More than 50% of local people used piled sand bags followed by 25-35% soil bag and only 11-15% people utilized brick pieces to protect from river erosion. Although, these coping strategies provide options for weak and short term flow of flooding, they are not sustainable against strong flows of river water [37].

Some local adaptation techniques have been practiced by the community people of the Teesta riverine area of northern Bangladesh who preserve pure water and dry foods for unwanted flood conditions. They practiced these adaptation techniques as Indigenous Technical Knowledge (ITK) and experienced gathering from their family ancestors or society. Around 50% community members were seen to follow the storage of food and pure water. Rest 50% of non-adopted community people claimed that it was very difficult for them to preserve food assets because of poverty [35].

Mobility or migration is one of the important adaptation strategies of the disaster affected people. During the last three decades, all affected community members experienced at least three times of shifting of their households due to riverbank erosion. Some community household has moved 11 times because of erosion losses of homestead. Most of the community people had permanently lost their cultivable land due to river erosion prompting them to frequently move to temporary shelter points in the nearby high lands, roads, neighbors or relative's houses or school buildings during flooding. Again, flood and migration of people to nearby towns or the capital city to see means of earning their livelihoods. People migrated mainly for two reasons including: i) the lack of employment opportunities during off-seasons characterized by lean periods. and ii)during the loss of their households, standing crops and cultivable lands due to floods and erosion, or lower yields resulting from water scarcity [35]. Nonetheless, migration is not a sustainable solution of the disaster affected areas, hence the need to create both on-and off-farm employment opportunities to reduce migration is a call for concern.

Different research organizations under the Ministry of Agriculture (MoA) have been working for the development and distribution of various crop resistant varieties to promote the 4th pillar (research and knowledge management) of the BCCSAP. Bangladesh Rice Research Institute (BRRI) has already generated 57 modern varieties of rice; out of which 17 are climate resistant. The resistant varieties of different cereals, vegetables and fruits already developed by different research organization are presented in Table 3.

The largest government extension organization, Department of Agricultural Extension (DAE) has been engaged in the dissemination of resistant crop varieties to the farmers. Besides DAE, several NGOs are also working in distributing and providing trainings in order to reach these varieties to the vulnerable farmers. But both government and NGOs extension agencies are not well equipped in providing proper information regarding characteristics and management practices of these tolerant varieties because of lack of formal network and coordination with the researchers. Although few farmers are aware of those climate resistant crops, they are not capable of cultivating tolerant crops due to lack of adequate input materials (seeds) and financial support [5].

Teesta river basin is a low lying land where farmer usually cultivated traditional rice varieties they however experienced the loss of rice yields due to the submergence of fields by floods. Farmers as a result of this, kept the land as fallow. After membership of village disaster management committees, very few farmers were aware of flood tolerant rice varieties of BRRI dhan (51) and received rice seeds from the NGO RangpurDinajpur Rural Service (RDRS) at a free cost. Although the rice field had suffered in submergence condition for 10 days, the grower farmers still witnessed good yields. The majority of farmers could not cultivate this flood tolerant rice due to lack of information access and input support through seed provision.

Practical action, a non-government organization promoted an innovative technology of floating gardens in the Gaibandha district of Bangladesh in 2007. A floating garden is prepared by a raft of water hyacinth usually about 8 meters long and 1 meter wide. The raft is composed of soil, compost, and manure, in which vegetable seeds are planted. The raft can be used for one yearbut particularly useful during dry seasons as

Table 3. Resistance varieties of different crops developed in Bangladesh

Name of varieties	Special feature	Research organizations
Rice		
BRRI Dhan 51	Submergence or flood tolerant	BRRI
BRRI Dhan 52	Submergence or flood tolerant	BRRI
BRRI Dhan 53	Salinity tolerant	BRRI
BRRI Dhan 54	Salinity tolerant	BRRI
BRRI Dhan 55	Cold and drought tolerant	BRRI
BRRI Dhan 56	Drought tolerant	BRRI
BRRI Dhan 57	Drought tolerant	BRRI
BRRI Hybrid Dhan 3	Short duration (145 days), Yield 9.0 ton/ha	BRRI
BRRI Hybrid Dhan 4	Short duration (118 days), Yield 6.5 ton/ha	BRRI
Binasail	Submergence or flood tolerant	BINA
BINA Dhan 8	Salinity tolerant	BINA
Wheat		
BARI Gum 20	Drought and heat tolerant	BARI
BARI Gum 21	Drought and heat tolerant	BARI
BARI Gum 22	Drought and heat tolerant	BARI
Potato		
Saikat	Salinity tolerant	BARI
Multa	Early maturing	BARI
Granola	Early maturing	BARI
Others crops		
BARI Chola 5	Drought tolerant	BARI
BARI Barley 6	Drought tolerant	BARI
BARI Mugbean	Drought tolerant	BARI
BARI Mustard 10	Salinity tolerant	BARI
BARI Amra 1	Salinity tolerant	BARI
BARI Amra 2	Salinity tolerant	BARI

Sources: BBS, 2012 [16], Rahman, 2011 [5]

fertilizers. Partially training facilities and inputs were provided to a group of people to demonstrate know-how on the spread of the widespread climate change awareness program. Now, community people are aware on the processes involved in the growing of vegetables in floating gardens such as: bitter gourds, green okra, and leafy greens, which provide subsistence for households during standing floods. It is also suitable for temporarily or permanently affected people for short-term disaster relief because the rafts can be moved from one area to another. But the main obstacle is that of most of the people not being able to preserve vegetables seeds as well as to bear the cost of making rafts due to poverty. This farming adaptation option could be capable of meeting the short term demand of household consumption as a post-flood activity [35].

Generally, farmers kept the char lands as unfertile fallow in dry seasons. After receiving trainings about the production technologies of sand bar pumpkin cultivation, in addition to the water fall in November, farmers made pits and mixed with soil, vermicompost and few amounts of chemical fertilizers. After cultivation of pumpkin in this pit, majority farmers harvested experienced good pumpkin yields. But, pumpkin farmers did not get good prices due to the lack of market access. The price of per pumpkin was seen to have doubled in Rangpur city, about 13 Km far distance from the crop fields [36].

4. DISCUSSION

In spite of climate change being a global problem, different adaptation techniques are followed in Bangladesh as to achieve the target of the Bangladesh Climate Change Strategy and Action Plan (BCCSAP). Community based adaptation programmes (awareness to early warning system, floating vegetable gardens, floating boat schools, ring or solar cell establishments) have been implemented by the intervention of various NGOs with financial support of donor organizations. These programmes partially fulfill the achievement of the 2nd pillar (comprehensive disaster management) of the BCCSAP in flood vulnerable areas of the country. Considerable shelters were set up as an immediately intervention scheme

and only 20% people took refuge in the multi-purpose cyclone shelter due to lack of awareness. It has been found that sufficient cyclone shelters have already established support to the 3rd pillar (infrastructures development) of BCCSAP; still the riverbank area is still vulnerable to erosion because of earthen embankments. Majority people depend on local indigenous adaptation techniques to protect the losses incurred from riverbank erosion. These local coping techniques have been proven to be temporary solutions, or sometimes having no potential to prevent the impact of the strong flow of water. Agricultural researchers have good progress in generating resistant crop varieties to buffer against climatic stress flood or drought, but having less emphasis for the generation of insect-pest resistance crop varieties. It is no doubt that these research organizations especially in agriculture sector have great achievements in tolerant crop variety developments to achieve the 1st pillar (especially that of food security) and 4th pillar (research and knowledge management) of the BCCSAP. However, there exists a major limitation concerning the dissemination of these technologies to the farmers. Indeed, farmers' awareness and adoption capacity (information access, seed availability, others input materials access) are very low regarding the resistant crop varieties. Also still have no crop insurance schemes for crop failure due to the natural disaster. Apart from solar cells, there is also lack of the sufficient scenarios of facilitating mitigation (5th pillar of BCCSAP) as well as capacity building and institutional change (6th pillar of BCCSAP). No literature evidence on proof records is available of creating on-and off-farm employment opportunities to stop post disaster migration. Most of the adaptation options of are based on the pre-and-post management of floods or cyclones, with less emphasis placed on droughts, salinity or riverbank erosion. There is lacking of definite adaptation measures for specific climate change vulnerable groups like: children, women or old aged people.

4.1 Proposed Integrated Conceptual Framework for Climate Vulnerability Adaptation

The vulnerability driven by intersecting dimensions of inequality indicates that socially, economically, culturally, politically, institutionally, or marginalized people are generally vulnerable to climate change hazards. Vulnerability is originated through the intersection of on social processes that cause inequalities in socioeconomic status and income, as well as responses to climate hazards. These social processes create discrimination on the basis of gender, class, ethnicity, age, ability or disability. Increasing and understanding various capacities of individuals, households, and communities require knowledge about the intersection of social processes in order to minimize the multidirectional vulnerability. Vulnerability decreases when people's adaptation capacities and opportunities are diversified and maximized [17].

This research lays out a proposal which focuses on the climate change impact (indicated through block arrow from left to right) as a causal determinant of affecting the socioeconomic status of vulnerable groups. Whereas, dotted arrows indicate the possible adaptation strategies and their interaction in order to combat the socio-economic impact of climate change faced by different vulnerable groups. The framework is illustrated in Fig. 1. The conceptual framework for this proposal reveals that the children, women, old aged, sick, isolated and poor people are more vulnerable to the impacts of climate change. Due to lack of proper adaptive strategies and coping capabilities, natural disasters such as: floods, erosion, and droughts affects the normal livelihood of the most vulnerable people thereby: Damaging crops, capitals, infrastructure amongst others, consequently leading to poverty, unemployment, food insecurity and finally migration for livelihood earnings. Social conflicts arise due to lack of resources among the poor people, especially with the provision of external incentives to the community people. Again, women are particularly insecure and lack rights to access resources. These are prominent socio-cultural problems that make women more vulnerable to natural disasters.

In circumstances of global climate change effects, the needs of technological innovations are discussed by Kurukulasuriya and Rosenthal [26] in the context of diversification of climate adaptation. Incentives aimed at facilitating credit schemes and input support for effective adoption of the technological innovations should also be provided. Furthermore, resources (wealth, human capital, material resources and infrastructure) access and right to utilization would be crucial to the diverse use of adaptiontechniques such as: planting date shifting, food safety, crop rotation, rainwater harvesting [27].

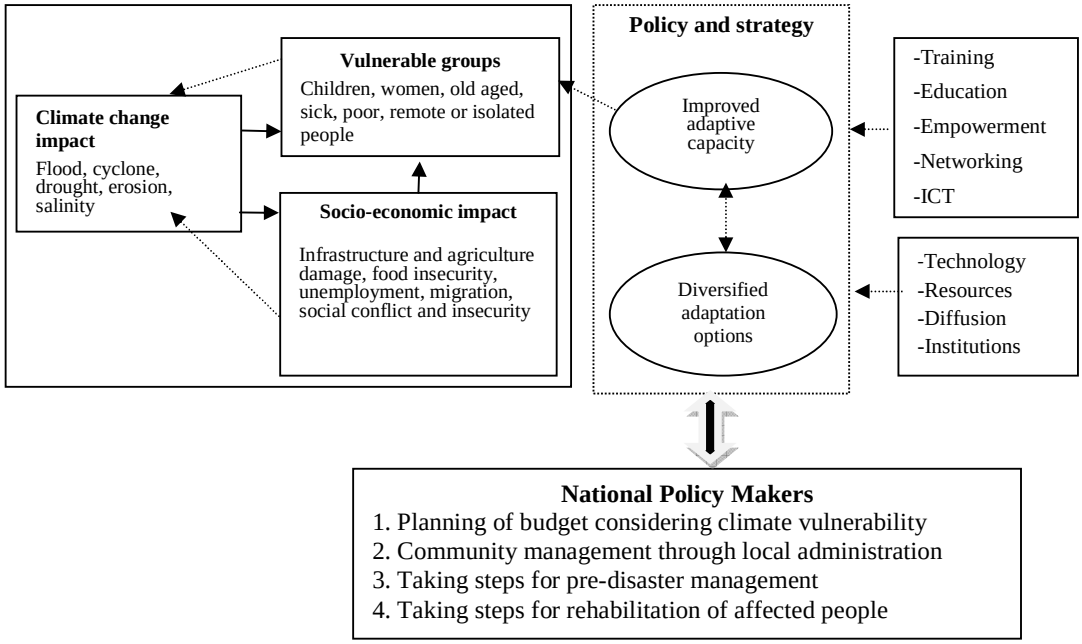

Fig. 1. Integrated framework composed of climate vulnerability and adaptation strategy

Institutional and organizational rearrangements should be considered for proper diffusion of the technological knowledge, skills and attitudes to different types of vulnerable groups.

The available adaptation options of climate change might be less or no effective due to lack of adaptive capacity of the vulnerable groups. In this case, training must be incorporated in the climate change adaptation model to increase the technical know-how of innovations and new technologies. In order to reduce the vulnerability of children, syllabi or courses related to climate change impacts with possible solutions might be included in the curriculum of primary, secondary and high school education level systems in order to create awareness among the children. Additionally, women empowerment and their rights to access physical resources should be given priority. Also, there is need for a change in the socio-cultural behavior and attitudes of people towards vulnerable girls or women, especially when faced with insecurity in times of disaster occurrence. Vulnerable remote people need close access to information sources such as radio, television which play a significant role especially in getting weather related forecasts [30]. Hence, Information Communication and Technology (ICT) based mobile phone and the internet may be crucial tools in transferring weather related forecasts and networking among community people [31]. This framework presents an integrated approach developed by the author as an 'initial step' of a proposed research project, which will help in the rearrangement and development of multi-stakeholder models, tools and strategies for the diffusion of climate change sensitive technologies. In future, empirical research findings will be presented to evaluate the sustainability of the framework.

5. CONCLUSION

Although there is lot of initiatives or adaptation programs in Bangladesh, however, still lacking or missing of long-term adaptation techniques considering all the determinants of climate change impact. The review presented has shown that ignorance of specific vulnerable groups to climate change adaptation. Therefore, with the progress of technological innovations, a concrete integrated framework must be considered for sustainable climate change adaptation. In response, this article has painted and formulated integrated model that highlights the next frontier of climate change adaptation in Bangladesh. However, this is the significant stage forward by considering local situations, vulnerable groups and boosting up their capacity on the diversified access to information, communication, technology and networking for the implication of sustainable climate change adaptation policies.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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