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Article

Impacts of Climatic Hazards on the Small Wetland Ecosystems (ponds): Evidence from Some Selected Areas of Coastal Bangladesh

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Abstract: Most climate related hazards in Bangladesh are linked to water. The climate vulnerable poor—the poorest and most marginalized communities living in remote villages along Bangladesh's coastal zone that are vulnerable to climate change impacts and who possess low adaptive capacity are most affected by lack of access to safe water sources. Many climate vulnerable poor households depend on small isolated wetlands (ponds) for daily drinking water needs and other domestic requirements, including cooking, bathing and washing. Similarly, the livelihoods of many of these households also depend on access to ponds due to activities of small-scale irrigation for rice farming, vegetable farming and home gardening. This is particularly true for those poorest and most marginalized communities living in Satkhira, one of the most vulnerable coastal districts in south-west Bangladesh. These households rely on pond water for vegetable farming and home gardening, especially during winter months. However, these pond water sources are highly vulnerable to climate change induced hazards, including flooding, drought, salinity intrusion, cyclone and storm surges, erratic rainfall patterns and variations in temperature. Cyclone Sidr and Cyclone Aila, which hit Bangladesh in 2007 and 2009 respectively, led to a significant number of such ponds being inundated with saline water. This impacted upon and resulted in wide scale implications for climate vulnerable poor households, including reduced availability of safe drinking water, and safe water for health and hygiene practices and livelihood activities. Those households living in remote areas and who are most affected by these climate impacts are dependent on water being supplied through aid, as well as travelling long distances to collect safe water for drinking purposes.

Keywords: climate change; Bangladesh; coastal zone; water; cyclone; salinity intrusion; flooding; ponds; impacts; adaptation; climate vulnerable poor communities

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1. Introduction

The coastal population of Bangladesh is exposed to a number of climate induced hazards. These include variations in temperature, erratic rainfall patterns, drought, cyclones and storm surges, flooding, salinity intrusion affecting existing water sources and rising sea levels. Potential Sea Level Rise (SLR) is expected to enhance current risks already impacting upon coastal livelihoods in various ways [1] state that a mean sea level rise of at least 2.5 mm per year in the Bay of Bengal has taken place since 1950. Alternatively, the [2] reports a rise of 30 cm and 50 cm in 2030 and 2050 respectively [3] indicate that an increase of 15 to 38 cm of SLR by 2050 may affect coastal ecosystems [3,4] reports an increasing trend of SLR at Hiron point (near Bangladesh's Sundarbans) by 5.3 mm per year during 1977 to 2002. In comparison, local coastal communities perceive SLR as "the current level of water in the rivers during low tide is the same level of water that there was for high tide about 20 years ago".

This increased SLR may intensify the impacts of cyclones and storm surges and result in increased salinity intrusion into existing water resources (such as ponds) and larger areas of agriculture land in the future. Cyclone induced storm surges combined with increased sea level, variations in temperature (especially during pre-monsoon in March, April and May) and erratic rainfall patterns (particularly late rainfall), are also likely to have negative implications on the quality and quantity of pond water sources. This will ultimately affect the livelihoods of the climate vulnerable poor farmers, those poorest and most marginalized farmers most at risk to these potential climate-related impacts.

These poorest and most marginalized communities are currently working hard to cope with and adapt to current changing circumstances. However, further support is required if households are to successfully undertake longer term sustainable adaptation practices to current climate variability and potential future climate change impacts. Locally-driven immediate and longer-term adaptation strategies generated through active participation of local people are likely to support households in undertaking sustainable livelihood practices.

This paper is comprised of four sections. Section One presents a brief overview of the impacts of climate induced hazards on small ponds along Bangladesh's coast. Section Two highlights the research tools and techniques used to collect relevant data from the study areas presented in this paper. Section Three discusses research findings, including the localized climate change vulnerability context and its impacts on pond water sources for targeted climate vulnerable poor households. Current household coping mechanisms undertaken and potential adaptation options to support households adapt with identified hydro-climatic risks are also presented. Section Four provides concluding remarks.

2. Materials and Methods

This research utilized both quantitative and qualitative data collection methods to explore current and potential future climate change impacts on small isolated wetlands (ponds) located in two Unions in Shyamnagar Upazilla in Satkhira, south-west Bangladesh. The survey used targeted households who have access to eight ponds in five villages in the above mentioned two unions. A total number of 309 respondents were targeted through the sample survey.

The sample survey was conducted using a two-stage cluster sampling procedure. During the first stage, the ponds (cluster unit) were selected based on pre-selected criteria, including location of the pond (within 100 km of the coast); multiple uses of the pond water (more than one use); number of users (>50 user households) and socio-economic status of users (*i.e.*, locally perceived poor and marginalized communities). During the second stage of this process, households were randomly selected from each cluster. The head of the family/household was given priority to respond to the questions. In absence of the head, other senior informed person of the household was requested to respond. However, in many cases either elder male or female responded in presence of all members of the family. Sometime they all discussed before responding to some question particularly on climate induced hazards and existing adaptation measures.

The survey questionnaire was designed to capture relevant data from the study areas. This included background information on selected ponds; socio-economic profile of the study households; household awareness and understanding of climate change-related issues including local perceptions on the impacts of climate induced-hazards on ponds and associated household livelihoods; current coping measures undertaken; loss and damages incurred; and potential adaptation options to mitigate future hydro-climatic risk. Fieldwork findings were also collected and validated through Focus Group Discussions (FGDs) and semi-structured interviews with target pond users in the study villages. In addition, secondary data sources were collected and reviewed. Relevant literature provided further understanding on related concepts and supported data analysis of study findings.

3. Results and Discussion

The coastal zone of Bangladesh is highly vulnerable to both slow and rapid onset events. [5] state that, "Accelerated global sea level rise and higher extreme water levels may have acute effects on human populations of Bangladesh (and parts of West Bengal, India) because of the complex relationships between observed trends in sea surface temperature over the Bay of Bengal and monsoon rains" It is predicted that a 62 cm SLR may inundate 16 percent of the country affecting approximately 43 million people by 2080 [6]. Cyclonic events, salinity intrusion, variations in temperature and rainfall, and drought conditions are already affecting Bangladesh's coastal population in numerous ways. This includes, for example, reduced agricultural yields, livelihood opportunities, availability of drinking water sources, and local fish production, plus increased incidences of water borne diseases [7]. The salinity intrusion caused by extreme events is now considered a major factor affecting water resources along the coast.

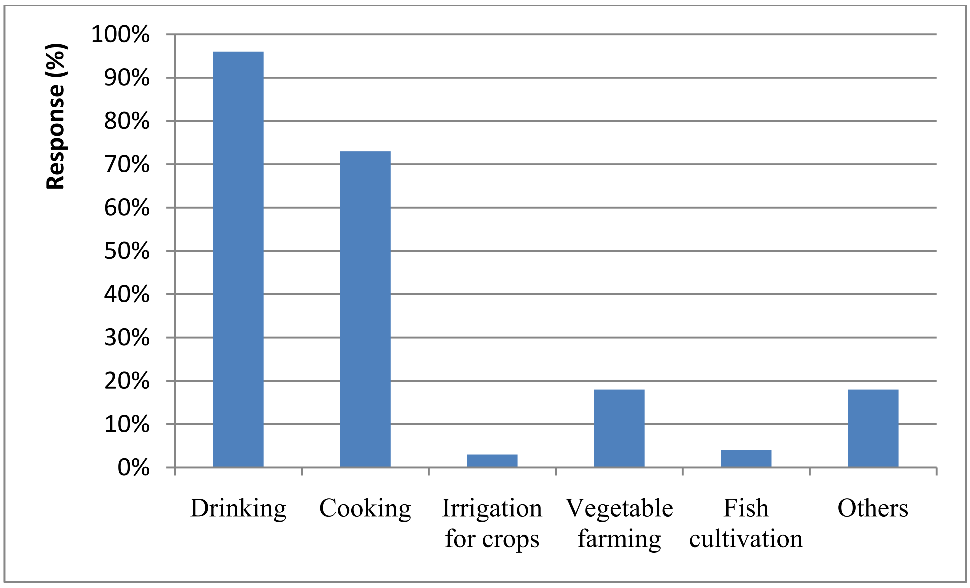
The Soil Resources Development Institute (SRDI) [8] states that surface water resources, especially on the south-west coast of Bangladesh, are severely affected by salinity intrusion that may be caused by climate variability and climate change-related issues [8]. The report indicates that the salinity level in the main rivers of the study area in Satkhira (namely Isamati, Malancha, kakshiali and Betna rivers) ranges between 25.5 dS/m and 35.9 dS/m [8]. It also found moderate salinity levels (2.3 dS/m) in the study area's sampled ponds .The salinity level in existing water resources varies from season to season. During the dry season, 29 percent of the total area of the coast remains under high salinity, decreasing to 12 percent during monsoon [9,10] state that, "Due to reduced dry season flow in the Gorai River (a distributary of the Ganges) as a result of upstream withdrawal in India, water salinity in the south-west region (of Bangladesh) has increased significantly". It is expected that potential SLR is likely to push saline water into inner coastal land areas while simultaneously intensifying cyclonic events and storm surges. This means that saline water may intrude into freshwater sources and cultivable coastal lands [11] argued that the wetlands are likely to be adversely affected by the number and severity of extreme events caused by climate change impacts. Moreover, it is stated that temperature and rainfall variations control salinity levels in coastal ponds [12], with intrusion of sea water also changing salinity levels [13].

Salinity intrusion caused by cyclones and storm surges has already resulted in devastating affects on Satkhira's coastal ecosystem, including small ponds that are the major source of water for drinking, cooking and agricultural practices for many climate vulnerable poor communities living in the region. Deterioration of quality and reduction in quantity of pond water has resulted in significant impacts on coastal livelihoods. For example, Cyclone Sidr and Cyclone Aila that hit Bangladesh's coastal zone in 2007 and 2009 respectively, led to many ponds being submerged in sea water. It was reported that over 6,000 ponds were adversely affected by Cyclone Sidr induced salinity intrusion [14]. Cyclone Aila hit the south-west coastal districts of Bangladesh on 25 May 2009. The storm surge caused by the cyclone Aila overflowed the embankments and submerged many small isolated ponds in affected districts including Satkhira. As a result, most affected households had to depend on aid water or alternatively walk considerable distances to fetch safe drinking water for three to six months after the hazard event. Many farmers could not continue with crop cultivation due to the lack of freshwater required for minor home gardening irrigation and cultivation of small pieces of land not covered by government irrigation schemes. Some households were able to clean nearby ponds by themselves or with government assistance. Even so, many households are still currently struggling with salinity levels in local pond water sources.

3.1. Uses and Services of Pond Water

Beneficiaries of eight small isolated ponds expressed their perceptions on the state, uses, services and impacts of climate induced hazards on these water sources. The study indicates that dependency on pond water is multi-purpose. The study shows that almost every household (96 percent of respondents) is dependent on pond water sources for drinking (please see Figure 1). Many households also collected drinking water from Pond Sand Filters (PSF) constructed near ponds. The majority of households (over 70 percent of respondents) are also dependent on pond water for cooking purposes. Similarly, 20 percent of respondents stated they use pond water for vegetable gardening. Moreover, 20 percent of respondents articulated that pond water is alternatively used for "other" purposes, including water access for local restaurants, tea stalls and fish markets. Lastly, a small number of respondents stated that they use pond water for irrigation of crops and fish cultivation.

Figure 1. Percent of respondents on the uses of pond water in the study areas.



3.2. Perceived Socio-Economic Status of the Study Communities

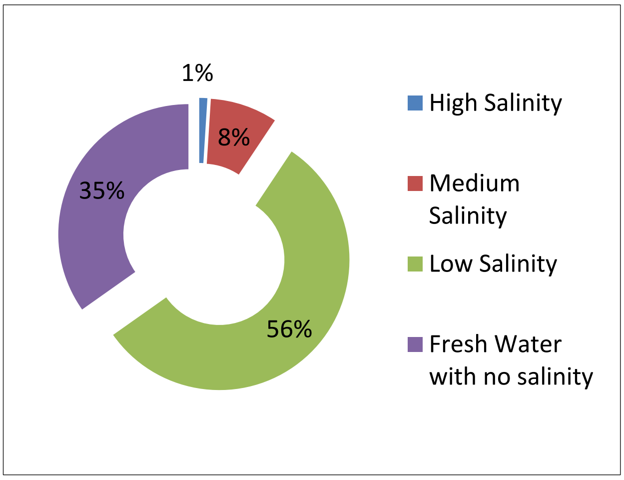
Respondents presented differing opinions on their economic status and/or level of poverty experienced. The local study communities in Satkhira perceived that their economic status is determined by their livelihood status and access to social support. Respondents stated that "extremely poor" people (31 percent of study households) constantly struggle with insecure occupations; on average consume two meals a day; live in poor housing and lack ownership of and access to land for cultivation. 50 percent of respondents perceived their economic condition as "poor". This means they live without severe food shortages and other basic needs; face difficulties in consuming three meal a day during certain seasons due to lack of income; and frequently change livelihoods to compensate for the limited number of income earning members per household. Only 19 percent of respondents perceive them selves as "not poor". This means that they can afford to eat three meals a day andthat they earn income from diversified sources including agriculture products, land ownership, foreign remmitances and shrimp farming. This latter categorization was not pre-selected prior to field work; it was defined by respondents themselves.

In regards to education levels of the study households, only eight percent of respondents have passed secondary school and embarked on higher secondary education. More than 35 percent of respondents have successfully completed high school education, with 25 percent educated to primary school level. The remainder of respondents is illiterate. On the age distribution of the study population, it was found that one-fourth of the total study population were less than 15 years of age. Most of the population (36%) was under 30–60 years range while 30% of the population was between 15 and 30 years of age. Only less than 10% of the population were old, fall under 60 + age group.

3.3. Perceptions on Pond Water Salinity Levels

Fieldwork findings reveal that pond water is affected by salinity intrusion, with respondents perceiving different levels of salinity. 56 percent of total respondents stated that pond water sources are affected by low levels of salinity (Figure 2 below). Eight percent of respondents stated medium salinity levels existed. Conversely, a significant portion of respondents (35 percent of total households interviewed) reported that pond water sources contain no salinity.

Figure 2. Percent of respondents on the salinity level of the pond water.



3.4. Impacts of Variations in Temperature and Rainfall on Salinity Levels, Quality and Quantity of Water of the Study Ponds

The quality and quantity of pond water varies according to the season. Both quality and quantity of water significantly deteriorates during the pre-monsoon (March-April-May). Analysis shows that the trend of average maximum temperature in both pre-monsoon and monsoon periods over a 30 year period (1981–2010) has slightly increased in the study area of Satkhira (author's analysis). It was observed that the trend of "days above 32 °C" in the last 20 years (1991–2010) has also increased. In comparison, rainfall patterns are changing in the study district. The same analysis used above shows that pre-monsoon rainfall is also decreasing over the above mentioned period. Likewise, the number of days without rainfall has increased over the same period. It may be argued that a longer span of rainless days, over extraction of water during warmer seasons and high rates of evaporation, especially during pre-monsoon periods, may present possible reasons for depleting water levels. Respondents expressed that pond water quality deteriorates when water levels decline. Further observations indicate that changes in salinity levels of pond water sources may be attributed to varying rainfall patterns. This observation is based on the comparison of rainfall experienced in January of 2011 and 2012 with the salinity levels of all study ponds for the following month, *i.e.*, February 2011 and 2012. It was found that salinity levels of all the study ponds had decreased by more than 50 percent from February 2011 to February 2012. It was also observed that the study district received 6 cm of rainfall in January of the current year (2012), compared to no rainfall in January in 2011. It may be argued that the change in salinity levels in February 2012 have occurred as a result of rainfall during the previous month of the year (Table 1 below). This changes or reduction of salinity varies from pond to pond. Reduction of salinity was found highest (65 percent) in pond-2 while the lowest (53 percent) was in pond-6. This finding is supported by [15] who found that 7 cm of rainfall may have contributed to a 37 percent decrease in salinity levels in coastal ponds in the same study area [15].

Table1. Changes in pond water salinity potentially related to rainfall levels in Satkhira.

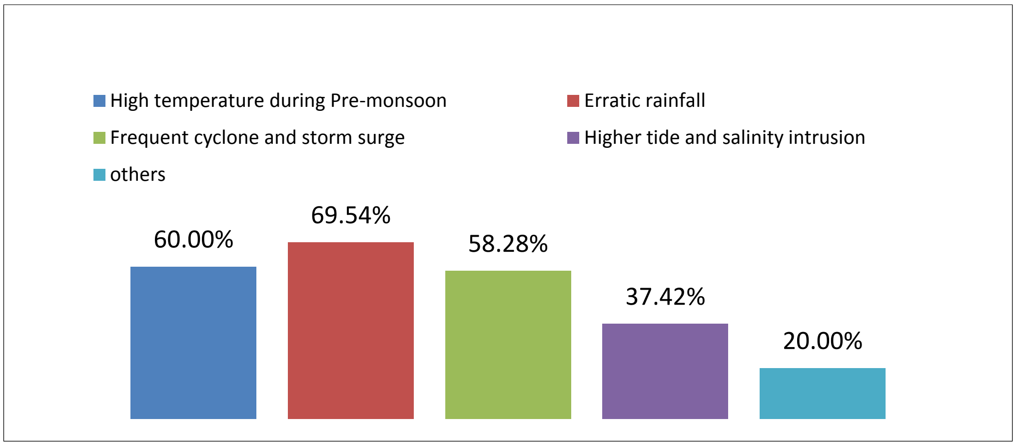
Pond	2011		2012		Changes (Reduction of salinity by %)
	Rainfall (mm) January 2011	Salinity (PPT) February 2011	Rainfall (mm) January 2011	Salinity (PPT) February 2012	
Pond-1	0	4.5	60	2	56
Pond-2	0	4	60	1.4	65
Pond-3	0	4	60	1.5	63
Pond-4	0	3.5	60	1.3	63
Pond-5	0	4	60	1.5	63
Pond-6	0	4.5	60	2.1	53
Pond-7	0	3.5	60	1.4	60
Pond-8	0	2.6	60	1.2	54

The pre-monsoon season (March-April-May) is also prone to hazards consisting of cyclones, storm surges and nor'wester. The nor'wester washes waste through surface runoff and deteriorates pond water quality. Moreover, the season is particularly prone to tropical cyclones, including Cyclone Aila that hit the area in May 2009. Another cyclone was also experienced in the pre-monsoon month of April in 1991, which killed more than 138,000 people living in Bangladesh's coastal areas [16].

3.5. The Major Climate Induced Hazards that Affect Pond Water Sources

Respondents expressed that climate change impacts have negative multi-faceted affects on pond water sources. They reported that the major climate change associated hazards impacting upon ponds in their locality, in order of decreasing prevalence, were erratic rainfall patterns (70 percent of households); high temperatures in pre-monsoon seasons (60 percent of respondents); frequent cyclones and storm surges (58 percent of respondents); and higher tides and salinity intrusion (37 percent of respondents) (please see Figure 3 for details).

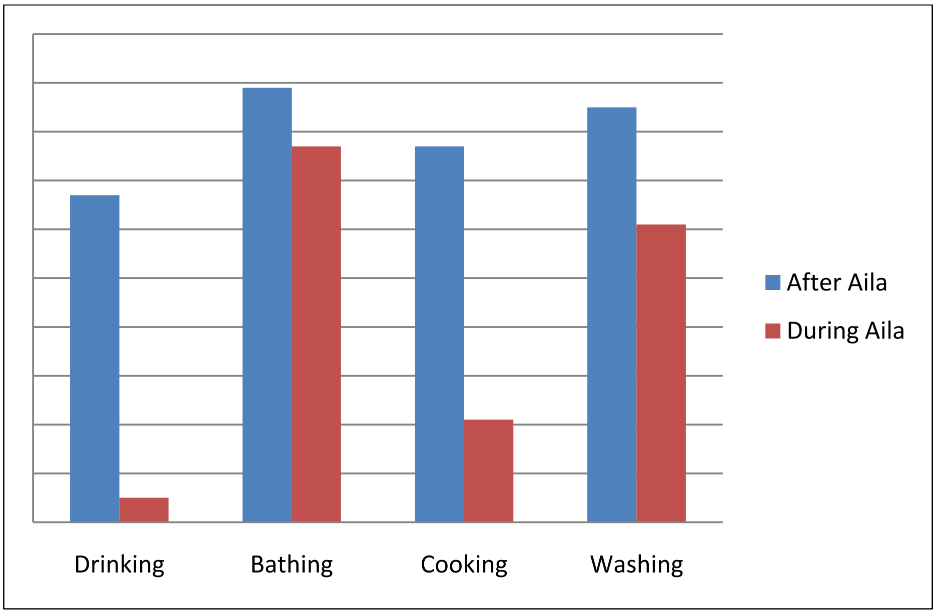
Figure 3. Percentages of HHs on the major hazards that affect/may affect pond water.



3.6. Use of Pond Water during (Immediate Impact period) and After Cyclone Aila Induced Storm Surges

The change in use of pond water during and after Cyclone Aila is significant. It may be noted that "during Aila" indicates the uses of pond water during immediate impact period of about 2 to 4 weeks while "after Aila" denotes the uses of pond water after cleaning/repairing of the cyclone Aila affected ponds. The usability of pond water was largely reduced as the quality of water dropped substantially beneath acceptable salinity levels. Only five percent of total respondent households used pond water for drinking purposes during Cyclone Aila (Please see Figure 4). However, one year later, respondent dependency on pond water for drinking sharply increased to 67 percent. Salinity intrusion in pond water also notably decreased the dependency of respondents on its use for cooking purposes. Only 21 percent of respondent households depended on pond water for cooking, with this dependency increasing to 77 percent one year after Cyclone Aila struck.

Figure 4. Use of Pond Water during and after (one year) Cyclone Aila.



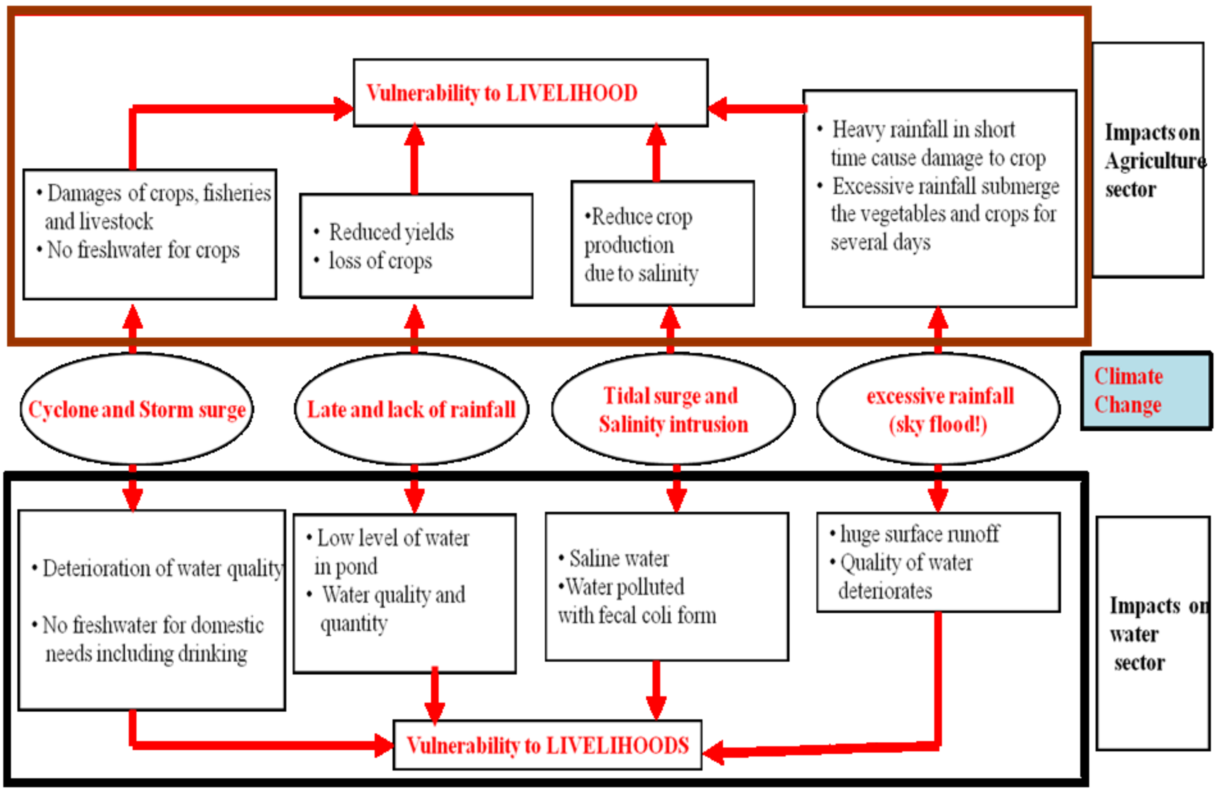
3.7. Common Waterborne Diseases and Perceived Causes

The study households were found to be suffering from a number of waterborne diseases, including frequent diarrhea, dysentery, skin disease and eye infections. Female respondents stated that they mostly suffer from diarrhea, fever, headaches and skin disease. In comparison, their male counterparts stated to suffer most from dysentery. Children of respondent households were recurrently found to experience a wide range of health issues, including fever, headaches, diarrhea, dysentery, skin disease, cholera and jaundice. According to 91 percent of respondents, the frequency of disease is highest during pre-monsoon seasons when pond water quality is at its lowest. Although six percent of respondents also stated to suffer from varying waterborne diseases during monsoon, the occurrence of disease was found to be at its lowest during monsoon months. Deterioration of water quality was found to be the main cause of diarrhea and dysentery as reported by more than 60 percent and 40 percent of respondents respectively. Around 20 percent of respondents stated skin disease was a consequence of degraded water quality. Moreover, approximately 15 percent of respondents expressed that deteriorating water quality was also the cause of fever and headaches.

3.8. Impacts and Vulnerability on Livelihoods

The majority of climate vulnerable poor study households dependent on pond water for drinking and agricultural practices were significantly affected by climate induced hazard impacts (Figure 5). With variations in temperature, rainfall and cyclonic events adversely affecting pond water sources, study households stated corresponding challenges in undertaking their main livelihood practices. As previously stated, Cyclones Sidr and Aila led to over 6,000 ponds being inundated with saline water along Bangladesh's coast. This resulted in a large reduction in the availability of safe drinking water for study households. Similarly, this resulted in a reduction in the availability of safe water for health and hygiene practices and livelihood activities.

Figure 5. Climate Change and Isolated Wetlands (ponds): Conceptual linkages of impacts and vulnerability.

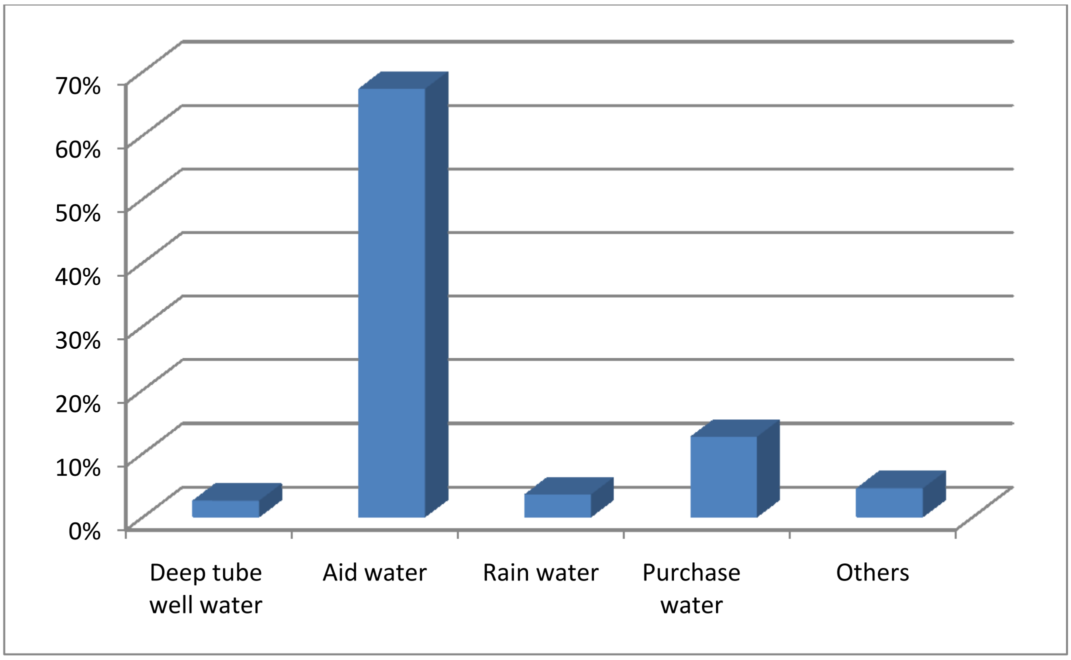


3.9. Adaptation Practices

3.9.1. Sources of Drinking Water Used During Most Recent Crisis Events

To gain access to drinking water during Cyclone Aila, nearly 70 percent of respondents became dependent on aid water (Figure 6). Many households had to purchase drinking water for a considerable length of time after the hazard. Some respondents had access to additional drinking water options, including access to deep tube wells and rainwater harvesting. Similarly, other households were able to collect drinking water from ponds that were not entirely submerged by saline water.

Figure 6. Sources of drinking water during most recent disaster (Cyclone Aila).



3.9.2. Construction and Raising of Pond Edges

The majority of respondents stated that raising the height of land surrounding pond edges could be one adaptation option undertaken to protect vital drinking water sources from future cyclonic events and associated salinity intrusion. In addition, some ponds may be re-excavated in order to keep the maximum depth of pond possible to ensure availability of sufficient water sources during pre-monsoon and crisis periods. Ponds are required to be cleaned regularly to ensure water quality remains at necessary levels.

3.9.3. Rainwater Harvesting

Respondents perceived that rainwater harvesting strongly supported the availability of access to safe drinking water sources during crisis periods. As a result, numerous households now view rainwater harvesting as an effective adaptation option in coastal areas. Rainwater harvesting is also expected to reduce the pressure on pond water sources, especially during periods of higher temperatures where need for increases in the amount of drinking water consumed rises.

3.9.4. Alternate Rice and Vegetable Farming

Respondents are shifting from cultivating traditional rice and vegetable varieties to alternate types. Local farmers stated that since Cyclone Aila they use crop varieties that are saline- and drought-tolerant and are able to survive in higher temperatures. An increased number of farmers are now growing pumpkin, lady's finger, eggplant, spinach and other vegetables that require minor irrigation mechanisms.

4. Conclusions and Recommendations

This paper presents that a number of climate induced hazards, particularly cyclones, storm surges, salinity intrusion, erratic rainfall patterns and variations in temperature are affecting the quality and quantity of safe and useable pond water sources in Bangladesh's south-west coastal zone. Research findings show that seasonal variations of these climatic risks have significant impacts on livelihoods and food security levels for the climate vulnerable poor households living in these areas. Degradation of water quality caused by Cyclone Aila in 2009 resulted in salinity intrusion and a decline in access to safe water sources, especially during pre-monsoon seasons when frequency of waterborne diseases increase. As a result, existing water management practices need to be improved in order for effective adaptation at local level to take place. This includes undertaking pond management on a regular basis, not just after hazard events. Similarly, exploring the use of alternative water sources is suggested. In addition, the following potential adaptation options are recommended:

- Construct and raise the height of the edge/boundary around pond water sources
- Excavate and re-excavate ponds
- Erectness around ponds to protect water sources from waste in surface runoff, especially during rainy seasons
- Undertake rainwater harvesting
- Reduce irrigation levels required for cultivation purposes

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Conflict of Interest

The authors declare no conflict of interest.

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