# Reducing Water Poverty in Coastal Bangladesh: Is Rainwater Harvesting a Sustainable Solution?


**By**

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## Declaration

It is hereby declared that this thesis or any part of this thesis has not been submitted elsewhere for the award of any degree or diploma. It has also followed no harm principle.

Mohammad Rafiqul Islam

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## Abstract

The background of this research is water poverty that intensifies survival challenges of coastal people in Bangladesh. More and less precipitation during monsoon and dry season respectively due to climate change, climatic disasters, and salinity are three leading responsible actors for water poverty crisis. This crisis affects socioeconomic status of coastal people, agricultural production, and environment. The focal point of this research is to examine whether Rainwater Harvesting System (RHS[1]) a sustainable solution for reducing Water Poverty (WP)[2] in coastal Bangladesh or not? To reach this objective, examine role of government, Non-Government Organizations (NGOs), see socioeconomic status of coastal people, social acceptability, availability of finance, and environmental sustainability of RHS. Socioeconomic, social and ecological system, and sustainability perspective have used as a conceptual framework in this study. Causes and effects of water poverty, alternatives for reducing water poverty, and sustainability of RHS used as analytical strategy. The primary data of this research derived from household survey, Focus Group Discussion (FGD), case study, and observation of coastal area's people such as farmers, fishermen, fisherwomen, day laborers, and women. The primary data also collected from water governance expert. The secondary data gathered from different kind of books, journal article (published and unpublished), seminar presentation, newspaper, and other sources related to rain(water) management, rainwater harvesting, transboundary rivers, climate change effect, and sustainability issues. As per research design of this study, the exploratory strategy is more suitable than other methods to analyze the data and information. To advise solution, the relation between water poverty (created by climatic disasters, mismanagement of rainwater, and salinity problems) in coastal areas and alternatives for reducing it and sustainability of RHS analyzed. The role of government regarding finance, training, awareness campaign, and policy about rainwater harvesting needs to improve in utilizing rainwater for resolving water poverty in coastal Bangladesh. Better performance of government also needs to make RHS more sustainable in coastal areas in Bangladesh.

[1]RHS = Rainwater Harvesting System/Technology
[2] Water Poverty = Water Shortage, Water Scarcity, Water Stress

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**Abbreviations**

| | |
|---|---|
| BARC | Bangladesh Agriculture Research Council |
| BBS | Bangladesh Bureau of Statistics |
| BDT | Bangladeshi Taka |
| BGD | Bangladesh |
| BRAC | Bangladesh Rural Advancement Committee |
| FGD | Focus Group Discussion |
| GS | Governance System |
| I | Investment |
| km/Km | kilometre/Kilometre |
| LGED | Local Government Engineering Department |
| l/L | litre/Litre |
| MEEM | Master of Environmental and Energy Management |
| m/M | metre/Metre |
| RH | Rainwater Harvesting |
| RHS | Rainwater Harvesting System |
| RS | Resource Systems |
| RU | Resource Units |
| RWHTs | Rainwater Harvesting Technologies |
| SES | Social Ecological System |
| U | Users |
| UK | United Kingdom |
| UNESCO | United Nations Educational Scientific and Cultural Organization |
| UT | University of Twente |
| UNFCCC | United Nations Framework Convention on Climate Change |
| UNFPA | The United Nations Population Fund |
| US$ | United States Dollar |
| WHO | World Health Organization |
| WP | Water Poverty |
| WWAP | United Nations World Water Assessment Programme |

## Chapter One

## Introduction

### 1.1 Background:

Water is an integral part of life and at the core of sustainable development. But densely-populated country Bangladesh faces challenges with supplying this resource to the people. This water crisis is more acute in coastal areas which cover nineteen districts facing or proximity to the Bay of Bengal. The coastal areas of Bangladesh known as vulnerable and opportunity zone for their features. This area is more vulnerable to man-made and climate induced disasters like cyclone, salinity intrusion, arsenic contamination, sea level rise, floods, than other areas due to proximity to the Bay of Bengal. However, the coastal people have been enjoying some advantages like beach, coral reefs, estuaries, seagrasses, mangroves, transport, water, fish, commerce, and other natural resources.

Water is a cross cutting issue for Bangladesh due to water governance and management problem. The country receives overabundance of water during monsoon[3]that inundated the country. The country received record volume of rainfall during April 2017 that inundated northeastern part and people are facing hardships due to this inundation (Davies, 2016). However, the country faces acute shortage of water during dry season[4]. Moreover, the country has already started to face the effect of climate change and this effect will exacerbate the problem as it is changing the pattern and intensity of precipitation that is predicted to be more and less during monsoon and dry season respectively. It will also extend the dry period and increase intensity of rainfall during monsoon. This widen gap between monsoon and dry period will create problem in the following ways:

[3] Monsoon=this season generally starts in June and ends in September. Sometimes this season starts earlier than usual due to climate change.
[4]Dry Season=this season usually starts in December and ends at the end of April. But this schedule is changing due to climate change. Sometimes it extends to at the end of May.

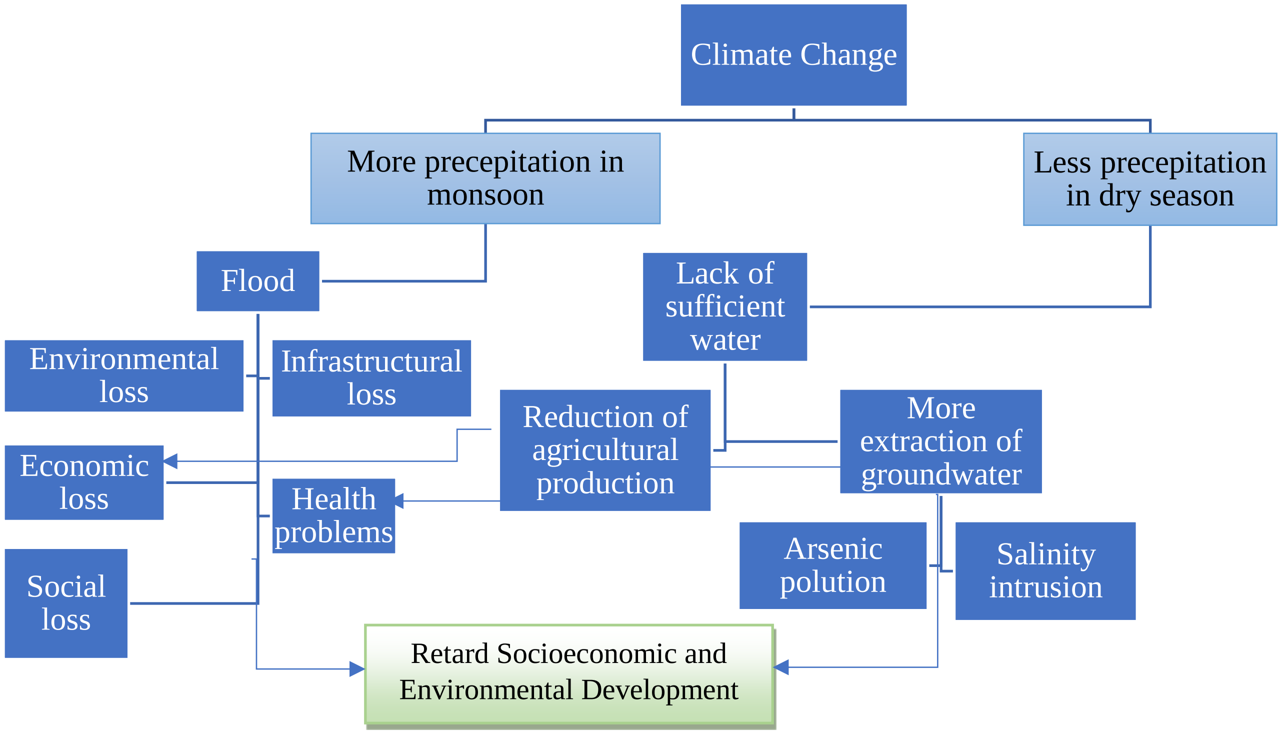



Figure 1.1: A schematic representation of climate change effect

**1.2 Water Poverty**

“Access to safe drinking water and sanitation is a human right” (WWDR, 2015). But the water for drinking and sanitation purposes is not available everywhere. Some people like coastal people of Bangladesh face fresh water shortage. This shortage of water can be called as “Water Poverty”. Water poverty can be defined as the shortage of water to meet water needs in the household, agriculture, and industrial sectors. According to United Nation Water (2006), water shortage (poverty) is a situation whereby water sources becomes inadequate for the community due to climate change, population growth or other factors that may lead to scarcity of water for consumption. Oxford Dictionary defines water poverty as the condition of not having access to sufficient water, or water of an adequate quality, to meet one’s basic needs (https://en.oxforddictionaries.com/definition/water_poverty). This definition measures water poverty in considering two aspects that is quantity and quality. These two aspects are interrelated to each other. For example, water is available but contaminated with either industrial and agricultural waste or arsenic or salinity. This kind of water is useless and can lead to water poverty. Raskin et al., (1997) measure water scarcity in terms of quantity as above 1700m$^3$ annual per capita water supplies indicates that little or no water scarcity and below 1000m$^3$ per capita indicates water scarcity that threat economic development, human heath, and wellbeing. Less than 500m$^3$ /capita water supply illustrate as absolute water scarcity. But coastal people of Bangladesh face water scarcity in terms of quality in major part of the year. The people of Bangladesh face this water poverty for various reasons but not limited to transboundary rivers water flow, salinity, climate change, and lack of good management of rainwater.

### 1.3 Causes of Water Poverty in Bangladesh:

Besides physical water scarcity other factor like arsenic contamination, rainwater runoff, salinity intrusion, and climate change effect are also responsible for creating water poverty in Bangladesh. Water poverty can be made in two ways such as physical water scarcity and quality water problem. The following figure shows how different actors are responsible for creating either physical scarcity or quality crisis of water.

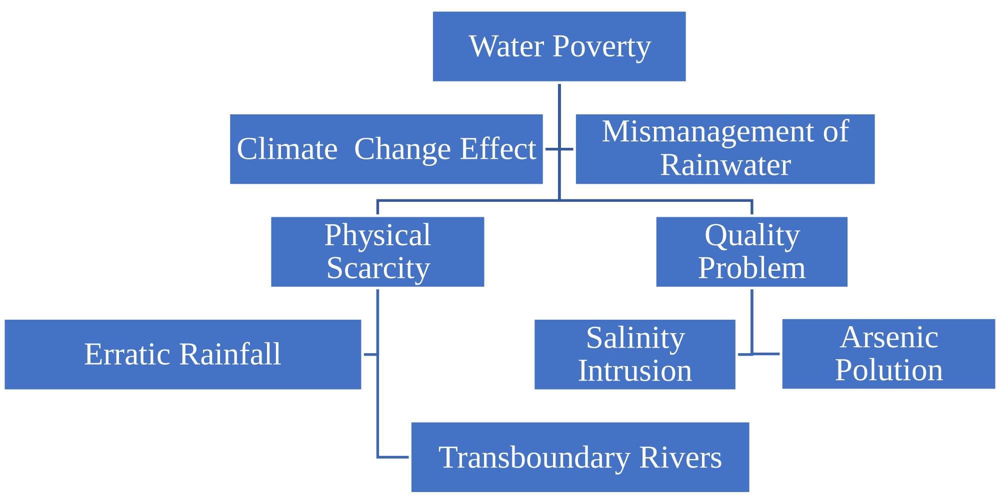



Figure 1.2: Causes of water poverty in coastal areas

The country has received average estimated annual rainfall 284km$^3$ between 1985 and 2010 (Ismail, 2016). This rainfall occurs mostly in monsoon that is three times more than evaporation rate. Almost entire of these rainfall runoffs and ends up in the Bay of Bengal (Ismail, 2016). Lack of initiative to use rainwater for potable purposes may assist to cause water poverty. Islam (2011) pointed out that mismanagement of rainwater causes water scarcity in Bangladesh. "Lack of water supply takes huge tolls on health and well-being and comes at a large financial cost, including a sizable loss of economic activity" (WWDR, 2015:3).

Climate Change is directly and indirectly responsible for water poverty in Bangladesh. It creates water poverty in both quantitative and qualitative ways. Less rainfall during dry season is quantitative ways and salinity intrusion, floods, and arsenic contamination is qualitative way to make water poverty.

The country is very much prone to floods due to geographical location and mismanagement of extreme rainwater. Heavy rainfall and Himalayans fed rivers in monsoon in 2007 created flood in Bangladesh that affected more than nine million people and inundated more than half of 64 districts of the country. Rainfall is an important natural factor that determines the agricultural production in Bangladesh (Shahid, 2009) and scientists predicted that it could change on global (Hulme et al., 1998; Lambert et al., 2003; Dore, 2005) and regional scales (Rodriguez-Puebla et al., 1998; Gemmer et al., 2004) due to climate change. The change is predicted to be more rainfall in monsoon and less in dry season due to climate change. The impacts of this change are important for Bangladesh where hydrological disasters like floods are common (Shahid, and Behrawan, 2008) during monsoon and water scarcity in dry season. In this context, the country needs to use the extra rainwater for reducing gap between more rainfall during monsoon and less rainfall in dry season otherwise the country will face severe water shortage.

One billion people could face water shortage due to drought by 2050 in Asia (Cruz et al., 2007). As one of the most climate vulnerable country, drought affects Bangladesh severely. The country has faced number of severe droughts in the last fifty years: 1951, 1957, 1958, 1961, 1972, 1975, 1979, 1981, 1982, 1984, 1989, and 1994 (Banglapedia, 2014).

Bangladesh lies at the confluence of three large rivers (the Ganges, the Brahmaputra, and the Meghna). These rivers come to Bangladesh through India. The upstream country India transfer water from these rivers unilaterally with dam, barrage, and river link projects. "India has built Farrakka Barrage which is known as "Barrage of Death" for Bangladesh" (Asaduzzaman and Rahman, 2015:2) due to adverse effect of this barrage on Bangladesh. This barrage diverts

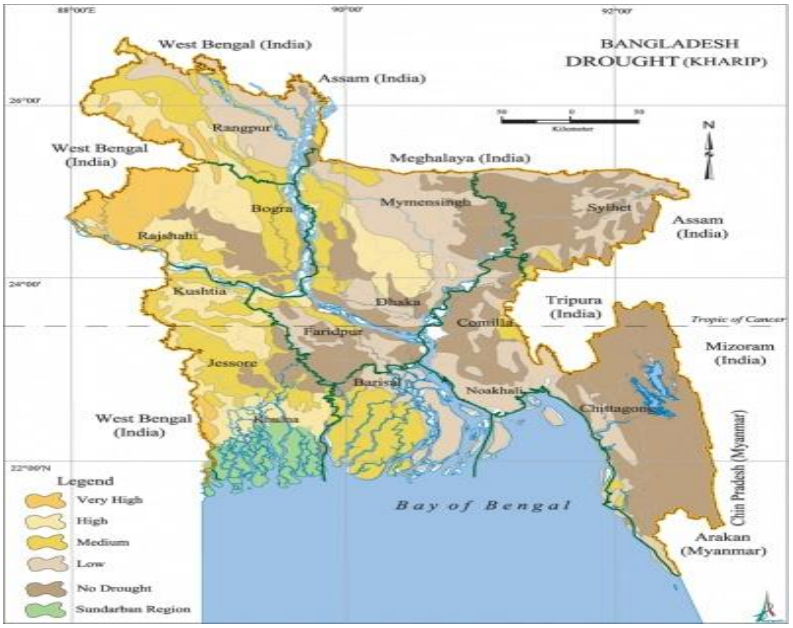



Figure1.3**:** Drought Prone Area in Bangladesh (Banglapedia, 2014)

water from the Ganges and that diversion created water scarcity in Bangladesh so that the environment, biodiversity, agriculture, and people are suffering due to lack of water. The proposed Tipaimukh Dam will another Farrakka for Bangladesh as it will hold 27% more water in June, 16% in July, 14% in August, and 4% in September during the period of agricultural cultivation and fisheries (Rashid, 2011; Asaduzzaman and Rahman, 2015).The following figures shows the erratic rivers flow that the leading factor for water poverty in Bangladesh (Ahmed and Roy, 2007) and lead the people to find alternative solution for their water crisis.

| **River** | **Station** | **Peak flow ($m^3$)** | **Lean flow ($m^3$)** | **Lean flow (% of peak)** |
|---|---|---|---|---|
| **Ganges** | Hardinge | 76,000 | 526 | 0.7 |
| **Brahmaputra** | Bahadurbad | 102534 | 2860 | 2.79 |
| **Meghna** | Bhairab Bazar | 19,800 | | |

Table 1.1**:** Peak and lean flow in the major rivers in Bangladesh (Ahmed and Roy, 2007)

The water flow of transboundary is highly variable and cannot rely to provide uninterrupted water supply to the people. Furthermore, anticipated climate change may increase intensity and frequency of extreme events in Bangladesh (Xenarios et al., 2013) that may deteriorate water crisis problem.

Salinity problem is another factor causes water poverty in qualitative terms. Although the water is available but not usable as it is salty. Besides salinity intrusion, arsenic contamination is also affected the groundwater sources that make the groundwater unusable for potable purposes.

Arsenic contamination is another qualitative water poverty that affect fresh water supply of the country badly. The present water extraction from groundwater is unsustainable because the extraction rate is higher than recharge rate and it causes arsenic problem. In 2010, groundwater was extracted at the rate of 53 billion $m^3$ per year. In the same time, it was recharged by 50 billion $m^3$ (Ismail, 2016). "Seventy-five million people are at risk of arsenic contamination in water and 24 million are potentially exposed to arsenic contamination" (Safiuddin, and Karim 2001:1). The salinity intrusion and arsenic contamination affected the groundwater but the country receives good rainfall every year that can be used for potable, agricultural, and industrial production.

## 1.4 Effects of Water Poverty

Natural ecosystems and human being suffer from lack of water in many basins areas. These areas are in Africa, South Asia, Northern China, the Mediterranean region, the Near East, Australia, the USA, Mexico, north-eastern Brazil, and the western coast of South America. In these areas, people and ecosystems are more vulnerable in more rainfall variation due to climate change (Kundzewicz et al., 2007: 190). This lack of water also affect the agricultural production, increase health related problems and creates division into society based on water availability.

The climate change induced drought has already damaged one-million-ton food grains in 1997 and 50% of food grains were destroyed in the 1982 floods in Bangladesh. Scientists predicted that rice and wheat production could shrink up to 28% (rice) and 68% (wheat) because of temperature rise by 1-2 degrees Celsius (Islam et al., 2011). However, sea level rise possesses the risk of estimated losses to reach 10% GDP (Gross Domestic Product) by 2050 (WB, 2000). Low rainfall lead to drought in 1994-1995 decrease in rice and wheat production by $3.5 \times 10^6$ MT (Rahman and Biswas, 1995). Agriculture sector in the dry areas used around 80% of the availability of water and the competition for this resource among sectors will reduce to 50% by 2050. This reduction will seriously threaten the food security and overexploit limited water resources that impeded social and economic development in the dry areas (Oweis and Hachum, 2003). Moreover, either water scarcity or extra water may create health related problems like malnutrition, diarrhea, cholera, malaria that exacerbate the situation.

Diarrhea and malnutrition are two climate change related problem that arise due to lack of fresh water or excess of water. This problem is the largest burden in the world particularly in Southeast Asian countries including Bangladesh. It is anticipated to increase illness and death from diarrhea diseases due to drought and flooding and are also expected from increased of cholera bacteria in coastal areas (UNFCCC, 2006). Many people will lose year-round access to drinking water due to irregular rainfall and recurrent costs of public health will increase. Mean rainfall in the pre-monsoon (March, April, and May) and monsoon (June, July, and August) will increase by 100 millimeters (Sarker and Ahmed, 2015). Besides this quantitative water shortage, lack of quality also creates water crisis that affect the socioeconomic and health sector of the country.

Ismail (2016) mentioned that "heightened exposure to arsenic can cause health problems for those that consume water with a high concentration of the element". Mason (2010) mentioned that arsenic contaminated water killing one person out of every five persons who have been shown off[5]in Bangladesh. The author also mentioned that countless tube wells are continuously dug without test of water for this toxin in Bangladesh. Mason (2010) mentioned the quotation of Richard Wilson, President of the nonprofit Arsenic Foundation and Physics Professor emeritus at Harvard University about the arsenic that is "The magnitude of the arsenic problem is 50 times worse than Chernobyl. But it does not have 50 times the attention paid to it". As rainwater is free from arsenic and salinity it can use for battling this effect with rainwater harvesting that can ultimately reduce dependency on groundwater.

Women were recognized as the central role player of water management in the Dublin Principles in 1992. It was adopted at the International Conference on Water and Environment (Wahal and Harti, 2012). Traditionally women and girls are responsible for collecting water in almost every developing country in the world (Wahal and Harti, 2012) including Bangladesh for household activities like cooking, sanitation, washing, and drinking. To collect this water, women walk around six kilometres per day in many developing countries (UNFPA, 2002) like Bangladesh. Some coastal areas of Bangladesh women spend half of the day to access to fresh

[5]Shown off means diseases exposed which caused by drinking arsenic contaminated water

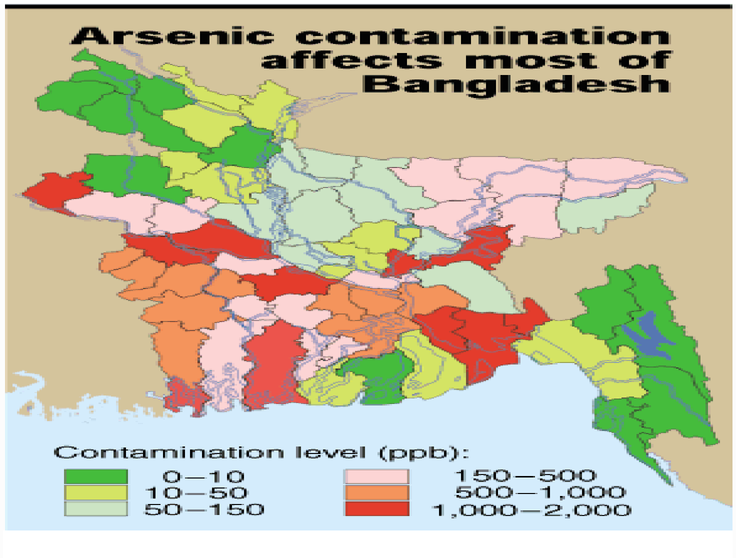



Figure 1.4:Arsenic Contaminated Areas in Bangladesh (IIBB, 2017)

water that is the basic need of a family (Khan, 2016). If the water is scarce or contaminated it is the responsibility of women to find alternative source that takes more time and effort to collect. As the water in coastal areas of Bangladesh is contaminated with arsenic and salinity, women face several health problems like skin diseases, excessive hair loss, urinary tract infections, chronic dysentery (Khan, 2016). Furthermore, a study conducted by Mandal *et al*., (1996) found a number of common arsenical manifestation and arsenic lesions such as different types of melanosis (e.g., diffused melanosis, lucomelanosis, mucus membrane melanosis, spotted melanosis), different kinds of keratosis (e.g., diffused keratosis, shyper keratosis, spotted keratosis, gangrene, squamoous cell carcinoma and hyperpigmentation) in palms and soles and non-cirrhotic portal fibrosis among the population affected by arsenic in Bangladesh. The patches may develop into cancer and foot will probably have to be amputated in a later stage (Pontius et al., 1994; Battacharaya et al., 1997). Furthermore, exposure to arsenic may create long term health effects such as skin cancer, hypertension, pulmonary diseases, peripheral vascular diseases, neurological effects, and internal cancers of bladder, kidney, liver and lunges (WHO, 2000). Additionally, water crisis creates social problems and isolated the water scarcity areas from water abundance areas.

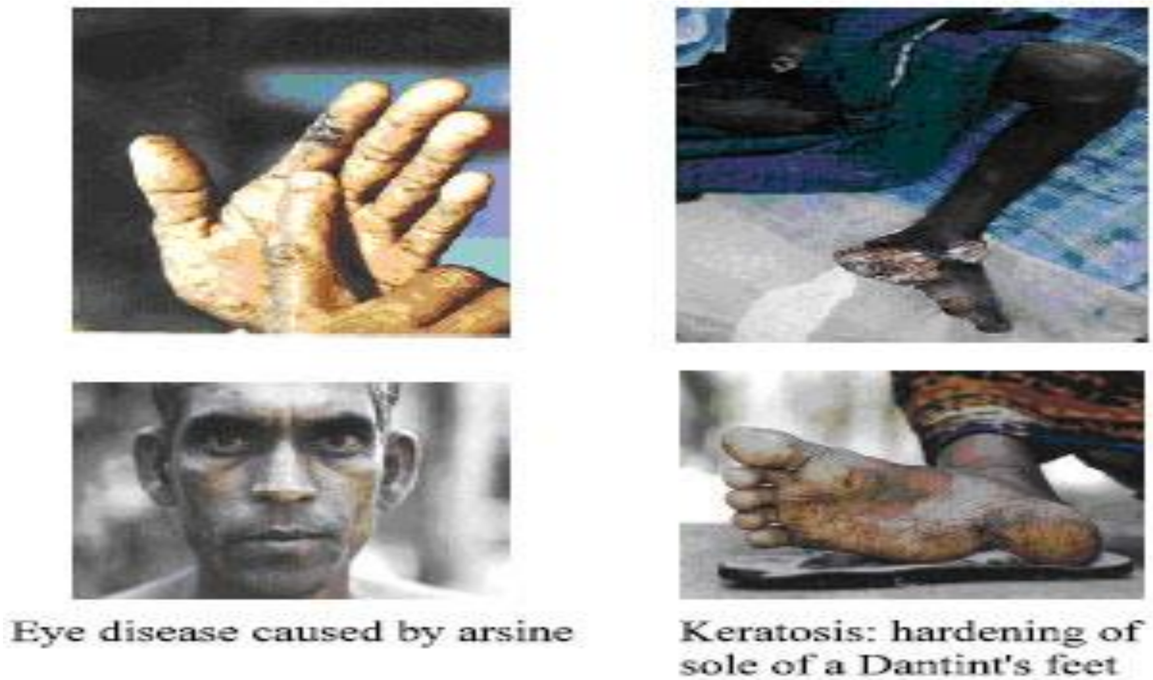



Figure 1.5: Arsenicosis including eye disease and keratosis (Adapted from Chowdhury et al., 2006)

According to Kibria (2014:2) “Rural women come under enormous pressure and water scarcity is often a cause of domestic violence”. He also links the water scarcity with marriage that the parents of the boys are not interested to select bride from saline prone areas due to the roughed skin of women from using saline water. Moreover, the parents of a girl do not want to select bridegroom from such communities where water is not available because after marriage their daughter will need to travel far way to collect water for her family (Kibria, 2014).

### 1.5 Objectives of the study

The study assesses overall scenario of potable water supply sources in coastal Bangladesh and find most suitable option to reduce water poverty for socioeconomic and environmental development in the study area. The more clearer and distinct objectives of this study are:

(i) To find out present status of potable water supply in the study area;
(ii) To examine different alternatives for solving water poverty problem;
(iii) To assess sustainability of rainwater harvesting ;
(iv) To evaluate water supply options through social ecological system framework and

(v) To recommend for socioeconomic and environmental development with reducing water poverty in coastal Bangladesh.

### 1.6 Organization of the study

Besides current chapter, rest of the study contains the following ways:

Chapter two presents the overview of potable water supply in coastal area of Bangladesh. It consists the origin and extent of existing water poverty problem in the coastal area. This chapter answers the question how different sources of water and climate change are responsible for water poverty? A comprehensive description of study area is presented in chapter four. The description includes the climate, river systems, vulnerability, socioeconomic status of people, and domestic potable water supply system in the study area. Chapter five presents the methodology of the study. It describes steps and processes of study framework and analytical strategy. Social Ecological System framework is presented in chapter three. It discussed the interaction between different actors such as governance systems, users, resources systems and units, in wide social, ecological, and political settings for better and sustainable outcome of the ecological resources like rainwater. This chapter also discussed the sustainability issue with considering local ecological context. Additionally, application of social ecological systems in water resource management particularly in Bangladesh context is also reviewed in the chapter. The chapter also describes primary and secondary data collection methods such as face to face interview, focus group discussion, case study analysis, secondary data sources, and observation. Result and discussion presents in chapter six. It is the summary of findings obtained from participatory process (e.g. focus group discussion, case study analysis, face to face interview, observation). It presents the findings for sustainable potable water supply in the coastal area with considering local ecological context and interaction theory. The last chapter includes the conclusion and recommendation for solving water poverty problem, and for socioeconomic and environmental development.

# Chapter Two

## Overview of Potable Water Supply at Coastal Area in Bangladesh

### 2.1 Introduction

Potable water is the water that meet up the international or local or both standard that can be consumed or used without any physical risk of instant or short term or long term illness. Humans have lack of sufficient access to potable water over large part of the world. These parts of the world use contaminated or unacceptable standards of water. Using such polluted water in food preparation and drinking purposes leads to widespread and acute illness and this illness is a major reason of death in many countries particularly developing countries. The people of rural areas in Bangladesh suffer acute shortage of potable water. Surface water sources are generally polluted and negatively influenced by climate change effect and upstream country's intervention. Furthermore, different part of the country's groundwater sources of potable water is contaminated with arsenic and salinity. Salinity intrusion from seawater deep into the land in the southeast part of the country are delivering groundwater disqualify for use. Moreover, agrochemicals into shallow aquifers may also make water unfit for human and animal consumption. Additionally, over extraction of groundwater for agriculture, potable use, and industrial purposes also lowered water table in different areas that out of reach for hand tube well.

Ground water is the main source of potable water in Bangladesh. Bacteriological quality of water received priority for potable water supply because of high prevalence of diarrheal disease in Bangladesh[6]. As groundwater is free from pathogenic and microorganisms (Islam et al., 2014), low cost hand tube well based water supply from shallow aquifers considered better option for supplying potable water in rural areas. With this initiative by government, NGOs and individual household, Bangladesh achieved remarkable success by bringing 97% of rural population under bacteriologically safe water supply (BGS, 2001). It is a matter of unfortunate that when rural people started to use tube well water for potable purpose, arsenic presence in groundwater with excess of acceptable limit in different region of the country make difficult to ensure safe drinking water supply with tube well.

[6] http://www.dphe.gov.bd/index.php%3Foption%3Dcom_content%26view%3Darticle%26id%3D96%26Itemid%3D104). Accessed on August 09, 2017

The achievement of hand tube well water supply in rural areas is on the edge of collapse because of arsenic presence in groundwater which is beyond acceptable limit in shallow aquifers in Bangladesh (BGS, 2001). According to the standard in Bangladesh acceptable limit of arsenic is less than 0.05 mg/L and excess of this limit is unsafe. But as per World Health Organization (WHO) acceptable limit of arsenic is 0.01 mg/L. The arsenic pollution alone has reduced the national population coverage by safe water from 97 percent to 74 percent (Ahmed, 1996). But with considering Safiuddin and Karim (2001) study, population coverage by safe water reduced from 97 percent to about 50% as total population of Bangladesh increased to around 150 million.

Surface water and ground water are two main sources of water in Bangladesh. The surface water includes rivers, rainwater, pond, reservoirs, lakes, canals. Moreover, ground water includes shallow and deep aquifers. Both sources are dependent on each other for playing active and effective role for maintaining the water supply at an adequate level. Several streams receive major portion of their water flow from groundwater sources. Moreover, during the dry season groundwater flows into surface water (withdraw water from ground source), and surface water enters ground in rainy season (rainwater penetrates into ground through evatranspiration) because of rainfall. As two sources are interdependent over-use of one of the source affect the availability of the other source. For instance, recent years over exploitation of groundwater for irrigation and potable use caused lowering ground water table and drying up surface water sources. Rainwater can be a good alternative source of water supply as groundwater and surface water is insufficient to meet the demand.

## 2.2 Status of Potable Water in Coastal Areas

The coastal area of Bangladesh (shown in figure 2.1) categorized into exposed and interior coast in terms of location of land. The areas that confront coast or river estuary are addressed as exposed coastal area. There are 147 Upazilas in 19 districts comprised in total coastal area of Bangladesh in which 48 Upazilas[7] fall into exposed coastal area and remaining 99 Upazilas fall into interior coast as those are located behind the exposed coast (Sikder, 2010).

[7]Upazila means Sub-district. It is sub-district level of local government. It covers several union (one union is made up of 20-30 villages).

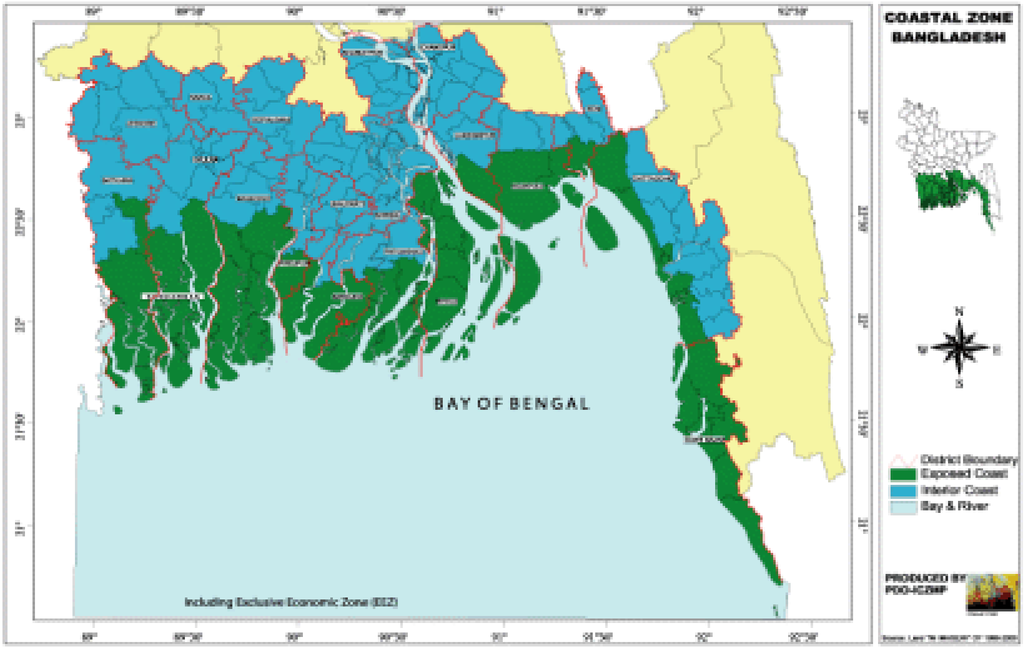



Figure 2.1 Coastal Area of Bangladesh (PDO-ICZMP, 2004)

More than 76 Upazilas in the coastal belt have been identified as problematic areas where complex hydrogeological conditions and contrary water quality make water supply hard compared to other parts of the country (Sikder, 2010). Lack of safe potable water supply has been identified as top priority issue in daily life of coastal population. Coastal people are mainly depended on the following sources of water for their potable use.

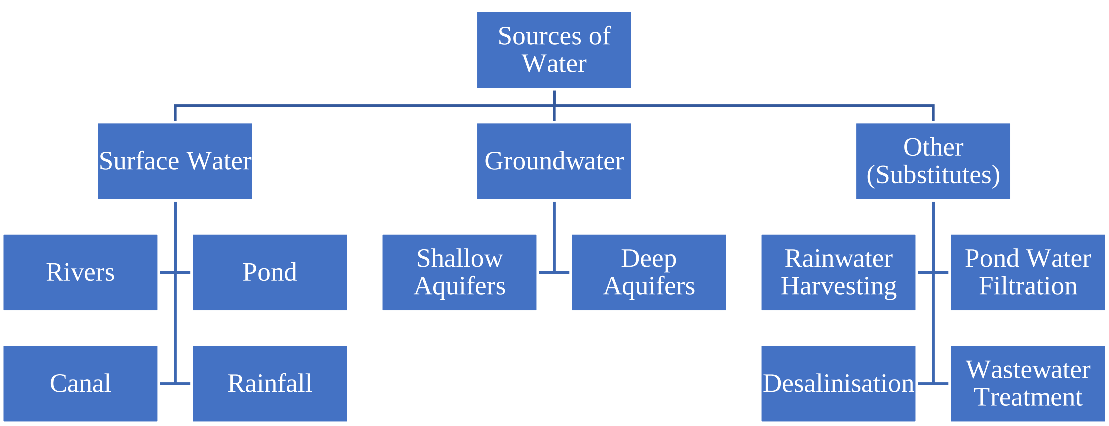



Figure 2.2: Water sources in coastal areas in Bangladesh

**2.2.1 Surface Water:** Surface water plays an important role for meet up demand of water in coastal areas in Bangladesh. The whole coastal belt is crisscrossed by different rivers and their tributaries.

The rivers include the Transboundary Rivers which come via India and Myanmar. There are 57 transboundary rivers flowing through Bangladesh and 54 out of 57 transboundary rivers come from India. Bangladesh is getting 92.5% of surface water from out of country sources and this dependency creates water scarcity because of water management pattern by neighboring states including designed interventions and anthropogenic actions (Kolås et al., 2013).Despite water sharing treaty with India like Ganges Water Sharing Treaty in 1997 the combined inflows of all transboundary rivers have reduced to 186km$^3$ from around 1,260 km$^3$ (Ismail, 2016).

Saline intrusion to the surface and groundwater due to lowering groundwater level, excessive withdrawal from aquifers, lack of recharge, and sea level rise is expected to reduce the freshwater availability (Essink, 2001; Peirson et al., 2001; Beach, 2002; Bueh et al., 2003; Chen et al., 2004) and this salinity affects the rivers and estuaries further (Knighton et al., 1992). There are 14,698 square kilometer areas are highly exposed to extreme salinity of 1ppt of zero sea level rise (Sarker and Ahmed, 2015). But increase sea level rise predicted as a consequence of climate change will exacerbate the situation significantly. Most of these highly saline exposed areas are southern part of Bangladesh as these areas beside the Bay of Bengal. In these areas, salinity intrusion creates problem for potable water supply and agricultural practices (Islam, 2004). The salinity level of some coastal districts is presented below:

| District | Salinity in surface water in ppm |
|---|---|
| Bagerhat | 5->10 |
| Barguna | 1-5 |
| Barisal | 0 |
| Bhola | 1-10 |
| Patuakhali | 1-10 |
| Pirojpur | 0-10 |
| Satkhira | 5->10 |
| Khulna | 5->10 |

Table 2.1: Salinity presence in surface water in some coastal districts (Source: Islam, 2004)

Water supply from canal and pond is relying on the rainfall and rivers. But water flow in river is reducing due to several reasons like water diversion from cross Border Rivers in upstream countries, erratic rainfall because of climate change, ineffective river water management. Furthermore, rainfall is erratic and will be more erratic due to climate change effect and this effect will impact more on coastal people. However, where groundwater is either saline or beyond capacity, pond water is playing important role for supplying water for domestic purposes for a short period of time in year. But this water is completely unsuitable for drinking because of industrial, agricultural and domestic waste expose to canal and pond. The water stores in pond mainly come from rainfall which could pollute with pollutants during flowing to pond. Furthermore, "Pond water is available and comparatively less saline but turbid, colored and contaminated by pathogenic microorganisms. Moreover, during cyclone or flood disaster, sea water enters into the ponds that are used for Pond Sand Filters (PSF) and damage the whole systems" (Islam et al., 2015:223). In this circumstance, water supply from pond and canal is no longer as a possible source for coastal community in Bangladesh.

**2.2.2 Groundwater:** The water supply sector in Bangladesh has achieved laudable success during the last few decades through over exploitation of groundwater source. This source can't take any longer extra pressure for over exploitation. In recent years groundwater based water supply is suffering from a number of major problems such as arsenic concentration, salinity intrusion, water table lowering, lack of recharge time and volume of water, and non-availability of suitable aquifer. "The people in 59 out of 64 districts comprising 126,134 square kilometres of Bangladesh are suffering due to the arsenic contamination in drinking water" (Safiuddin and Karim, 2001:3). "There are 12 districts with high % of arsenic concentration, of which 7are in coastal zone: Chandpur (90%), Gopalgonj (79%), Noakhali (69%), Satkhira (67%), Sariatpur (65%), Bagerhat (60%), and Laxmipur (56%). There are 12 districts with less problem arsenic, three of which are located in the coastal zone: Barguna (0%), Patuakhali(0%), and Cox's-Bazar(2%)" (Mahadi, 2009:3). According to Islam et al., (2014) around 41 MCM[8] of the aquifer dewatered by the year 1988 that increased to 2,272 MCM in 2002 and this extraction may severely threaten the sustainability of aquifer (Hoque et al., 2007). Additionally, groundwater level in Dhaka city is going down three metres every year (Sengupta et al., 2012). Moreover, water extraction from ground source with water pump requires energy (Abdullah and Rahman, 2015) but the country faces energy crisis.

The process of groundwater uptake makes the country vulnerable to arsenic contamination (Abdullah and Rahman, 2015) and may be vital reason for creating a zone of aeration in clayey and peaty sediments which contain arseno-pyrite (Safiuddin and Karim, 2001) that accomplice

[8] Million Cubic Metre

arsenic contamination in Bangladesh. At the other hand, as major part of Bangladesh composed of a vast thickness of alluvial and deltaic sediments which contain pyrite that favoured arsenic contamination of groundwater in Bangladesh (Safiuddin and Karim, 2001). Coastal areas are on the Ganges Basin and most of the arsenic problems occurring in the younger sediments derived from the Ganges Basin and arsenic in sediment or water can move in adsorbed phase with iron, which is available in plenty in the Himalayas (Safiudin and Karim, 2001) which is the source of Ganges River[9]. "The investigators also found that there is a layer containing arsenic compound at a depth of 20 to 80 metres" (Daily Independent, 1998) and the geological investigation identified that this layer is rich in arseno-pyrite, pyrite, iron sulfate, and iron oxide (Safiuddin and Karim, 2001) that contribute on arsenic contamination in ground water. The layer of tube well in Bangladesh is well under this (20 to 80 metres) ground level.

**2.2.3 Other (Alternative):** Rainwater is another good source of water in coastal area of Bangladesh. As a tropical country, Bangladesh receives profound rainfall during rainy season and intensity of this rainy season's rainfall will increase due to climate change. Rainwater collection in large size earthen pitcher and use for potable use is a common practice in some coastal areas where salinity problem is acute. If the people have had enough storage capacity rainwater is sufficient enough to meet up the demand of water need in whole year. As most of the people in coastal area are poor they cannot afford to construct sufficient storage capacity to store rainwater for whole year. Furthermore, if the collected rainwater does not keep in safe tank the quality of collected rainwater in terms of colour and odour deteriorates after few months. In this context, the users need to rely on other unreliable and unavailable sources of water to satisfy their demand.

As mentioned earlier that river is the main source of water of pond water. But availability of water in river is not reliable because upstream country diverts water from rivers and as a down-stream country Bangladesh receives less water in river day by day. From another point of view, natural disaster like storm surge and cyclone bring saline water into the pond and contaminated pond water with salinity. As a result, pond sand filtration process is not reliable for water supply in the coastal area.

[9]This river comes to Bangladesh via India and major water source for Bangladesh.

The use of available water like seawater as a source of potable water supply demands economically very expensive treatment like desalinization by reverse osmosis or electro dialysis. It is not a viable solution for coastal people because of their socioeconomic situation. Development of alternative water supply system needs to consider socioeconomic and environmental context of coastal people. Due to the income poverty of the majority of the population the newly developed system should be low cost and environment friendly.

### 2.3 Conclusion

Despite the commendable success of safe water supply with over victimization of groundwater in Bangladesh, its safe water supply is in danger due to natural hazards like cyclone, storm surge, arsenic contamination, salinity, over extraction of groundwater, and climate change effect. The coastal area is more prone to these natural hazards and clime change effect as most of the natural hazards related to water and coastal people are always proximity to water. The country need to find alternative sources of water which are reliable, low cost, and environmental friendly.

# Chapter Three

# Literature Review

### 3.1 Introduction

This study has been identified number of causes of water poverty, effects of this crisis, and solutions regarding this problem. But every solution is not viable for coastal people in Bangladesh due to their socioeconomic position, ecological, environmental, and sustainability concerns. The coastal people use rainwater to meet up their potable water demand. Rainwater harvesting system has been gaining popularity between coastal people due to low cost, easy to manage, and other advantages. Besides these advantages, it has connection with variety of aspects like challenges of rainwater harvesting and rainwater harvesting as a flood protector, water supplier, energy savers, agriculture developer, and climate change mitigator.

### 3.2 Rainwater Harvesting

Rainwater Harvesting is an integrated system that includes rainwater catchments areas, water storage and transportation systems. Rainwater harvesting is a system of inducing, collecting, storing, using, and conserving local rainwater either from roof top or in open space for agricultural, potable, or industrial purposes. Rainwater Harvesting (RH) involves a system of concentrating, storing, and collecting rainwater for agricultural, environmental, domestic, and industrial uses (Hatibu and Mahoo, 1999; Sutherland and Fenn, 2000). “Rainwater Harvesting strategies may vary from direct runoff concentration in the soil for direct uptake by the crops, to collection and storage of water in structures (surface, sub-surface tanks, ponds and small dams) and aquifers for future productive uses” (Pachpute et al., 2009: 2816). They also classified the rainwater collection systems as roof top catchment system, in-situ catchment systems and run off catchment systems. Most popular system is roof top catchment system in coastal area of Bangladesh.

3.2.1 Catchment Area: The catchment area is rooftop of building where the rain falls. It is manmade structure. The volume of water collection and performance of rainwater harvesting depends on this rooftop. “There are various materials that can be used on the catchment surface to reduce permeability, such as water repellent, gravel-covered plastic sheeting, concrete, asphalt fiberglass” (Yuan et al., 2002: 2). Islam et al., (2014) found four different types of rooftop catchment in southwest coastal region of Bangladesh. These catchment shows in figure 3.1:


Iron/metal sheets


Tiles


Flat roof


Thatched

Figure 3.1: Types of rooftop for rainwater catchment (Islam et al., 2014)

The volume of rainwater collection directly related to the size of catchment area. If the catchment area is big then rainwater collection is huge and vice versa.

3.2.2 Guttering: Gutter collects rainwater from rooftop of building and conveys water to the downpipe. Gutters can be prepared by plastic pipe, wood, and bamboo. The size of gutter depends on the size of rooftop of the building. Figure 3.2 shows guttering system where use plastic pipe as gutter.


Figure 3.2: Guttering system of rainwater harvesting system (Source: field data)

3.2.3 Down Pipe: A material needs to make connection between gutter and storage tank. The connector conveys harvested rainwater from gutter to storage tank. There are a number of different materials use as down pipe such as polyethylene, plastic pipe, and rope. In the most cases, plastic pipe uses as connector. The following figure (3.3) shows that plastic pipe use as connector between gutter and storage tank of rainwater harvesting system. If rope uses as connector then there is required of hanging iron metal on the last part of rope which fall into the storage tank because it prevents rope to move away from the storage tank by wind.


Figure 3.3: Down pipe in rainwater harvesting system (Source: Filed data)

3.2.4 Storage tank: Storage tank is the most expensive material in rainwater harvesting system and also more important for storing harvested water. The size of the tank should be matched with: the volume of water to be harvested, demand and supply of water in particular household (water demand in household depends on the size of family), and intensity of rainfall in particular area. There are different types of storage tank use in Bangladesh like ferro-cement tank, earthen pitch, and plastic tank in different sizes (500 litres, 1000 litre, 1500 litre, 5000 litre). As per observation, plastic pipe is more popular tank in the study site.

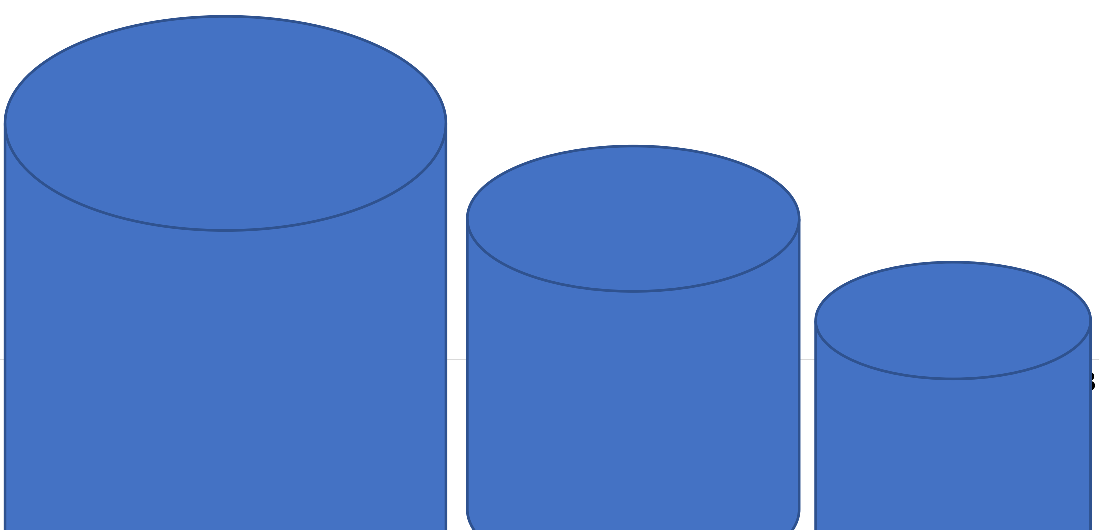


Figure 3.4: Different sizes of storage tank in rainwater harvesting system

3.2.5 Foul Flush Diversion: The first rain in the season likely contains dust, dropping and debris and leaves collected on the roof. These contaminants should be flushed away to avoid pollution the collected rainwater. This flush can be achieved in different ways like pipe can turn away from the mouth of the tank or a switch adjust to divert the water from the pipe and flush away. The time of flush should be five to ten minutes.


Figure 3.5: Foul Water diversion switch (Source field data)

Figure 3.6: Foul water diversion pipe (Source: field data)

### 3.3 Challenges of Rainwater Harvesting

Widespread use of rainwater harvesting must consider the constraints of technological, ecological, social, economic, political (Li et al., 2000), quality, and knowledge factors. Lack of knowledge and data on critical drivers and processes about rainwater harvesting technologies in Bangladesh slow the adoption of this technology (Abdullah and Rahman, 2015) for socioeconomic development by utilizing ample rainwater. Lack of awareness about the maintenance and operation of rainwater harvesting system negatively affect the performance of the system (Rahman and Jahra, 2006). Financing from either public agricultural development schemes (supported by both bilateral and multilateral programmes) or international or national NGOs is limited and not efficient in terms of consistency and successful up scaling (Abdullah and Rahman, 2015). Islam et al., (2014) found that lack of space for storage tank and low mineral salt in rainwater is another challenge to use rainwater for potable purposes. Mineral salt is an important nutrition for health which can be found in water. It may need to add mineral salt to the collected rainwater to counter the low mineral salt levels. Mineral salt addition with harvested rainwater may increase cost of using rainwater harvesting system. RH may be an attractive from economic, technical, and ecological point of view but potential health risks from intake of harvested rainwater related to microbiological and chemical contaminants need to take into consideration (Ghose et al., 2015). Chemical as well as microbiological contaminants have been found in the harvested rainwater and sometimes exceed international and national guidelines for safe drinking water (Simmons et al., 2001; Chang et al., 2004; Zhu et al., 2004).Although RHS has some drawbacks but it is playing important role for supplying safe water supply in coastal area in Bangladesh.

### 3.4 Rainwater Harvesting and Water Supply

Rainwater has good quality for potable and agricultural use. The harvested rainwater is free from arsenic contamination and represents suitable and acceptable means of potable water as it meets physical, chemical, and bacteriological quality (Rahman and Jahra, 2006). As rainwater is free from arsenic contamination it is good for health. Hunter et al. (2010) illustrate that there is a positive relation between adequate fresh water supply and health. This relation has direct and indirect impact on health. For example, poor-quality drinking water is an important contributor for diarrhea (Pruss and Havelaar, 2001; Fewtrell et al., 2005) and "diarrhoeal disease is the second most common contributor to the disease burden in developing counties" (Hunter et al., 2010: 2).

On an average, Bangladesh receives about 2400mm rainfall per year (Ghosh et al., 2015). Collected rainwater is enough to supply water for 8-10 months in the driest region (Rajshahi) of Bangladesh (Rahman and Jahra, 2006). Dallman et al., (2016) did a study at California about the possibility of rainwater harvesting for resolving water crisis. They found that rainwater harvesting systems were able to save 12.74 million $m^3$ water per annum where average annual rainfall in the watershed was 381 mm during their analysis period.

Water scarcity is becoming severe in southwestern coastal areas of Bangladesh (Harun and Kabir, 2013) due to salinity intrusion, arsenic contamination, lack of water in rivers, and over extraction of groundwater. This scarcity creates high food insecurity (Yu et al., 2010) and health related problems as they are not being able to get enough water for agriculture and potable use. "This problem can be overcome by wise adoption of Rainwater Harvesting Technologies (RWHTs) (Abdullah and Rahman, 2015: 11).

### 3.5 Rainwater Harvesting and Climate Change

Currently, climate change is widely recognized as the most critical issue facing by the world and Bangladesh is one of the most vulnerable countries. Within the country, coastal people are more vulnerable than other region's people of Bangladesh. Global warming due to carbon emission is the main actor for this climate change. Using rainwater for potable purpose reduce groundwater demand which need energy to extract, treat, and distribute. Reduced demand of groundwater for potable purpose associated with energy savings and carbon emissions. These two resources are closely linked as energy is required to extract water from ground source, transport, treat, and distribute (Ruberto et al., 2013). Anticipated climate change may increase intensity and frequency of extreme events (Xenarios et al., 2013) and erratic rainfall in Bangladesh which may deteriorate to water crisis problem in coastal area due to the area's vulnerability to climate change.

Agricultural productions in Bangladesh rely on rainfall (Shahid, 2009) and this rainfall is predicted to change on global (Hulme et al., 1998; Lambert et al., 2003; Dore, 2005) and regional scales (Rodriguez-Puebla et al., 1998; Gemmer et al., 2004) due to climate change. Water and climate are interacted to each other in such a complex way that any change in these ways can accelerate change in other with quantity and quality of water (Kundzewicz et al., 2007) that can cause water poverty. The impacts of this changes are important for Bangladesh where hydrological disasters like floods are common (Shahid, and Behrawan, 2008) during monsoon and water scarcity in dry season and as well as in monsoon (quality problem). The negative impact of climate change on water supply can reduce with rainwater harvesting for agricultural or potable or industrial purpose. Furthermore, rainwater harvesting strategies may use for irrigation purpose in agriculture.

### 3.6 Rainwater Harvesting and Agriculture Development

Islam et al., (2016) mentioned that cropping intensity has increased from 155 to 300% due to rainwater harvesting in hill slope and hilltop study areas of Bangladesh. Rainwater harvesting increased grain yield and fertilizer effectiveness significantly. Traditional practices of irrigation yield 455 kg $ha^{-1}$ over three years but rainwater harvesting resulted in average grain yield 712 kg $ha^{-1}$ and fertilizer application alone gave an average grain yield of 975 kg $ha^{-1}$ but supplemental irrigation with fertilizer application gave an average grain yield of 1403 kg $ha^{-1}$ (Fox and Rockstrom, 2002). Since 1993, rainwater harvesting has been promoting in Gansu, China to alleviate water shortage and increase water availability for stabilizing agricultural production (Li et al., 1999). Rainwater harvesting can improve soil fertility and soil erosion (Wang et al., 2005). Rainwater harvesting increases agricultural productivity with improving water-use efficiency, reduces soil erosion, and improves soil fertility (Zhao, 1996; Li et al., 1999; Wang et al., 2005) and allows breakthrough in dryland farming (Deng et al., 2004).

### 3.7 Rainwater Harvesting as Energy Saver

Rainwater harvesting saves energy as it does not require any kind of energy to operate and maintain. For instance, to abstract 7548 $m^3$ of water from ground source required 2174 kWh energy (Islam et al., 2016). Same volume of water can be collected from either rooftop or open space with rainwater harvesting techniques without energy as rainwater harvesting technique operates and maintain without energy. Rainwater collects from rooftop of buildings using pipe as gutter, down pipe to convey collected water to storage tank. Replacing potable water use for landscape irrigation and other outdoor water uses with rainwater can save up to 3.8 billion kWh of energy in the United States, valued at US$ 270 million (Malinowski et al., 2015). Emissions of GHGs affiliated with water related energy consumption which is more than 100 million metric tons of $CO_2$ equivalent gases (Elkind, 2011).

### 3.8 Rainwater Harvesting and Environmental/Ecological Development

Extreme rainfall can degrade environment substantially with risk of flood, and soil erosion. For instance, heavy rainfall inundated 16 districts in 2016 where 42 people were died and damaged transport, crops, and other infrastructure substantially (Davies, 2016). As the rainwater is stored that reduces the risk of local flood that cause by extreme rainfall during monsoon. "Rainwater harvesting is in itself a useful measure in soil and water conservation by capturing and storing runoff, which can directly contribute to the reduction of soil and water erosion" (Xiaoyan et al., 2002:3) and this source can reduce the pressure on groundwater that may minimize the risk of arsenic contamination due to over extraction of groundwater and sea level rise. People can improve ecological environment by capturing rainwater as it carrying pollution to rivers, lakes, and beaches (Dallman et al. 2016). However, the problem of other sources of water like groundwater and cross boundary rivers flow accelerate the need of using rainwater for domestic, agricultural, and industrial production purposes as it is available for the country.

### 3.9 Rainwater Harvesting as Economic Developer

The role of rainwater harvesting as factor in economic development comes in terms of reducing health care cost, saving time, and alleviates poverty. Haller and Bartram (2007) found that every US$1 investment on water supply and sanitation would provide economic return between US$5 and US$46 with the highest return in least developed countries. Most of this additional income comes from time saved by having reliable water supply near to the household. “A 2012 estimate suggests that cutting just 15 minutes off the walking time to a water source could reduce under-five child mortality by 11% and the prevalence of nutrition-depleting diarrhoea by 41%” (Harlin et al., 2015). This saved time can be used for income generating activities like small business in household, poultry farming, livestock rearing, and fisheries. These income generating activities are suitable for both men and women. Moreover, investment in water can alleviate poverty (Carter and Bevan, 2008; Hanjra and Gichuki, 2008). Besides poverty alleviation and time saving, improved safe water supply can reduce health care costs (Hunter et al., 2010:3) that can increase the economic saving of household. Deng et al., (2004) mentioned rainwater harvesting technology as strategic measure for socioeconomic development with providing crucial and effective means of alleviating poverty in semiarid regions. Additionally, improve water access of poor countries experienced 3.7% growth rate per year. The availability of clean water near to home can reduce the workload of women and saved time can spend for other productive activities like crop production (Wahal and Harti, 2012) and can take care of her health and children. Rainwater harvesting could contribute to household income improvement by improving water supply to the household (Hatibu et al., 2006). Safe water supply may provide livelihoods and entrepreneurial opportunities in various areas like services, constructions, and small businesses for poor people and it can generate high returns for local economies regarding employment creation and multiplier effects (Harlin et al., 2015).For example, drinking polluted water causes health related problems which might limit employment and income opportunities. Additionally, irrigation from rainwater harvesting is more economical than forced mode pumping of groundwater due to installation and annual operating cost of pump.

**3.10 Conclusion**

Rainwater harvesting has long history in the world and coastal areas in Bangladesh. It has some advantages like energy saver, climate change mitigator, economic developer, and contribute in agricultural development etc. in one side and some disadvantages like lack of salt in rainwater, can create health risk on the other side. In addition, it faces some challenges like lack of awareness among people about maintenance and operation, lack of finance to get popularity among people.

# Chapter Four

## Study Site

## 4.1 Introduction

The study conducted in Chila village, Mongla Upazila, under Bagerhat district. The village was selected due to its geographical location and vulnerability to climate change. The people and their water supply systems of the study area are vulnerable to climate change effect like salinity intrusion, storm surge, sea level rise, floods, and cyclone. The other aspects have taken consideration are rainwater harvesting system use by local communities for potable water supply due to the effect of climate change on surface water, and groundwater sources of water in the study area. As ground water and surface water from pond and river is not reliable due to salinity problem, local people have identified rainwater harvesting as a good alternative source for freshwater that is suitable with their socioeconomic position to solve their potable water supply problem.

## 4.2 Study site selection

The field site Chila is a coastal area within Mongla Upazila[10] under Bagerhat district in Bangladesh. It has similar features with other coastal areas in Bangladesh. For this similarity it selected as a representative of coastal areas in Bangladesh. Similar characteristics are as follows:

a. Water crisis: Lack of safe water supply is one of the main obstacle faces by coastal areas in Bangladesh. Potable water crisis is more acute in coastal areas (Islam et al., 2011, and Kamruzzaman and Ahmed, 2006) due to surface water particularly river water is highly saline and turbid (Islam et al., 2015). In addition to salinity problem, storm surges, river bank erosions, floods, and cyclones are major threat for creating water crisis in coastal areas of Bangladesh. The people in Chila also face potable water crisis for these factors. For instance, Cyclone Sidr (2007) and Aila (2009) damaged all water infrastructures in Chila. Furthermore, as the study site near to the Bay of Bengal climatic disasters also responsible for water crisis and create livelihood challenges for local people.
b. Climatic disaster prone area: In Bangladesh, coastal areas are the most vulnerable areas to the risk of climate change effects (Kabir et al., 2016). The coastal areas were hit by Sidr (2007) and Aila (2009) and these disasters were affected Bagerhat (study site), Barguna, Patuakhali, and Pirojpur districts mostly (Davidson, 2008). Furthermore, massive amounts

[10]Upazila (sub district) is a rural administrative unit

of water may be melted due to global warming and it might speed up flows from the Himalayans to Bangladesh through Ganges-Brahmaputra and into the coast (Litchfield, 2010). Chila is on the Ganges basin areas, predicted flow may increase intensity and recurrence nature of floods in this area. Rising intensity of tidal waves will influence river bank erosion (Chowdhury et al., 2007) in coastal areas of Bangladesh. Number of participants lost their houses and croplands due to river bank erosion within study group at Chila, Mongla (source: household survey).Arsenic problem is acute in coastal areas. There are 60%, 67%, and 30% tube-well's water contaminated with arsenic (exceeded 50mg/l) in Bagerhat (study site), Satkhira, and Barisal districts respectively (PDO-ICZMP, 2004). These climatic and natural disasters are responsible for water crisis and the coastal people stride hard to solve their water crisis.

c. Rainwater harvesting: Coastal people are always creative to solve their problem with innovative way. Rainwater harvesting is one of the creative way to resolve their potable water crisis. In recent years, rooftop rainwater harvesting has received good attention as a potential solution of potable water crisis in coastal and saline affected areas in Bangladesh (Karim et al., 2013). It has also been introduced as a potential alternative source of potable water in Mongla (Islam et al., 2015).

d. Location: Location is another criteria used to select the field site for study. The study is about checking sustainability of rainwater harvesting system. As the coastal people are using rainwater harvesting technique to solve their water crisis, Chila (coastal area) selected as study site. The study site located in coastal zone of Bangladesh. The figure 2.1 shows that Bagerhat district is one of the coastal districts of coastal zone in Bangladesh.

e. Sundarbans: Study site[11] is very near to the Sundarbans[12] (show in figure 4.1) that provides ecosystems services having vital importance for local livelihoods, national economy, and environment (Uddin et al., 2013). The Sundarbans is surrounded by Bagerhat, Satkhira, Khulna, and Patuakhali districts (shown in figure 4.1). More than 3.5 million people who are living around the Sundarbans directly and indirectly relying on ecosystems services of the mangrove forest (Giri et al., 2007; Biswas et al., 2007). Entire community of Chila largely dependent on the Sundarbans and Passur River for their livelihoods. The

[11]Passur river in between the Sundarbans and study site
[12] Mangrove forest in Bangladesh

Sundarbans serve as coastal defense (Rahman, 2009) but as the village on the bank of Passur River, the Sundarbans may not able to protect Chila community from tidal wave from the river.

### 4.3 Area and Location

The selected study site (shown in figure 4.1) beside the Sundarbans and on the bank of Pasur River. The Sundarbans declared as World Heritage site by UNESCO in 1997. It is the largest mangrove forest in coastal environment in the world. It also recognized as Ramsar Site in 1992. It is famous for Royal Bengal Tiger, Reptiles, Sundari Trees, Goal Pata, and different kinds of animals, plant, and species. The study area lies between $21^{o}49$ and $22^{o}33$ north latitudes and between $89^{o}32$ and $89^{o}44$ east latitudes (Banglapedia, 2015). Figure 4.1 shows that the study site is surrounded by Rampal Upazila (North), Morrelgonj and Sarankhola Upazila (East), Bay of Bengal (South) and Dacope Upazila of Khulna District (West).

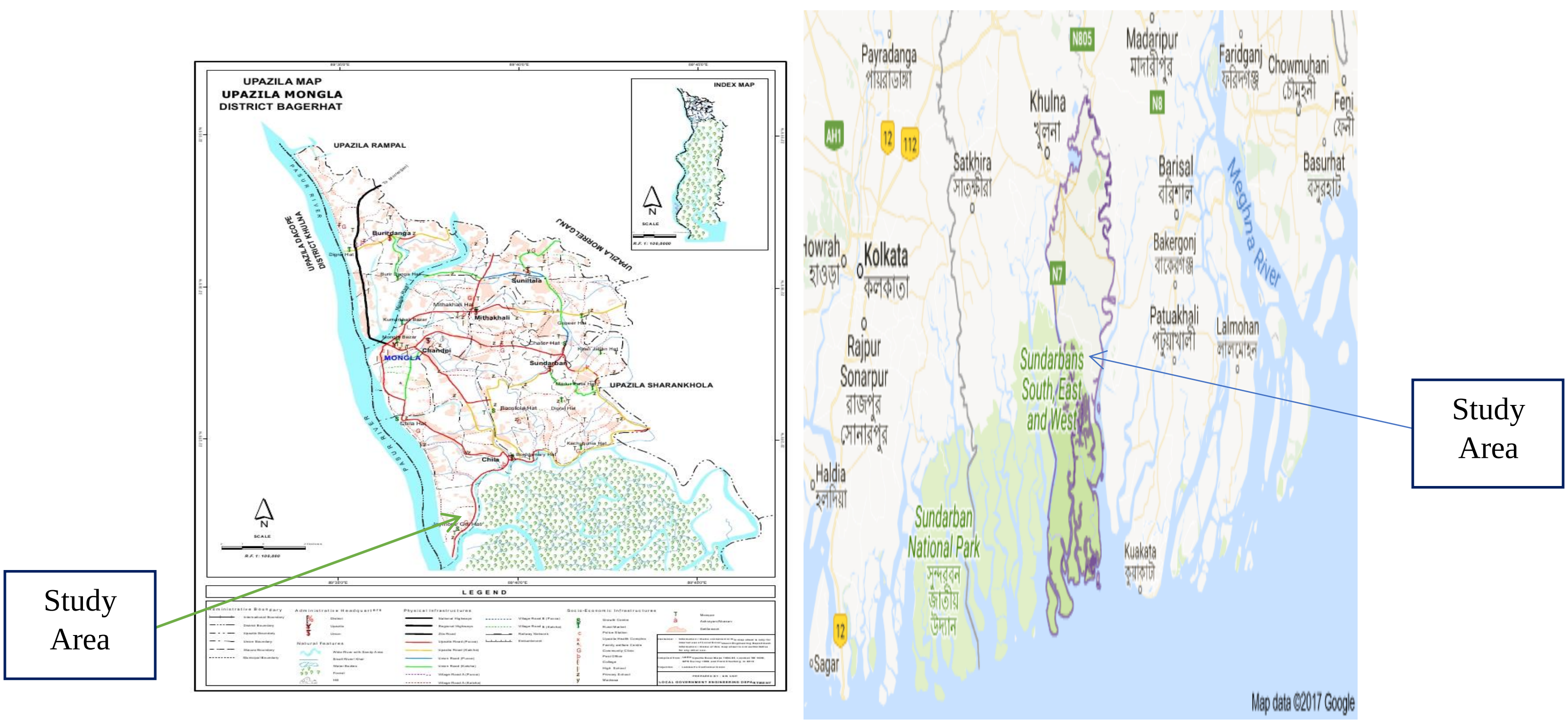


Figure 4.1: Upazila map of Mongla (LGED) and District Map of Bagerhat (Source: footnote[13] for Mongla Upazila and [14] for Bagerhat)

## 4.4 Climate

The study area is under tropical monsoon rainfall. Bangladesh has six different seasons. But the winter, summer, and the rainy seasons is strongly distinguished in the study area like other parts of the country. Generally, the summer starts March and ends in May. This season is also considered as pre-monsoon season. Within this period rainfall does not take place but in 2016 heavy rainfall usually associated with the monsoon started May. In this month, 366.1mm rainfall occurred in this single month. It was the highest rainfall in a single month in 2016. Usually, the Rainy Season starts in June and lasts up to October but it was longer in 2016 (May to November). More than 90% of total rainfall in 2016 occurred during the period between May and November. There was 1547.9mm rainfall happen in 2016[15]

The variation of temperature in this area is relatively low due to the proximity of Bay of Bengal. The average temperature of Bagerhat District is about 25$^{o}$c (2016) and temperature rising start from March and end in November.  The maximum temperature was in April (about 38$^{o}$c) and minimum temperature was in January (near around 18$^{o}$c) in 2016 (Source: see footnote 15).

## 4.5 River System

Pasur River is a large river in Sundarbans area and it is the extension of Rupsa River. Rupsa flows south of Khlulna and the Bhairab and further south and rename as Pasur near Chalna and falls into

13 https://www.google.it/search?q=Upazila+map+of+Mongla&dcr=0&tbm=isch&imgil=2d3s0nBNN2hzKM%253A%253BO77tNGJWAo63UM%253Bhttps%25253A%25252F%25252Fwww.researchgate.net%25252Ffigure%25252F303094270_fig1_Fig-1-Map-of-Mongla-Upazila-Sub-district-Bagerhat-in-Bangladesh-Source-GIS-Centre&source=iu&pf=m&fir=2d3s0nBNN2hzKM%253A%252CO77tNGJWAo63UM%252C_&usg=__Izxomc5V21ohllbAvtPGNOt-fds%3D&biw=1366&bih=628&ved=0ahUKEwiLiL2PmYHWAhVD6xQKHafhClAQyjcIPg&ei=0dunWcvbNcPWU6fDq4AF#imgrc=68HE-7PjoXI8qM:

14 https://www.google.it/search?dcr=0&biw=1366&bih=628&q=Bagerhat+map+&oq=Bagerhat+map+&gs_l=psy-ab.3..0j0i22i30k1l3.5865.10761.0.11063.21.12.0.0.0.0.184.1189.0j9.9.0.foo%2Cersl%3D1%2Cfett%3D1%2Cewh%3D0%2Cnso-enksa%3D0%2Cnso-enfk%3D0.3..0...1.1.64.psy-ab..15.6.833...0i8i7i30k1j0i7i30k1j0i67k1.SMyNLVcpki4

15 https://www.worldweatheronline.com/bagerhat-weather-averages/bd.aspx.  Accessed on August 11, 2017

the Bay of Bengal (Banglapedia, 2015). The river is brought together by Mongla Canal near around 32 km south from Chalna and further goes down south and connects the Shibsa that is 32 km north from its mouth (Chowdhury, 2015). The length of this river is about 142km and wide about 460m at Rupsa and 790m at Bajuyan and 2.44 km at the confluence of the Pasur-Shibsa (Banglapedia, 2015).

### 4.6 Socioeconomic status of people

Chila is a rural village that is composed of seven *para* or sub-village: Purba Chila (East Chila), Paschim Chila (West Chila), Gabguniya, Amtala, Dakshin Chila, Sindpur Tala, and Ulukata. With a population 7502 people, Chila is the largest village under the jurisdiction of Chila Union Council that is fall within Mongla Upazila (Sub-district) within Bagerhat District. Population density of Chila Union is 1097 per square kilometres and average household size is 4.1 (BBS, 2015). The population in Chila is not highly educated as the literacy rate is only about 42.7%. A person who can write an alphabet also included in this rate (42.7%) (BBS,2015). People are migrated from this place to other places where good education facilities are available. Main source of income is agriculture (mainly fisheries, crab farming,), service, and commerce (Banglapedia, 2015). Within agriculture fish farming (shrimp and crab farming) is the main activities.

### 4.7 Water Supply Alternatives

There are only 4.4% people get the facility of tube-well in Mongla Upazila, 6.6% from tap and remaining 88.9% households use other sources of water like rainwater harvesting , pond water filtration, river water etc. for their drinking water purposes (BBS, 2015). Very few number of people use tube-well as the source of drinking because ground water is saline. The area is proximity to the Bay of Bengal and saline water enters into the area easily and pollutes the ground water.

### 4.8 Conclusion

Chila is rural area in Bagerhat district where people are not well educated and their socioeconomic position is not so good as well. As people are not well educated and economically strong that creates number of problems for them like inadequate fresh water supply. But they have good sources of water like river where water stay during the whole period of the year. Salinity problem makes river and groundwater unusable for potable purpose. For this reason they face safe water crisis and use other different sources of water to meet up their freshwater demand. Rainwater harvesting can be a good alternative for them. But as they have different problems whether it is sustainable or not for them that is a major question.

# Chapter Five

# Methodology

## 5.1 Introduction:

In this study, research methodology is an overall strategy to answer the questions posed by the researcher. This chapter is going to answer how the questions will be answered about how climatic and other factors create water poverty and it affects the coastal community. Besides this, is rainwater harvesting a viable solution for coastal people in Bangladesh?

## 5.2 Research questions:

### Main Research question:

How can rainwater be used to reduce water poverty for socioeconomic and environmental development in coastal Bangladesh?

### Sub-research questions:

a. What roles are played by different sources of water for supplying potable water at coastal area in Bangladesh?
b. How climate change effect is responsible for water poverty in coastal Bangladesh?
c. What is the alternative solution for reducing water poverty in coastal Bangladesh?
d. What are the advantages, disadvantages, and challenges of rainwater harvesting?
e. Is rainwater harvesting sustainable in terms of technical feasibility, economic profitability, availability of finance, social acceptability, environment, and quality of harvested rainwater?

### 5.3 Sources of data:

Research materials are including all type of data and information generated and used in the scope of study to answer the set of questions for achieving certain objective. These data and information collected with applying different methods. Such methods are documents analysis, focus group discussion, participant observation, search method[16], experience[17], and household survey. Field work was held during the period between May 07 and July 21, 2017 in Bangladesh. Household survey and focus group discussions were held from June 17 to June 25, 2017 in Chila community within Mongla Upazila under Bagerhat district in Bangladesh.

#### 5.3.1 Primary data:

**Focus group discussions**

As a major data source, focus group discussions were held with different group of people at Chila. Such group includes day laborer, housewife, student, rich person[18], fishermen, fisherwomen, farmer, and driver. There were five[19] focus group meetings held in Chila for extracting deeper information about local water practices, period of fresh water crisis, reason of fresh water crisis, expenditure for water, government roles, and community livelihoods. The groups were divided

[16]Search method is finding related documents (online and print media)
[17]Experience is previous professional and educational experience
[18]For explanation please see footnote 41 about high income family.
[19]Five focus group discussion meetings were held in three days; June 17, June 21 and June 22

into men and women group for extracting more reliable and accurate information[20]. The participants in focus group discussion were in different age group and socioeconomic status.

Many people lived in Chila for seven generations or more and focus group discussions allowed me to gather information about generational rainwater harvesting practices and present challenges for this practice. The target groups were local rainwater harvester of varied socioeconomic status. A significant number of women rainwater harvester attended in the focus groups discussions.

The participants of focus group discussions were over 40 years of age because they have more knowledge about rainwater harvesting practices, socioeconomic and environmental benefits or problems for this practices, and local livelihoods. This study excludes below 18 years of age participants. Local research assistants helped me to arrange these focus group meetings.

Nineteen male and female household members attended the focus group discussions, including one rich fisherman (Doctor), one farmer, two fisherwomen, two fishermen, five day laborers and three housewives. All of these household members are rainwater harvesters. One research assistant assigned to one rich fishermen and farmer, 1 to one farmer, 1 to two fishermen, 1 to five day laborers, and 1 to three housewives and two fisherwomen. Research assistants were assigned to different group of participants separately for collecting more specific and extract more data from them[21]. The participants were also busy with their jobs so that research assistants required adjusting time schedule with them. Local dialects were used as a means of communication with them. With their verbal consent, their conversations were recorded and noted down. At the end of the focus group meetings, five local community members from different socioeconomic position were selected for in depth case studies.

### In-depth case studies and participants observation

In order to gain as much insight as possible into rainwater harvesting practices, its environmental and economic benefits, government and NGOs roles, and other aspects of rainwater harvesting, I selected five older rainwater harvesters who possessed leadership quality and extensive local and rainwater harvesting knowledge. Based on these criteria, I selected Dr. Bipul, Mohon, Biswanath,

[20] Most rural women do not feel comfortable to talk in front of men. It is a social culture in Bangladesh. If the group is mixed with women and men, women might give less information about the study subject.
[21]Research assistant (female) assigned to arrange focus group discussion with fisherwomen and housewife.

Shohor Banu, and Arcona Roi who represented fishermen, farmer, day laborer, and fisherwomen. I did not use their profession in a respective way as mentioned their name (earlier) to protect their privacy.

**Dr. Bipul Chowdhury**

Bipul is a 45-year-old doctor, farmer, and fishermen who lived his entire life at Chila. He completed his MBBS educational degree but did not apply for an office job because he received 25 acre of land where he does fish farm, fruit gardens, and vegetable production. He does practice in Keyabunia. His brother is also a doctor and does practice in Chilla Bazar (Chilla Market). Dr. Bipul does not get married till now. He has three fisheries project and four fruits gardens and two vegetable gardens. All of his assets are within four three kilometres of his house. In addition to his current house in Chila he has another house in Mongla town. He has enough storage facility to meet up water demand for whole year. Sometimes, he gives water to local people who face water crisis. He is trying to grow crops in his land but not success till now because of water problem.

**Mohon Bachar**

Mohon is a 60-year-old fisherman and day laborer who lived in Chila since his birth. He has completed his secondary school certificate but his parents did not allow him to do an office job. He got married in the decade of 1970s. He has one son and one daughter. He has got large tank from Rupantor and training. Currently he lived a decent livelihoods based on his own resources and his daughter and son also help him. He received only two bigha land (including house) from his parents but his total land (excluding house) is five *bigha*[22] now. He has one fishery and doing fish trading with his own money.

**Arcona Roi**

Fifty one year-old Arcona is a fisherwoman whose family has lived in Chila for more than five generations. She did not finish her secondary school (up to sixteen years old) and now works as

[22] One bigha equals to 0.33 acre or 33 decimal of land.

fisherwoman. Total area of her house is 7.5 decimals[23] which she owns as houseland and does not have cropland. She got married and has three children.

**Biswanath Bala**

Biswanath is 45-year-old fisherwoman and rainwater harvester whose family has lived in Chila for more than six generation. She has neither cropland nor formal education. She has only house and area of the house is 23 decimal. She has four children. She has received training on rainwater harvesting and got large tank, gutters, pipe and other materials from Rupantor.

**Shohor Banu Begum**

Shohor Banu is 50 year-old rainwater harvester, fisherwoman, and day laborer who lived in Chila since her birth. She has 7 decimals of house and no cropland. She has two daughters and one son. She has got training and large tank and other materials for rainwater harvesting from World Vision[24].

For data collection purpose from these five people my male research assistants and I were intimately confiscated to the male case respondents and female research assistants were closely dealt with female rainwater harvesters. Research assistants and kept records in audio and written down in paper.

***Chila household survey***

In order to collect qualitative and quantitative data about their socioeconomic background and sustainability of rainwater harvesting the household survey script comprised 51 questions developed based on experiences of focus group meetings and literature survey. The survey covered 80 respondents from the village. Among these respondents 37 were female (46.25 percent of total respondents) and 43 male (53.75 percent of total respondents). Within the group of respondents 17 (21.25 percent of total respondents) respondents were landless.

[23] One decimal equals to 436 square feet or 40.5 square metre of land

[24]World Vision is an Non-Government Organization who took initiative (first) for providing training, large tank, and awareness campaign for rainwater harvesting in this area

### 5.3.2 Secondary Data:

Secondary data were collected from different sources like Bangladesh Water Development Board, Bangladesh Meteorological Department, published and unpublished articles, seminar presentation, journals, and books.

## 5.4 Data validation

There were two main sources of data used in this study. The following measures have taken to validate data:

Sampling: There were 80 households out of 4327 randomly selected for data collection purposes in Chila. Random sampling technique was used for preventing bias information collection by research assistant from household[25]. In this study, one criterion was used to select household that is the household has been using RHS in the house. Otherwise, they would not able to provide information about RHS. The household survey questionnaire was prepared based on FGD and used for primary data collection. The collected data have written on separate paper from each respondent. The data were collected from only one participant from particular family. The respondents must be above 18 years old and mentally sound[26].

Research Assistant: The people of the study site were not known to the researchers. They might feel uncomfortable to talk with the researchers so that local people used as research assistants[27] to collect primary data from household in study site. There were two groups of respondents in terms of gender. For this reason female research assistants were assigned to collect data from female respondents[28]. Short briefing was given to research assistant about data collection and study objective before going field for data collection. Because it was assumed that it would help them to collect accurate data more effectively and efficiently. As they are local they can use local dialects for better communication with the respondents which is not possible for researchers in this study.

[25] Easy for him or her to collect data but may not accurate data
[26] It means he/she is not mad, mentally ill (obsessed, depressed, and drug addicted)
[27] The qualification of research assistants were minimum undergraduate (completed) in the field of social science
[28]Assumed that female respondents might feel shy to talk with male research assistants

Focus Group Discussions: Focus Group Discussions (FGD) were held for understanding WP issue in coastal community. Based on FGD, household survey questionnaire were prepared. Focus group discussions also managed by male and female research assistants separately as male and female participants participated the FGD separately. There were several FGD held during this study in the field site for deeper understanding. Some FGD meetings were held after household survey for cross checking collected data from household survey.

Ethical consideration: Oral consent was taken from the respondent during the beginning of data collection from every respondent. An overall idea was given to the respondents about the study during this consent so that he/she can assume what kind of question will ask by research assistant. Oral consent also included the option that the participant can leave participation from study or leaves any question[29]so that he/she should feel free to participate in the study.

Field Site: Field site is one of the coastal areas in Bangladesh where RHS use in every household and more prone to climate change effect which can deteriorate water crisis problem. As they use RHS for reducing their water crisis they would know more about RHS than other. For this reason this site was selected for study about RHS.

Secondary data were taken from different scientific journal, international seminar, different books, different reports publish by different organizations (who work in particular field, for instance climate change by UNFCCC), and online sources. Being critical to use online data and keep the web address of the online source of data and give the date of access. Proper references were given to check the data (if necessary).

Besides these efforts data may not be collected in proper way which may affect the quality of data and ultimately affect the reliability of the study. For instance, ethnographic measure requires for making judgment but it was not done in this study because the study period was short. But ethnographic study requires long period for staying in the field to observe the participants more closely. However, utmost efforts were given to collect reliable data from primary and secondary sources for increasing reliability of the study.

[29]Which he/she does not want to give answer

### 5.5 Research framework:

"Research can be seen as an elaborate argument, culminating in an answer to preliminary questions" (Vershuren, and Doorewaard, 2010: p66). Research framework is the systematic presentation of the aim of research. It means step by step action to achieve research goal (Vershuren,and Doorewaard, 2010: p66). The research framework consists seven steps as given below:

**Step One:** *Brief description of research objective*: The objective of this research is to find sustainable solution of water poverty in coastal Bangladesh.

**Step Two:** *Decide research object:* The object of this research is water poverty in coastal Bangladesh.

**Step Three:** *Presenting the nature of research perspective:* This research is concerned with a diagnostic, intervention-oriented research. This study is examining possibility of rainwater harvesting for sustainable solution of water poverty problem.

**Step Four:** *Finding the sources of research perspective:* The research uses scientific literature and social ecological system approach during the development of conceptual model of this research project. Additionally, Bangladesh receives ample rainfall but wash out to the Bay of Bengal through rivers. In the same time, the country faces water shortage in the dry season (December-May). This gap is going to wide due to climate change effect and the anthropogenic activities of neighbouring countries. Besides this consideration, the socioeconomic status of basin people and their dependency on natural resources for survival also considered as they are the main stakeholder of this system. The following key concepts and theories are used in this research:

| Key Concepts | Theories |
|---|---|
| Reducing Water Poverty with Rainwater Harvesting System in Coastal Bangladesh | Socioeconomic theory<br>Social Ecological System based on interaction |

Water Poverty | Sustainable Development
Rainwater Harvesting
NGOs

**Step Five:** *Schematic drawing of research framework*:

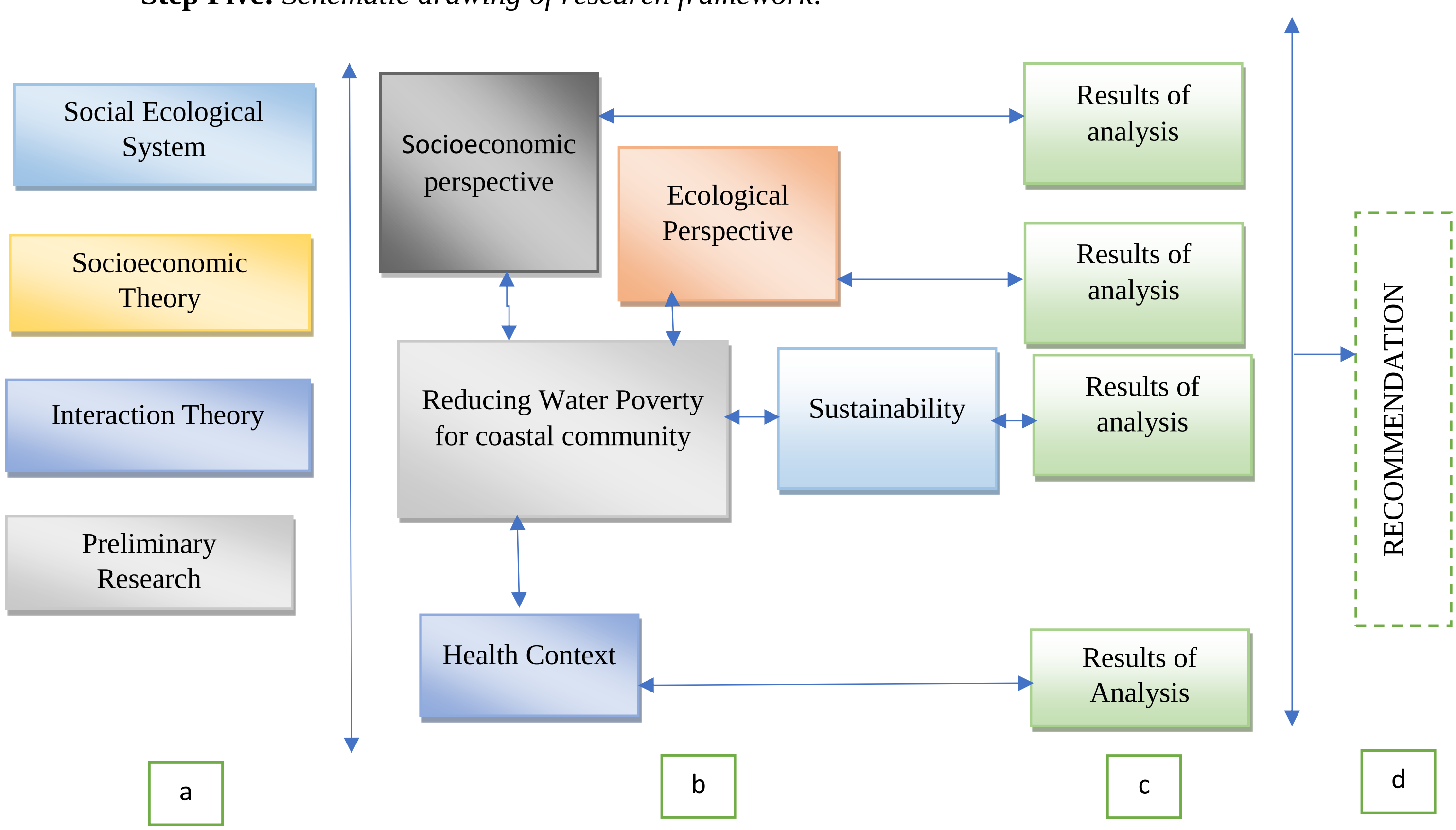


Figure 5.1: A schematic presentation of research framework

**Step Six:** Establishing the research framework in form of arguments:

a. An analysis of the rainwater harvesting concept and preliminary research to find out the effects of climate change and transboundary rivers on water poverty
b. The environmental, social, and economic problems created by water poverty to the coastal people
c. The possibility of rainwater harvesting system to reduce water poverty that ultimately reduce environmental, social, and economic loss
d. Confronting challenges to make the system sustainable and make the system vulnerable as the basis for advice
e. Recommendation to make the system more sustainable and provide better outcome from the ecological resource (rainwater)

**Step Seven:** Checking: This study is an iterative process and as more data are collected about research object, changes made to the framework in focus group discussion phase of data collection

**5.6 Defining concept:**

There are some key concepts used in this research project as these are related to this research. These are as follows but not limited to:

**Water Poverty:** Water poverty is the scarcity of water to meet the demand of water. This scarcity can be in household, local community, regional, and international level.

**Rainwater harvesting:** Rainwater harvesting is the system to collect, and store the rainwater for future use. It can collect from the roof of the building or in open space. Here, it uses only from the roof of the house.

**Interaction:** Interaction is particular way to affect each other in certain context. In this research project interaction between user of ecological resources, governance of these resources, and resources systems considered.

**Social Ecological System (SES):** Social Ecological System is the interaction process between users, governance, and resource units and systems in wide socioeconomic context with considering sustainable use and local ecosystems requirement.

**Sustainability:** Sustainability is the way to manage resources without harming environment and society but meet the needs of people. In this study, check sustainability of RHS in terms of technical feasibility, economic profitability, government role, availability of finance, environment, social acceptability, and quality of harvested rainwater.

**Ecology:** It is about the environment relates to the living organism. Moreover, it is the branch of science that deals with interaction among the member of species and between them and the environment.

**Socioeconomic:** Socioeconomic is the social science perspective that study how economic activities and social processes mutually shape and affect each other. . Generally, it involves social and economic factors. It is a two way process.

### 5.7 Analytical framework:

The following graph presented the analytical framework of the study:

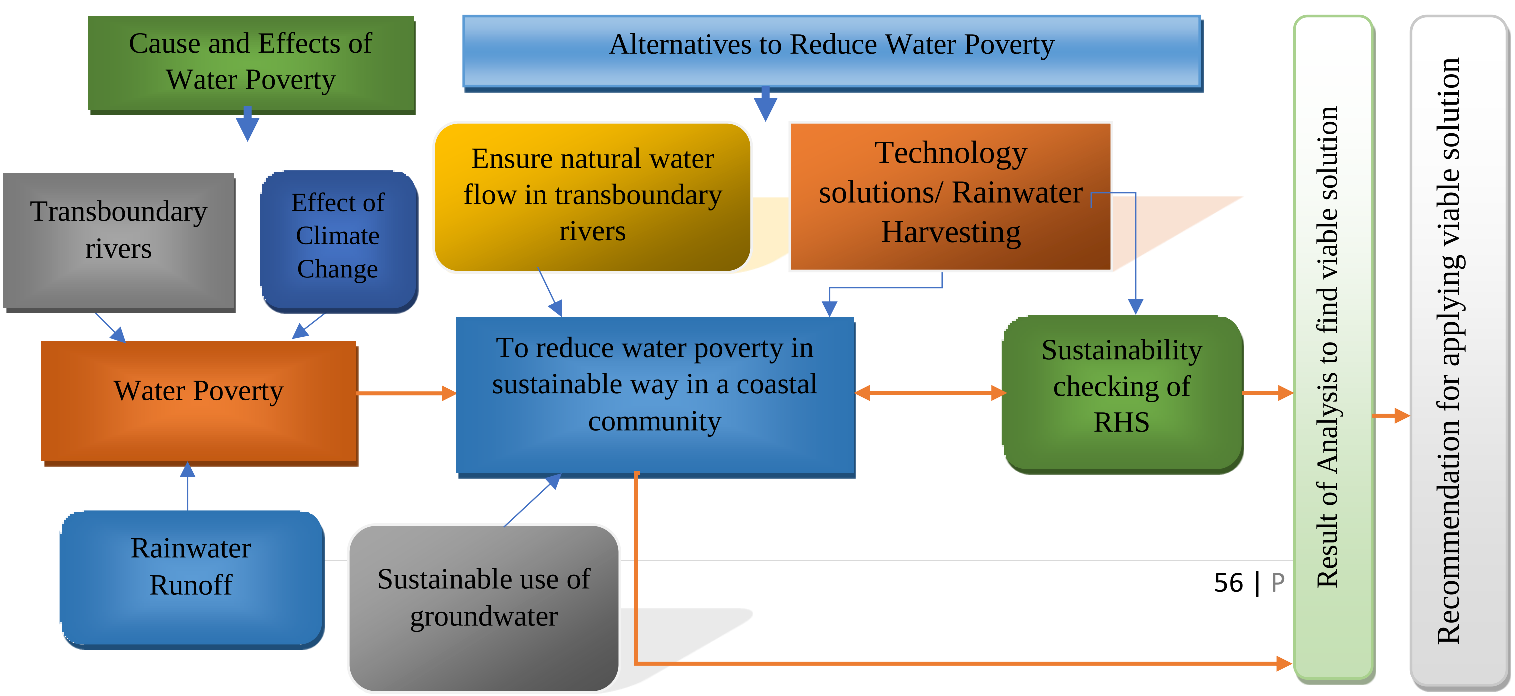



Figure 5.2: Analytical framework

The data analysis of this research conducted in the following order:

**First Step:** The effect of climate change and the role of transboundary rivers to water poverty analyzed. It includes how sources of water affected, its socioeconomic, and ecological impact.

**Second Step:** Primary data collection from the coastal community, water governance expert, and water body. Coastal communities include but not limited to women, farmers, fishermen, fisherwomen, and day laborers. The main characteristic of these participants were rainwater harvester.

**Third Step:** Analyse the possibility of rainwater harvesting to reduce water poverty with considering advantages, disadvantages, and challenges

**Fourth Step:** Analyze sustainability of rainwater harvesting systems in terms of technical feasibility, economic profitability, availability of finance, government roles, social acceptability, environmental sustainability, and quality of harvested rainwater.

**Fifth Step:** Based on the analyses recommend particularly to the governance aspect to take necessary steps for utilizing rainwater for betterment of coastal community, economy, and environment. Interaction approach of SES (Social Ecological System) framework of Elinor Ostrom used for this recommendation.

## 5.8 Ethics:

This research project followed these key guidelines for ethical aspect:

a. No harm principle to the participants
b. Participant will participate in this research voluntarily
c. Seek informed consent
d. Ensure quality and integrity of the research

e. This research will be independent and impartial
f. Keep identity of the respondent confidential and anonymous (if they do not want to expose their identity)
g. Use information only for research purposes
h. The respondents can withdraw his or her participation from this research at any stage of the research

## 5.9 Theoretical approach

### Social Ecological System

Potential loss of fisheries, forests, and water resources is a major problem face by world (Ostrom, 2009). These resources are embedded in complex Social Ecological Systems (SES) framework and it is an important analytical tool to understand the interactions between four different subsystems[30]. Ostrom established this framework (shown in figure 5.3) and found that: "analysis of how attributes of a resource system, the resource units generated by that, the users of that system, and the governance system jointly affect and indirectly affected by interactions and resulting outcomes achieved at a particular time and place" (Ostrom, 2007). An ecological resource's outcome and long term sustainability depends on interaction between these sub-systems (shown in figure 5.3).

[30]Subsystems include resource systems, resource units, governance systems, and users

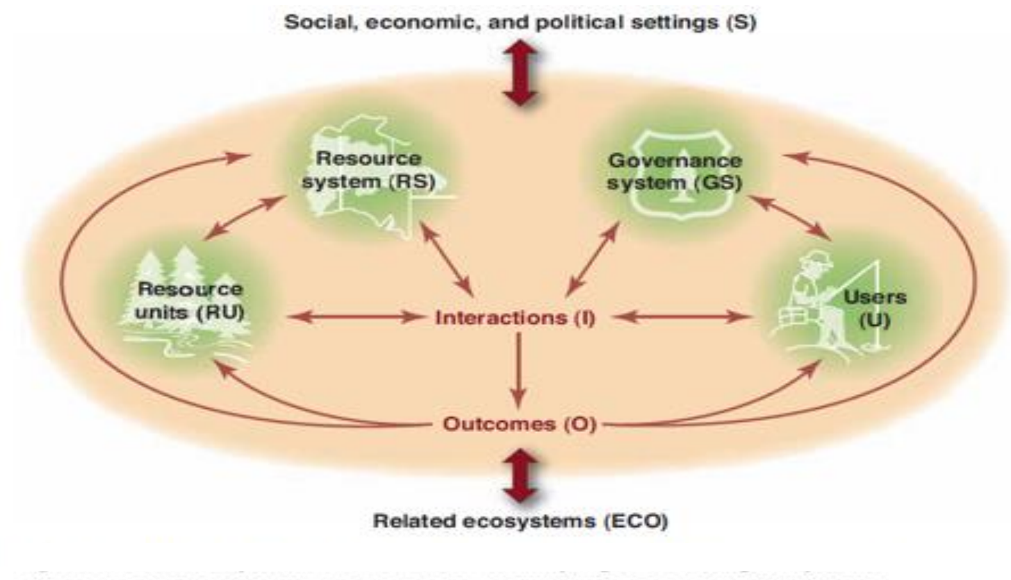



Figure 5.3: The subsystem in SES framework (Ostrom, 2009)

Under each of these subsystems has several multiple second level variables and the framework helps to identify relevant variables for studying (Ostrom, 2009). In this study, under wider social and economic context the following variables selected to check sustainability of rainwater harvesting:

| **Subsystem** | **Variables** | **Subsystem** | **Variables** |
|---|---|---|---|
| Resource Systems (RS) | RS1: Sector (Water)<br>RS9: Location (Chila, coastal area) | Resource Units (RU) | RU 4: Economic Value<br>RU 5: Number of units |
| Governance System (GS) | GS1: Government organizations | Users (U) | U1: Number of users<br>U2: Socioeconomic attributes of users |

| | | | |
|---|---|---|---|
| | GS2: Non-Government Organizations | | |
| | GS5: Operational rules<br>GS7: Monitoring and sanctioning process | | U3: History of use<br>U4: Location<br>U5: Leadership/ entrepreneurship |

Table 5.1: Subsystem of SES and related variables to be used for sustainability checking of Rainwater harvesting (Adapted from Ostrom, 2009).

5.9.1 Resource Systems (RS)

RS1[31]and RS9[32]variables are to be used under resource system's subsystem in this study. Silva et al., (2015) argued that climate variability and water governance might affect water shortage. To prove this argument, they have applied Ostrom's SES framework particularly "clearly define boundaries" principle. In this study, how socioecological problems[33] creates water poverty to be examined.

Ostrom (2009) argued that if resource system provides ample resource the users will not see a need to manage it or conserve it for using in the crisis period. Waste of rainwater in Bangladesh is suitable example in this context. Ample rainfall does not bring any benefit to Bangladeshi people. Even it damages the crops by inundation as it does not manage effectively. Additionally, same people face water crisis during dry period as they do not feel to conserve or manage it for utilizing the resource. In this circumstance, to manage rainwater effectively requires setting rules either by government or users that will give sustainability of this harvesting approach.

5.9.2 Resources Units (RU)

There are two resource unit's variables to be used in this study. Such variables are RU4[34] and RU5[35]. In this aspect, economic viability of rainwater harvesting system will be checked. For checking financial viability of RHS some question to be answered in this study: Is rainwater

[31]RS1: Sector: Water
[32]RS9: Location (Chila, coastal area in Bangladesh)
[33]Floods, drought, salinity, river bank erosion, and other
[34]Economic value
[35]Number of units

harvesting financially viable[36]. If yes, how? If no, why? However, for number of units of an ecological resource (rainwater) some questions will also need to be answered: how much rainwater they can harvest? Are they able to harvest more rainwater they need? If no, why? If yes, what would they do with extra rainwater collection? What are the other purposes use rainwater except drinking?

### 5.9.3 Governance Systems (GS)

Four variables used under governance system of ecological resource[37] in this study. It includes government organization (GS1), Non-government organization (GS2), operational rules (GS5), and monitoring and sanctioning process (GS7). The performance of government organization regarding finance, training, awareness campaign, and policy related measure assessed in this study for checking sustainability of rainwater harvesting system in Chila. In addition, some variables are only applicable for government organization like operational rules, sanctioning process of rainwater harvesting system. Long term sustainability depends on the rules those are initially set by either government or users match with the attributes of the resource systems, resource units, and users (Ostrom, 2009). Furthermore, if initial set of rules are not congruent with local conditions, long term sustainability may not be achieved (Dietz et al., 2003). In this circumstance, the socioeconomic attributes of coastal people need to consider.

SES model "enables one to organize how these attributes might affect and be affected by the larger socioeconomic, political, and ecological settings in which they are embedded, as well as smaller ones" (Ostrom, 2007). As the ample rainwater receiver, Bangladesh needs to use this resource with good interaction between governance of rainwater and local community that may be resulted to solve water poverty.

### 5.9.4 Users (U)

In this study, four variables such as number of users (U1), socioeconomic attributes of users (U2), history of use (U3), and location (U4) are related under this subsystem. Rainwater harvesting is popular in coastal areas in Bangladesh. Chila is one of the areas in coastal Bangladesh. In this

[36]Financial viability measures in terms of illness, medical cost, expenditure for water, health status
[37]Rainwater

context, feasibility of rainwater harvesting is checking in terms of age of rainwater harvesting, and socioeconomic attributes of users in coastal Bangladesh[38].

For analysis, those principles will investigate in terms of sustainable solution of water scarcity to coastal people of Bangladesh who have been facing water crisis. Rahman and Jahra (2006) mentioned that rainwater is enough to meet up the demand of water for eight to ten month in the driest areas of the country. Number of users (U1) is always relevant for managing natural resource like rainwater. Around 75 million people are in danger of arsenic contamination in Bangladesh (Safiuddin and Karim, 2001) and those people are mostly in coastal areas. These people need to get fresh water to drink and use. Self-organization for rainwater harvester in coastal Bangladesh for using rainwater harvesting is relevant to leadership and entrepreneurial perspective of SES (U5) as they are harvesting rainwater and contributing socioeconomic development of their family and country.

The SES framework is useful to use rainwater for reducing water poverty in coastal community. To use this framework for achieving the aim of reducing water poverty focuses on this question: When will the users of a resource invest time, money, and energy to solve a problem? According to Ostrom (2009:3), "a theoretical answer to this question is that when expected benefits of managing a resource exceed the perceived costs of investing in better rules and norms for most users and their leaders, the probability of users' self-organizing is high".

### 5.9.5 Interactions and outcome for sustainability

Moreover, for better and sustainable outcome from rainwater harvesting system needs interaction between subsystems and related variables in this study. Harvesting levels of diverse users (I1), Investment activities (I5), and self-organizing activities (I7) variables (Ostrom, 2009) use for interaction purposes. For those variables some questions to be answered: how much rainwater they can collect? What is the source of finance? How they organize? For social sustainability whether it is socially acceptable system or not and is family member cooperate rainwater harvester or not to be examined. Furthermore, does harvested rainwater have quality problem or not also examined? For environmental sustainability: is it environmental friendly system or not? If yes, how? If no, what aspect?

[38]Chila is an area in coastal region of Bangladesh

### 5.10 Conclusion

The secondary data and fieldwork evidence were helpful for explaining the socioeconomic and ecological characteristics. Salinity is the single most immediate cause of water poverty associated with hardships throughout the coastal community in Bangladesh. But my study indicates that lack of good governance of ecological resource (rainwater) is the root cause of socioecological and socioeconomic concern over Chila. This governance failure decreases the outcome of socioecological resources (rainwater) and create problem for sustainability for rainwater harvesting practices. This governance problem is described with theoretical approach of Social Ecological System framework of Elinor Ostrom. Based on this theoretical approach, rainwater harvesting is whether a sustainable solution for reducing water poverty or not is testing in this study.

# Chapter Six

# Findings

### 6.1 Introduction

For present study, check the sustainability of rainwater harvesting for supplying potable water in coastal community by interaction four first level core subsystems of Social Ecological System (SES) that linked social, economic, and political settings and related ecosystems. The first subsystems are resources systems that are related to coastal area's potable water supply systems in this study. Resource units are the second subsystems that connected to the volume of water in the coastal community. The third subsystem is the role of government and non-government organization regarding the water supply with rainwater harvesting. For instance, is there any financial and technical assistance provide by either government or non-government organization? Is there any policy regarding rainwater use? Users are the fourth subsystems of an SES. Users are the coastal communities in the current study. The outcome of an ecological resource like rainwater depends on the interaction of these sub-systems. If interaction is strong then the outcome of particular ecological resource is better and sustainable. The outcome and sustainability of RHS measure in terms of technical feasibility, economic viability, availability of finance, government role, social acceptability, environmental concern, and quality of rainwater.

### 6.2 Socioeconomic Condition of Participants

The household survey covered 80 poor[39], medium[40], and high income[41] families in Chila village, Chila Union within Mongla Upazila under Bagerhat district. Within these groups of respondents, majority of them are poor, few are medium and one or two respondents are fall into rich group of income. The respondents are 53.75% (43) male and 46.25% (37) female. All of them are adult. The following figure shows the age category of the respondents.

[39]Who has less than one bigha of land (either cropland or houseland) and yearly income less than BDT 60,000
[40] Who has more than one but less than three bigha of cropland and has house and yearly income more than BDT 60,000 but less than BDT 1,00,000. Please see footnote 22 and 23 for measuring size of *bigha* of land
[41] Who has more than three bigha of cropland and yearly income more than BDT 1,00,000

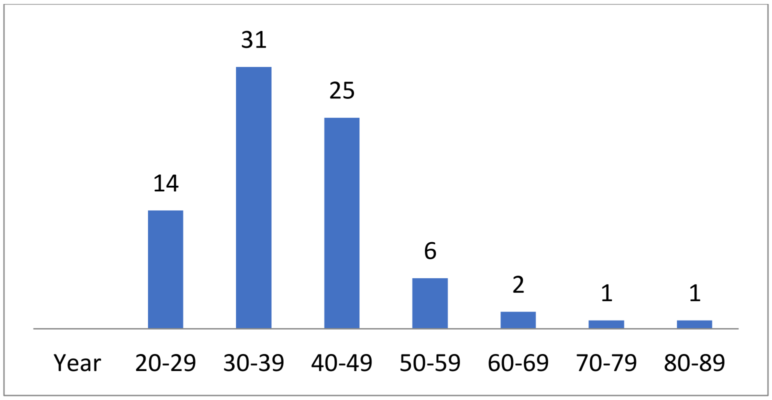



Figure 6.1: Age of the participants (Source: field data mutually exclusive)

The above figure (6.1) shows that participants are mostly fall into the age range of 30-39 (31), 40-49 (25), and 20-29 (14) year of age old. They are middle age and young as well. These three age category covered 87.5% of total respondents. Remaining respondents are fall into 50-59 (6), 60-69 (2) and one from 70-79 and 80-89 years of age. In this mixed age category indicates that the study covered young, mid age, and old person as well which help to collect more accurate and clear data about the study subject.

### 6.3 Ecological Problems and Water Poverty

| Types | Household | Percentage |
|---|---|---|
| Drought | 45 | 56.25 |
| Flood (Tidal surge/storm surge) | 57 | 71.25 |
| Salinity | 75 | 93..75 |
| River Bank Erosion | 19 | 23.75 |
| Other (Specify) Storm | 1 | 1.25 |

Table 6.1: Ecological disasters create water poverty (Source: field data mutually inclusive)

Chila is highly vulnerable to tropical cyclone, salinity, river bank erosion, drought, and storm surge as the village just beside the bank of Passur River. These natural and climatic hazards create freshwater crisis for the villagers. The topography of the village is almost flat and only few feet above the sea level. . The entire part of the village is exposed to the Pasur River and high risk to cyclones, storm surge, and tidal waves. Cyclone with high storm surge water and heavy wind speed causes heavy damage and jeopardize the life and livelihood of the people of Chila. Almost all sources of freshwater are inundated with saline water from tidal surge, storm surge, and floods, and destroyed freshwater and sanitation facilities.

The household survey found that 56.25% people face drought problem. In this time, the villagers face extreme freshwater crisis as water in the river is saline and the villagers can't use river water for washing cloth, and taking bath and other household activities. Besides this factor, other factors such as less water in river and less rainfall also contributing on freshwater crisis problem for the villagers. On the other hand, 71.25% respondents revealed that they face flooding/storm surge problem which creates freshwater crisis for them. Water crisis is more severe during floods as flood water drowns everything like water collector[42], collected water, sweet pond, and made entire water source salty and unusable for potable purposes. Some reasons behind the flood like heavy rainfall, overabundance of water in river, tide, and tidal wave.

Salinity problem is highly integrated with the villager's daily life. Because the village is located just beside the Pasur River where water is salty and has direct connection with the Bay of Bengal. Flood and storm surge are also contributing to salinity problem as it brings saline water from Bay of Bengal to Pasur River and comes to the village from river. As per household survey 93.75% respondents said that they face salinity problems that create water poverty for them. The saline water mainly comes from the Bay of Bengal and inundates the village via Pasur River. Here, Pasur River works as the channel of flowing saline water from the Bay of Bengal to Chila. The main reason of salinity problem in Chila is proximity of Pasur River and the river has connection with the Bay of Bengal.

Moreover, 23.75% respondents in Chila village said that river bank erosion creates freshwater crisis for them. Besides this crisis, it destroyed house, cropland, roads, fish farm, projects, school, college, market, and other infrastructure. It brings the village nearer to the saline water by destroying all infrastructures which block the way of erosion. There are some factors which are responsible for river bank erosion in Chila and creates freshwater crisis for the communities. Such factors are lack of navigability of Pasur River, and extreme stream of Pasur River. Two

[42] Container to keep water (storage tank).

respondents have lost their entire land holdings and become landless and three respondents lost all cropland due to river bank erosion of Pasur River in Chila.

The land of village is low lying so that the saline water can enter the village easily. Lack of embankment is another reason for salinity problem. As the village beside the Pasur River it needs embankment to prevent saline water to enter into the source of freshwater of the villagers. It has a road but not enough high to block saline water of Pasur River. During rainy season, heavy rainfall increases saline water level of the river and flows over the road and contaminated freshwater source of the villagers. The road is not well structured and has many leaks and saline water flows through those leaks which polluted the source of freshwater.

### 6.4.1 Dimensions of Water Poverty faced by villagers

| Dimension of crisis | Household | Percentage |
|---|---|---|
| Saline water mix with freshwater in pond | 37 | 46.25 |
| Cooking water crisis | 57 | 71.25 |
| Bathing water crisis | 9 | 11.25 |
| Drinking water shortage | 65 | 81.25 |
| Freshwater supply problems | 3 | 1.75 |
| Need to collect freshwater from far distance | 19 | 23.25 |
| Water crisis for washing cloth | 1 | 1.25 |
| Agricultural water problem[43] | 5 | 6.25 |
| Need to buy water | 4 | 5.00 |
| Lack of water in sweet pond | 1 | 1.25 |

Table 6.2: Dimensions of Water Poverty (Source: field data mutually inclusive)

Water has connection every aspect of life. Access to freshwater can turn problem into possibility. But the natural disasters create number of challenges for irrigation and domestic water purposes in Chila village. The challenges create water poverty for drinking, cooking, bath, agricultural production, washing clothes, irrigation (agriculture) water, and saline water mix with freshwater in pond, freshwater supply problems, need to collect water from far distance, need to buy water, and lack of sweet water in ponds.

The table 6.2 shows that drinking water shortage is the highest dimension (65) of water crisis that force people to drink saline water which creates health problem like diarrohea, cholera, and skin

[43] Agriculture water problem include: Water crisis for vegetable production (1), water crisis for poultry and duck farming (1),

problem and these health problems increase medical costs. This problem is the highest degrees of crisis as river water and pond water[44] is not suitable for drinking as these waters are available. The extreme poor[45] always drink saline water except rainy season period due to incapacity to buy freshwater or rainwater reservation.

Besides the drinking water problem, cooking water crisis is the second most serious dimension (57: shown in table 6.2) of water crisis in Chila. Pond water (sweet pond water) can use for cooking but the cooked rice is not last twelve hours for eating. But cooked rice with rainwater last long for twelve hours. Cooking water crisis is the second most severe water poverty dimension. This water crisis has connection with salinity because salinity also creates cooking water crisis.

Saline water polluted water in pond (37 shown in table 6.2) and people can't use such water for drinking and cooking purposes and is the third dimension responsible for water crisis. During the extreme events like Sidr or Aila it damages entire freshwater sources and even polluted collected rainwater. On the other hand, farmer can't cultivate their land due to salinity. As natural disasters create freshwater crisis, vegetable gardener can't grow their vegetable, fish farmers can't farm white fish like common carp, grass carp, Kalibaus, Katla, Rui, Sarputi, Silver carp, and Telapia.

The community in Chila needs to collect water from sweet pond and this is the fourth dimension of crisis (19 shown in table 6.2). The men, women, and children need to spend whole day to collect water from near freshwater source[46]. They can't collect water during the stormy season due to the possibility of storm as they need to cross Pasur River to collect water. They have to wait until the river calm down for collecting water. Beside the time and risk they also need to spend around BDT 500 (US$ 6.25[47]) as transport cost to reach the destination. They rent a trawler with this money and expenditure share between them. Around 10 to 15 people[48] can cross river by one trawler[49] and bring water from other part of the river. Additionally, the sweet ponds became salty pond during 2007 and 2009 due to Sidr and Aila. The villagers were fully dependent for freshwater on

[44] Except sweet pond water. The sweet pond waters are far away to collect.
[45] Who does not have land (neither cropland nor houseland), do not have large storage tank (1000 litres, or bigger) for rainwater harvesting and earn less than BDT 30,000 per year.
[46] Sweet pond
[47] Assumed that US$1=BDT 80
[48] Including men, women, and children
[49] It is a medium size of boat in Bangladesh. It uses particularly fishing in river and sea.

bottle water, water supply by many charitable organizations, Non-Government Organizations, and government support during these extreme events.

Bathing water crisis is the fifth (9 shown in table 6.2) dimension of crisis in Chila. Although river water creates skin problem for bathing the people in Chila use this water for bathing. Their bodies adjusted with it. Most of them do not face any problem with this practice. Agriculture water problem (5), need to buy water (4), and freshwater supply problems are consecutive dimension of water crisis in Chila. Lack of water in sweet pond and water crisis for washing cloth are the least water crisis dimension in Chila.

The dimensions of water poverty intensify water poverty in Chila in different degrees[50]. Some people face more dimensions of WP than other. These degrees can be measured in terms of facing water crisis in the number of months, and monetary expenditure for purchasing water. It is assume that there is positive relation[51] between WP and number of months faces water crisis problem and monetary expenditure for purchasing water. The following table shows the degree of WP face by villagers in Chila:

| **Water shortage (in month)** | **Degree of WP** | **Monetary expenditure for buying water (in BDT)** |
|---|---|---|
| More than eight months | Very acute WP | 4500 – Plus |
| More than 6 but less than 8 months | Acute WP | 3500 - 4499 |
| More than 4 but less than 6 months | Moderate/average WP | 2500- 3499 |
| More than 2 but less than 4 months | WP | 1500 - 2499 |
| More than one but less than 2 months | No WP | 500[52]- 1499 |

Table 6.3: Degrees of water poverty in Chila

The table 6.3 shows that there are five different degrees of water poverty face by community in Chila. In these categories the local communities in Chila who face water crisis more than eight month and spend more than BDT 4500 per annum may face very acute WP. The following one is

[50]Degrees can be measured with fulfilling either water shortage (in month) or monetary expenditure for purchasing water characteristics or both
[51] More months and expenditure may lead to more severe water poverty and vice versa
[52]Assumed that, every household spends BDT 500 (at least) for purchasing water so that data interval started from BDT 500.

acute WP. The people who face water crisis more than 6 months but less than eight months over the year and spend BDT 3500-4499 fall into this group. Moderate/average WP face by the people who suffer for fresh water for more than 4 months but less than six months and purchase water by BDT 2500-3499 in the year. Some people may face water shortage less than average/moderate that categorize as water poverty. In this group, people may face water crisis for more than 2 months but less than 4 months and purchase water for BDT 1500-2499 over the year. The people who face water crisis for more than one month but less than two month and spend money for BDT 500-1499 do not face water poverty. For additional information please see section: time of water poverty in Chila's community (70-71), and expenditure for water purchase (page 73).

Within the communities in Chila, people may not face same degrees of water poverty due their socioeconomic position. For instance, rich people may not face water poverty as they can either collect enough rainwater or buy bottle water from market that meet freshwater demand over the year. But poor people face water poverty as they may not be able to collect enough rainwater due to storage problem, incapable of buying bottle water from market and may not be able to collect sweet water due to transport cost. According to survey, 17 people out of 80 are landless who have been living in other's house. These 17 households may face very acute water crisis as land ownership is one of the main indicator of socioeconomic position. Additionally, three respondents lost their income source due to river bank erosion which affects their water supply opportunity greatly because positive relation between income source and water supply[53]. Old aged people are another group of people who may face more dimension of water crisis than other due to lack of strength and income sources[54]. That more dimensions may lead to more severe water poverty. Moreover, children are relying on other for water supply. They may also face more water poverty than other.

**Time of Water Poverty in Chila community**

These climatic concerns create freshwater crisis for local community in Chila. The community in Chila faces water poverty in different period over the year. For instance, the household survey found that twenty five respondents face water poverty for eight months of the year. Within these

[53] Assumed that reduction of income sources reduce the money spend for water purchasing that hamper water supply to the family

[54] Assumed that he/she rely on himself/herself for income and water supply

groups, they face water poverty in the same number of month but not same period over the year like seventeen people face water crisis during October 14 – June 13 and eight people suffer for water between September 14 and May 13 over the year. Within the respondents of eighty local community of Chila, three community members face water shortage problem over seven months of the year. In this group, one face water deficit between November 14 and June 13 and the other face between December 14 and July 13. There are four respondents face water poverty during the period between December 14 and May 13 (2) and January 14 and June 13 (2). In the same way, twelve people (December 14 – June 13 and November 14 – May 13) face water poverty over six month of the year. But their number of people of response from each period is same. In the other hand, same number of respondents (twelve) faces water poverty during the period between September 14 and June 13. In the similar way, nineteen respondents of eighty total respondents suffer for water over ten months in the year. They do not have enough containers due to lack of financial capacity and training to cultivate rainwater more efficiently and effectively to reduce their water poverty. Comparatively some people do not face or face least time water crisis in the year. Within eighty respondents, one does not face water crisis, one for two months, one for three months, and two for four months of the year. If we compare with major part of the community it is negligible time in the year for water crisis as most of them (59 out of 80) face water crisis for more than six months over the year.

| Months | Household | Percentage |
|---|---|---|
| February 14-June 13 (4) | 1 | 1.25 |
| October 14 – June 13 (8) | 17 | 21.25 |
| September 14 – May 13 (8) | 8 | 10.00 |
| November 14 - June 13 (7) | 2 | 2.50 |
| September 14 - June 13 (9) | 12 | 15.00 |
| December 14 - May 13 (5) | 2 | 2.50 |
| December 14 – June 13 (6) | 9 | 11.25 |
| January 14 - June 13 (5) | 2 | 2.5 |
| December 14-July 13 (7) | 1 | 1.25 |
| November 14 - May 13 (6) | 3 | 3.75 |
| January 14 – May 13 (4) | 1 | 1.25 |
| March 14 – June 13 (3) | 1 | 1.25 |
| August 14 – June 13 (10) | 19 | 23.75 |
| April 14 - June 13 (2) | 1 | 1.25 |
| No Crisis | 1 | 1.25 |

Table 6.4: Local community face WP in the number of months in Chila (Source: Field data)

**Period of time for buying water**

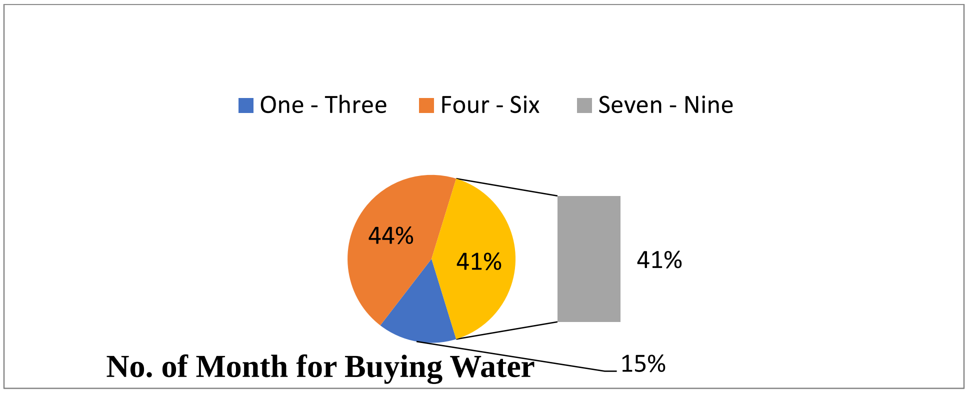
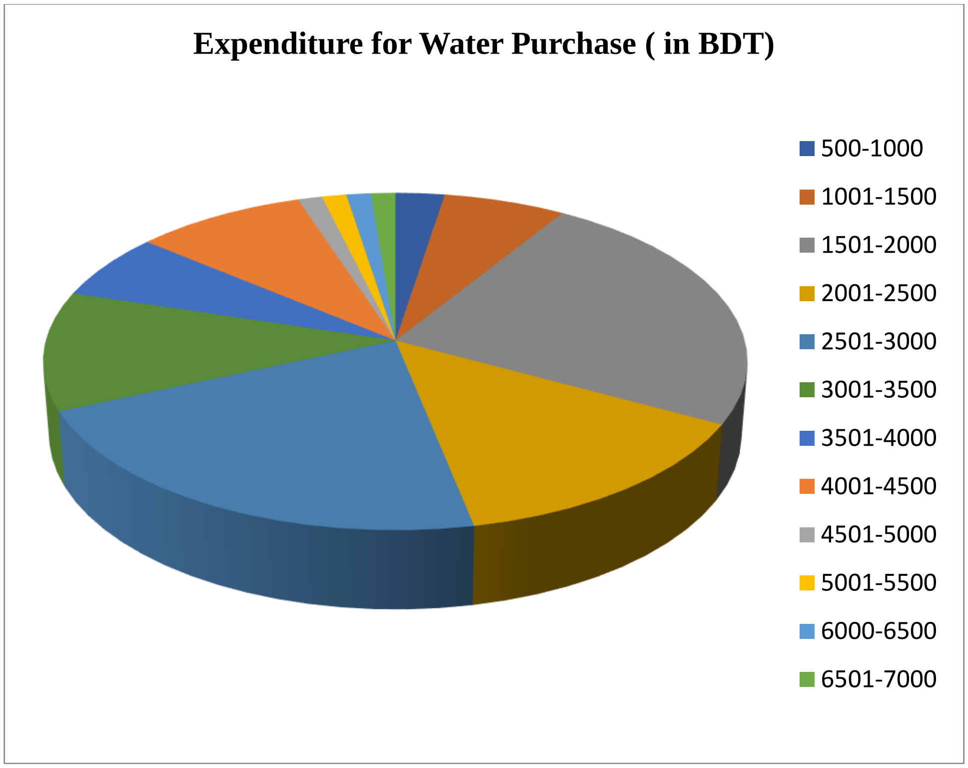



Figure 6.2: Number of months of buying water (Source: field data)

Everyone in Chila spends money for purchasing water except one person. This expenditure varies depending on water demand of each family. Water demand relies on family size, number of adult person, number of child and infants, and purpose of water use. Within the study group one person does not need to buy water because that person can collect and store enough rainwater for whole year. For this reason, here the study calculates the cost for seventy nine respondent's water purchasing. In the above figure (shown in 6.14) indicates that 44% respondents buy water for the range of 4-6 months of the year and 41% for 7-9 months of the year. It is mentionable that 85% of seventy nine water purchasers buy water for four and nine months of the year. Remaining 15% respondents meet water demand over 1-3 months of the year with purchasing water. Their time of water purchase varies with their expenditure. The following figure shows the pattern of their expenditure for water:



[55]

Figure 6.3: Expenditure for Water purchase (Source: field data)

In the above (figure 6.3) figure shows that 24% people of total respondent's water cost fall into BDT 1501-2000 range (US$ 18.76 – 25). About 14% of total respondent spend BDT 2001-2500 for water purchasing purposes each year. On the other hand, 22.50% spend BDT 2501-3000 for the same purpose. With accumulation of these three expenditure group cover sixty percent (47) of total respondent. Nine respondents spend BDT 3001-3500for buying water from either water trader or bottle water. It is noticeable that BDT 4001-4500 spend for water purchasing purpose by five people a poor community like Chila where 80.5%[56] and 6.3% people live in *kutcha* and *jhupri*[57] house respectively (BBS, 2015). In the same way, five persons spend more than BDT 5000 for water purchase purposes within this study group. In a nutshell, people spend a good portion of their income for water purchasing purpose in Chila. This kind of high expenditure for water is not needed even in most part of Dhaka city which is one of the most populated cities in the world. This type of practice makes them poorer. But they can't leave this because it is related to their health issue which can make survival issue more challenging.

[55] One US$ equals to BDT 80
[56] Its floor builds by soil. Generally, if people have money their floor make by brick, cement, and sand
[57] This kind of house is made with polyethylene, bamboo, and bush. It can damage with normal speed of wind

### 6.4 Alternatives to Solve Water Crisis

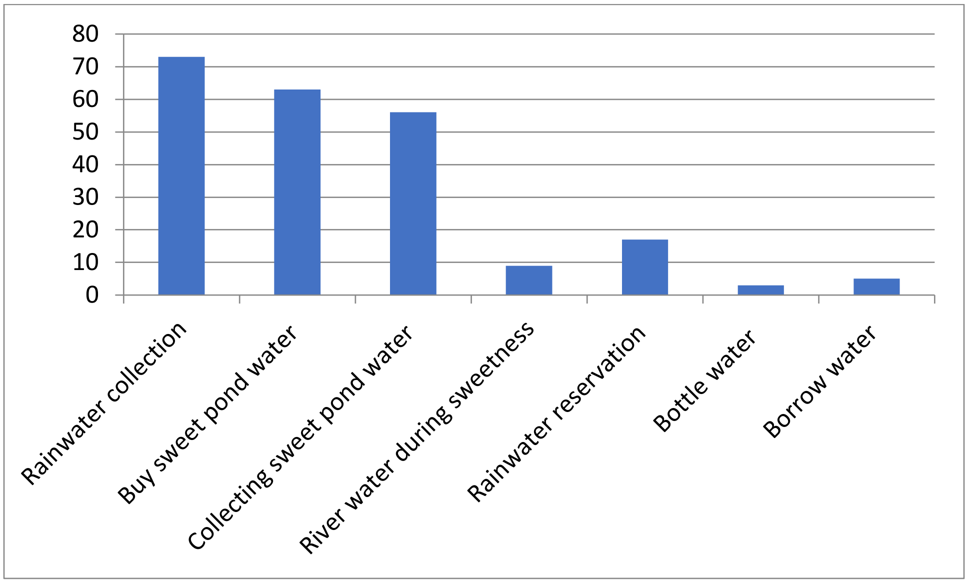



Figure 6.4: Alternatives for solving WP (Source: field data mutually inclusive)

Rainwater collection is one of the most popular techniques to reduce water poverty in Chila. According to survey, 75 people out of 80 respondents use rainwater collection beside other technique to solve their WP problem. It indicates that mostly rely on rainwater harvesting to reduce their water poverty. .

The second alternative is to buy water from sweet pond water sellers[58]. The 63 respondents use this technique combined with other options to reduce water poverty. The seller of pond water does not have any permanent location of their store. Local people need to inform them via telephone or by person. After informing them they will collect freshwater from sweet pond and come to them for selling water. Sometimes, they can't come due to lack of water in pond, or bad weather or physical illness. The price of this water is varied within short distance. Some people pay BDT 20 for 20 litres. But other people pay BDT 40 for 20 litre of pond water. The pond water has different kinds of problems. The pond water is not fully germs free and fresh as rainwater. Some people face almost same kind of problems like diarrhoea, cholera, and skin problem by using saline water.

[58]Some people are doing business with sweet pond water. They collect water from sweet pond and sell to people. They also known as sweet pond water trader

Water collection from sweet pond is another alternative to resolve their WP problem. The survey found that 56 respondents out of 80respondents use water collection from sweet pond as an alternative to resolve water poverty. But it has some negative side. The first negative aspect is time. They have some large sweet pond such as *Rashmondir* (4 miles away), *Kanainagar Guchwogram* (10 miles away), *Madorpalta Kobiraj Dighi* (15 miles away), Joimoni Nagrpukur (10 miles away), and *Koromjol* (20 miles away). The least distance of sweet pond is 4 miles. The people used to collect water from *Madorpalta Kobiraj Dighi* 20 years ago. But they do not collect now. In these ponds freshwater is available during the whole period of the year. They have another two sweet ponds such as *Bimol Roi* and *Krishnopodo* in Chila but water is sweet only for two months (December and January).

Collection water from these sweet ponds has some drawbacks that make unsuitable for local people in Chila.. They have to spend lot of time for travelling and standing in queue for collecting water. They have to travel at least 4 miles. During dry season they need to stand in queue to reach water source as water demand is very high during that period of year. Sometimes, it takes whole day to reach water source and return home at night. Besides the spending of time the owner of the pond sometimes reject to give water during acute dry season. Biswanath Bala told that she spent whole day to reach water source but could not get water due to the owner disagreement to give water to them. The owner did not give permission[59] to take water (free)from his or her pond because water level in pond did go low and he feared that it would create water scarcity for him. The second problem is expenditure for transport purposes. The people must rent trawler or van[60] or other transporter to collect water from such large distance. On an average the villagers need to spend BDT 50 (US$ 0.6) each time to collect water. The collected water from sweet pond is enough for ten to fifteen days. Without such kind of transporter it is not possible to collect water. Third problem is quality. As mentioned earlier that pond water is not fully fresh.

The villagers of Chila can use river water during certain time of the year (June to October). But during this time they get enough rainfall for their use. But some people do not have enough storage capacity to store water during the interval of rainfall. According to household survey nine respondents use river water for resolving their water poverty.  These people are fully relying on

[59]Sweet pond is a private property.
[60]It is three wheel transport which do not have shade. It usually use for transporting goods. It is a small size transporter.

river water for their freshwater demand. Buy bottle water is another way to work out freshwater crisis. Only 3 respondents use this way as other option to rectify water poverty. It is very expensive technique to resolve freshwater crisis. It is not suitable for the villagers of Chila. The last way to resolve water poverty in Chila is borrowing water from neighbor. It is very difficult to get water from others as it is very scarce in this area. They will lend rice for eating but not water because it is more scarce and valuable than rice. They survey found that only five persons use this technique with other way to solve WP in Chila.

### 6.5 Sustainability of Rainwater Harvesting

The present study is about to check sustainability of rainwater harvesting system for mitigating water poverty to the coastal people in Bangladesh. The sustainability checks in terms of technical feasibility, economic viability, availability of finance, government role, social acceptability, and environmental sustainability of RHS.

#### 6.5.1 Technical Feasibility of Rainwater Harvesting

**Age of Rainwater Harvesting**

The capturing, storing, and using rainwater is not new in Chila. Continuous suffering for freshwater problem forces Chila community to be creative to resolve their problem. The following figure shows rainwater capturing, storing, and using time of each respondent.

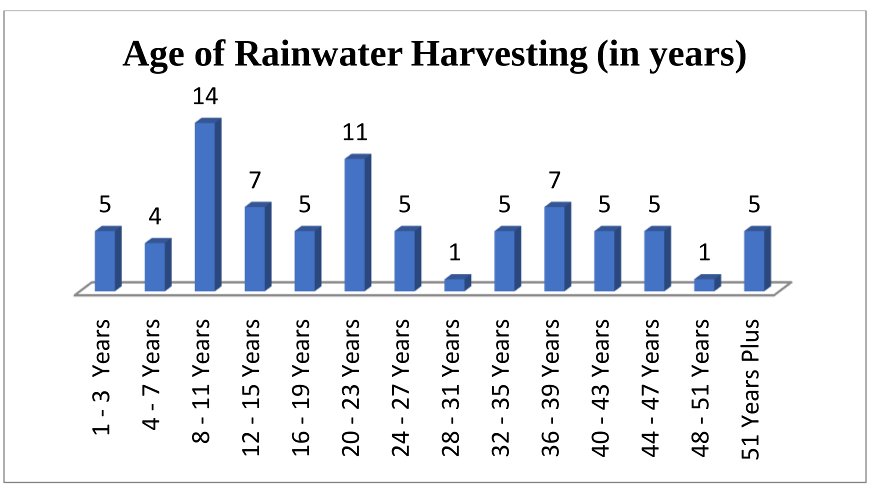



Figure 6.5: Age of RHS in Chila (Source: Field data mutually exclusive)

According to survey, 14 (17.50%) respondents use RHS to resolve water poverty for 8-11 years. Within the category of 8-11 years, the respondents may use rainwater for solving water poverty since Aila (2009) and Sidr (2007) hit the area. On the other hand, 11 (13.75%) respondents use rainwater harvesting technique for 20-23 years. There are 7 (8.75%) respondents use rainwater collection and storing system for the period between 36-39 years. It means that they use this technique for almost 4 decades. The survey revealed that, 5 (6.25%) respondents use rainwater harvesting method from each category of 1-3, 16-19, 24-27, 32-35, 40-43, 44-47, and more than 51 years to solve water crisis problem. However, only 4 (5%) participants fall into 4-7 years of age of rainwater harvesting in Chila and 1 (1.25%) respondents use RC from each category of 28-31, and 48-51 years. Besides the age of RHS the major question is how they do know about it? The following table gives some important facts about the promotion of the technique from generation to generation.

### Know about Rainwater Harvesting

The figure 6.6 shows that family or parents are major promoter of rainwater harvesting techniques in Chila. More than fifty percent (53.75%) respondents revealed that they know about the technique either from their parents or family. So, this technique has been going on from generation to generation.

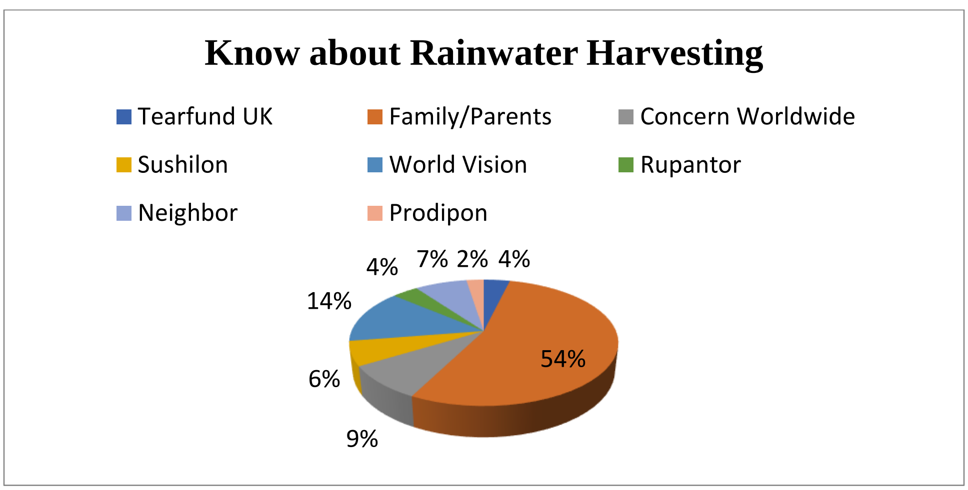



Figure 6.6: Know about RH (Source: field data mutually exclusive)

Besides the parents or family, local and international NGOs (Non-Government Organizations) such as World Vision[61] (13.75%), Concern Worldwide[62] (8.75%), Sushilon[63] (6.25%), Tearfund United Kingdom[64] (3.75%), Rupantor[65] (3.75%), Prodipon[66] (2.5%), and Neighbor (7.5%) play important role to let people know about the technique of rainwater use. The role of family and NGOs also helps to solve their water problem with their own resources and technology.

**Managing Rainwater Harvesting System:**

Different respondents manage RHS in different ways. The way of RHS managing is summarized below:

Protection from germs: They use cover of the storage to protect collected water and storage from germ. There are different kinds of coverage system in RHS use in Chila. It includes plastic cover, cloth, and polyethylene. If they do not use it then collected water may pollute with dirty ingredients like dust, leaves, worms, excreta of birds. Some people use cotton cloth in the mouth of either plastic pipe[67] or storage tank's mouth to prevent dirty ingredients to fall into the storage.

Catchment point: Rainwater cultivator can collect water from different catchment point like open space, and rooftop of the house and store it in different places like underground, pond, canal, and large tank. The local communities in Chila collect rainwater from rooftop of the house and store it in large plastic container and ferro-cement tank. The household survey found that the highest capacity of a single tank/storage in Chila is 5,000 litres.

Collection technique: During the first rain of the year they do not collect water in the first thirty minutes of rainfall. There is a switch and it is opened during the first thirty minutes[68] of the first rain to prevent water to go to the storage. It drains out because it helps to wash out the pollutants from the catchment area. After that period they collect rainwater from the catchment area. The rainwater cultivator/collector use either bamboo stick or plastic pipe for collecting water from

[61]an international NGO
[62]an international NGO
[63]is a local NGO
[64]an international NGO
[65] is a local NGO
[66] is a local NGO
[67] Down pipe
[68] They learned it from different sources like parents, awareness campaign, and training. The people use assumption as thirty minutes passed who do not watch or observe neighbor because rain starts same time and the neighbor also collects rainwater

rooftop. It works as connector between rooftop and storage. At first the rainwater falls into the rooftop of the building/house then it goes to the storage via pipe.

Using technique: The respondents do not use collected rainwater from the large storage tank. Because if the large tank open now and then that creates difficulty to maintenance the tank. Another thing is that if it opens now and then it increases the possibility of contamination of water with pollutants. Collection water from large tank is difficult task for children. For these reasons they use smaller container to transfer water from large storage and use it from smaller container as per their need.

Collection and reservation time: They collect rainwater and reserve it for later use in the last part of rainy season (the second week of September). They do not have extra storage tank so that they need to use same tank as storage for whole year. If they reserve collected rainwater earlier time for later use then they can't collect and use rainwater during the period of rainy season. Because it blocks their storage and do not have extra storage capacity. After collecting water during the last phase of rainy season they close the mouth of container and reserve it for later use.

**Number of time of cleaning**

The infrastructure of RH needs to clean for protecting collected water from pollution. The total respondents could not say about the cleaning ingredients or how many time they cleaned the setting. They think that it is difficult to say about how many times clean the container. Because after finishing collected water they clean container. After cleaning the container, they collect rainwater again. This process is going on in rainy season (June 14-September 13) period. For instance, a 1500 liter tank can supply water for around fifteen days for a standard family (4-5 persons). Within this range, the container needs to clean 4-5 times during rainy season. But the researcher tried to find out more clear information regarding cleaning time of infrastructure and survey disclosed that 97.50% of total respondents clean the whole infrastructure at least one time each year.

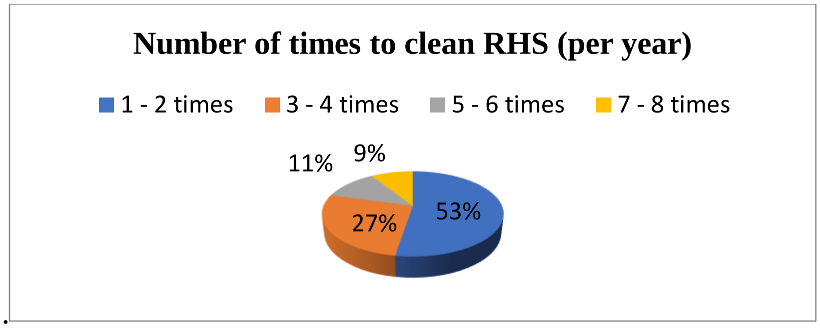



Figure 6.7: Number of times to clean RHS (Source: field data)

Among the total respondents who clean the RHS, 52.56% (41) respondents clean the setting one or two time every year. However, 26.92% (21) villagers cleaned the infrastructure three or four times every year. Within the total cleaner respondents, 11.54% (9) cleans the base 5-6 times and 8.97% (7) rainwater harvester clean RHS 7-8 times every year. It is clear from collected data that they do not follow any strict rule or methods to clean the infrastructure. The main theme of their cleaning the tank and other components of the setting is that when the tank is empty then they clean it.

**Ingredients of cleaning**

The household survey found that all respondents do not clean the tank, gutters, and pipe of RHS. Around 97.5% (78) respondents clean the infrastructure of rainwater harvesting and remaining respondents do not clean the RHS every year. Within this group of people 39.74% (31), 26.92% (21), 19.23% (15), and 14.10% (11) respondents use bleaching powder, wheel powder, shampoo, and cloth and other ingredients respectively for cleaning tank, gutters, and pipe of RHS.

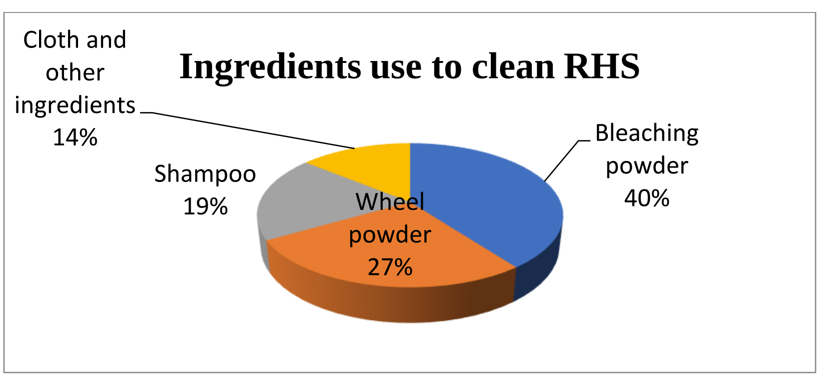



Figure 6.8: Ingredients use to clean up RHS (Source: field data)

Using ingredient is the result of technical knowhow knowledge about to manage the set up for full utilize of collected rainwater and keep it safe from pollutants. Training also contributes for using these ingredients to clean RHS.

**Perception about the requirement of expert knowledge for Rainwater Harvesting**

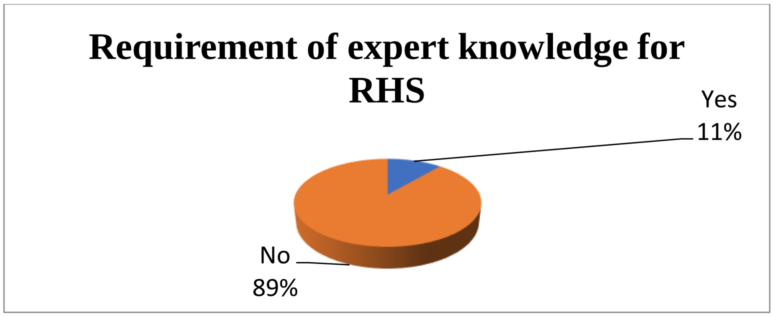



Figure 6.9: Expert knowledge for managing RHS (Source: field data)

RHS is very simple to use. It does not require any expert technical know to operate. Any individual can operate and maintain it. According to household survey, 88.75% of total respondents said that it does not demand specialized knowledge. They can maintain, operate, and manage RHS without expert knowledge. Remaining 11.25% respondents think that it requires specialized knowledge to handle. The first expert knowledge is the procedure to bring out air from the storage tank. They collect rainwater in June and it stores for later use. For this reason the air is accumulated within the tank. But the mouth of the tank is closed by polyethylene and rope. The gas can't come out from the tank. If the mouth of the tank does not open for one month interval use of this water creates health problem. Another expert knowledge is tank should keep under the rooftop/premises or shade of trees where the ray of sun not hit directly. If the sun hit directly on tank then it damages the heat resistant power of the tank and heats the collected water within the tank. As a result, the tank will destroy quicker than as usual time and quality of water will deteriorate. Some people use polyethylene to collect water from gutter to tank. The polyethylene should not straight link to tank. Because it hampers the water flow from gutter to tank and some water pour outside of tank. All of the rainwater collector do not use plastic pipe because of financial problem. They use bamboo stems as a gutter. It needs to cut in right size. Otherwise it is useless. This technical knowledge helps them to collect and utilize rainwater properly. Technical knowhow person can operate setting more efficiently and effectively than other people who do not know these knowledge.

### Training for Rainwater Harvesting

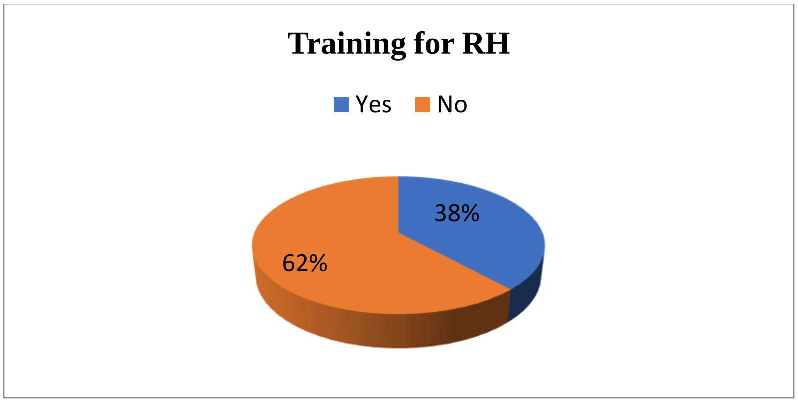



Figure 6.10: Training for RH in Chila (Source: Field data)

Most people have some weaknesses in their working skills regarding rainwater harvesting in Chila. Training allows reducing those weaknesses what needs to improve. The survey disclosed that only 38.75% (31) of total respondents have got training and remaining villagers 61.25% (49) did not get any training from either government or private organization. These people do not know why they did not get training from either government or private organization. Even they do not know when the training takes place. Some respondents informed that they did not get training because they are illiterate and do not engage with any NGOs. Without their training they can't use rainwater more efficiently and effectively.

### Trainer for Rainwater Harvesting

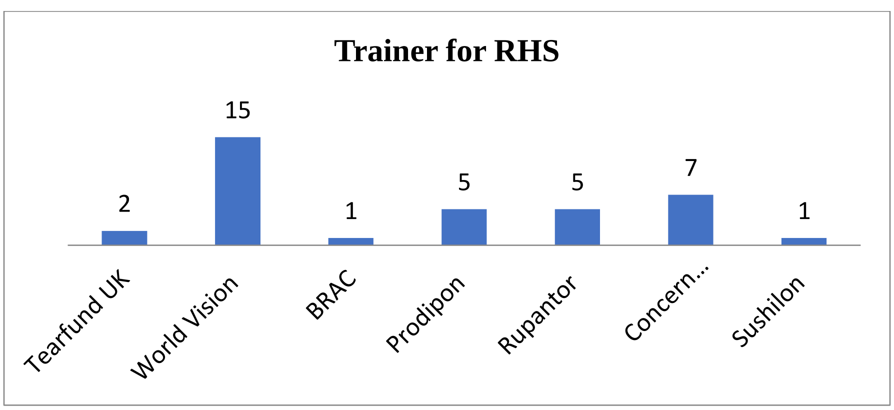



Figure 6.11: Trainer for RH in Chila (Source: field data)

Within the positive response about training, World Vision is pioneer who provides training to 15 villagers in Chila which is 41.67% of total training receiver in this village. Beside World Vision, Concern World (7), Prodipon (5), Rupantor (5), Tearfund United Kingdom (2), BRAC (1) and

Sushilan (1) also play important role with providing training to men and women in Chila. The training receiver gets different kinds of knowledge and ideas from training regarding rainwater harvesting. These knowledge and ideas are summarized below:

Technique of collecting rainwater: The trainer trained the local people about the technique of collecting rainwater. For instance, they should not collect rainwater during the first 30 minutes of first rainfall of the year. RHS

About the container type: There are three types of containers use in Chila. It includes plastic container, soil, and ferro cement container. Plastic container is better than other types of container because saline water can enter into soil and ferro-cement container with moisturizing. Another problem of soil and ferro-cement container is small worms are grow in collected water after few days passing.

Various use of collected rainwater: The collected rainwater can use various purposes like vegetable production, trees plantation and other purposes. They can wash their hand before eating and after eating into the vegetable garden that can work as irrigation for their crops. But they did not know about it before participation of training. Arcona Roi told that she started vegetable gardening in her house after getting training. This vegetable gardening reduces her vegetable expenditure and does not need to cook stale vegetable because vegetables are not fresh in the market.

Pond water use: Pond water needs to make it safe before use. There are two ways to get sweet pond water. The first one is collection and the second one is to buy from seller. It can make safe with using Alum after either collecting or buying. Making safe is learned from training. Biswanath Bala said that she used to drink pond water without making it safe that create health problem for her. After getting training in 2008 she started to make it safe before use. Since then her health problem reduced significantly.

**Managing problems**

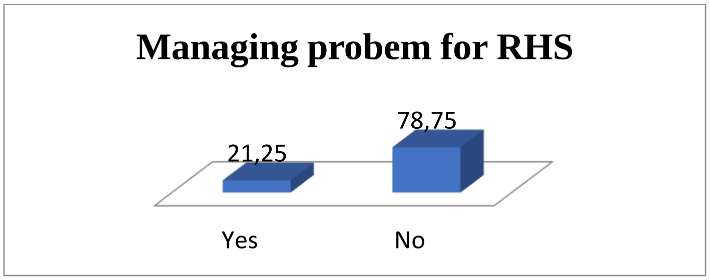


Figure 6.12: Facing problems for managing RHS (Source: field data)

Managing RHS is not always easy task for uneducated and unskilled people like local people of Chila. Even some people can't remember what the trainer taught them that creating managing problem for them. There are 78.75% of total respondents (80) did not face any difficulty to manage it. Only 21.25% (17) respondents face difficulty to manage the system. The problem includes broken tank and cover, difficulty to clean soil and ferro-cement tank[69], difficulty to set up, place choice to keep tank, and leaked tank. It is important to note that most of them (9) the problems they face solve themselves. Besides self-help, NGOs like World Vision (4), Concern Worldwide (2), Tearfund United Kingdom (1), Sushilon (1), help them to resolve the problems.

### 6.5.2 Economically Profitable

| Economically Profitable? | Household | Percentage |
|---|---|---|
| Yes | 80 | 100 |
| No | | |

Table 6.5: RH economically profitable (Source: field data)

The survey covered eighty household in Chila. All of the respondent provide positive response about economic viability of rainwater harvesting. Their freshwater supply improves by RH which contribute on their own and their family member fitness. Their own fitness enables them to perform their professional responsibility well. Shohor Banu, Arcona Roi, and Mohon Bachar told that their average water expenditure is Taka 3000 (US$ 37.5) for eight months. They capture rainwater and use it in remaining four months of the year. If they do not capture rainwater then their expenditure will increase to taka 4200 (US$ 52.5). They save taka 1200 (US$ 15) each of them each year with their current storage capacity. In the other hand, if they have had enough storage capacity they do

[69]Cost depends on the size of the tank. BDT 5,000-6000 needs for preparing 1500 litres capacity

not need to spend single money for water purpose. They can collect enough rainwater for over the year.

Mohon Bachar and Shohor Banu could not work for a period of nearly one month during their severe water crisis period (December 14-May13) last year. The reason behind this was they suffered with diarrhoea and stomach pain for around fifteen days. They have spent around taka 1200 (US$ 15) for that treatment. As per their doctor treatment the reason behind their illness was polluted water. But they never faced same kind of problem during rainwater use period. The study revealed that 100% respondents of this study think that their health status improved with rainwater harvesting. More specifically, seventy one respondent out of eighty told that their diarrhoea, dysentery, and stomach pain stopped during rain water use period. But they face those problems during collected pond water and buy pond water use period. For this reason their medical expense is more during pond water using period than rainwater using period.

The community of Chila collects water from sweet pond water during severe water crisis period (December 14 – June 13). But it takes a lot of time for travelling for going sweet pond and standing in queue to reach water source.

With the expenditure BDT 500-700 (US$6.5-8.75[70]) for transport purpose ten to twelve people can collect water and this water is enough for seven to ten days for a standard family[71]. So, each pond water collector needs to spend around US$ 0.62 - 0.75 for single time water collection from pond.

**Water Supply Improvement:**

The household survey to bring out that 100% of total respondents think that rainwater harvesting improves their water supply. All of the villagers use rainwater for their drinking water purpose. Besides drinking water purpose, collected rainwater also uses for the following purposes:

[70] One US$ equals to BDT eighty

[71] Standard Family includes two adults and two children.

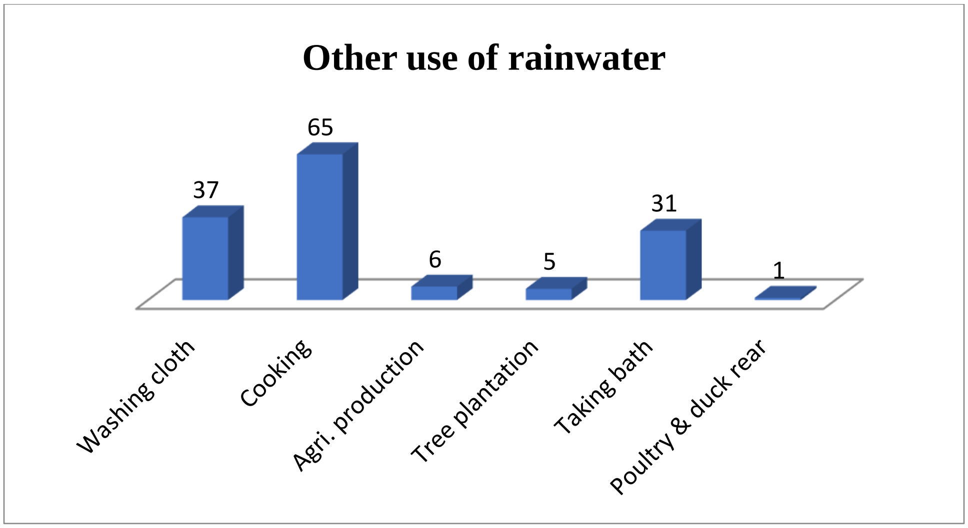



Figure 6.13: Other use of collected rainwater (Source: Field data mutually inclusive)

Drinking water supply is the main purpose of rainwater harvesting in Chila. Besides this purpose, they also use rainwater for washing cloth (37), cooking (65), agricultural production (6), tree plantation (5), taking bath (31), and poultry and rearing duck (1).

**Health Improvement**

| Health improvement? | Household | Percentage |
|---|---|---|
| Yes | 79 | 98.75 |
| No | 1 | 1.25 |

Table 6.6: Is RH improving health?

Safe drinking water is very important for reducing health related risks arise from water. According to survey in Chila, 98.75% (79) of total respondents (80) believed that rainwater harvesting helps to improve their health via supplying safe drinking water. Remaining 1.25% (1) respondents think that his or her health did not improve.

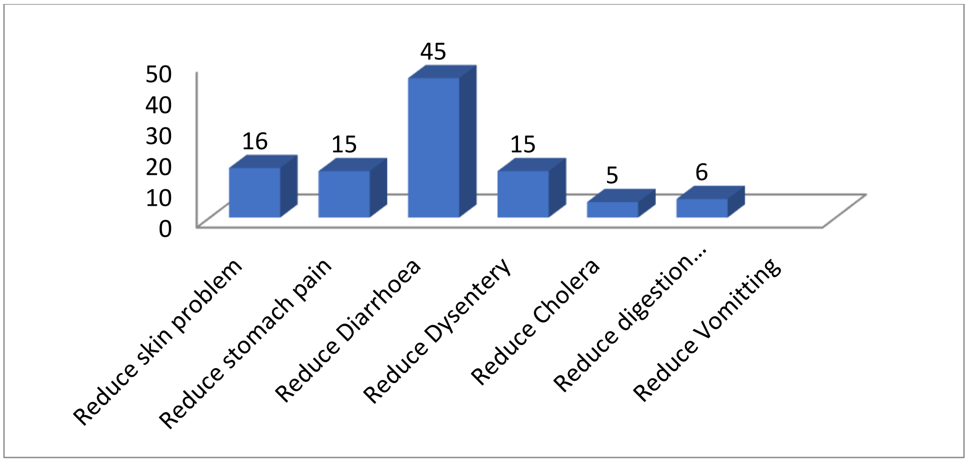


Figure 6.14: How RH improving health status of Chila's people (Source: field data mutually inclusive)

The RH has been improving health of local people in Chila by reducing skin problem (16), stomach pain (15), diarrhoea (45), dysentery (15), cholera (5), digestion problem (6), and vomiting. Children are the worst victims of lack of safe drinking water globally. Bangladesh is not outside of this problem. In the study area, children suffer less health related problems such as diarrhoea, jaundice, cholera etc. due to RH practices. Also, , the local people are physically stronger during rainwater harvesting period than buying water period due to less health related problems. When they use collected rainwater as drinking water then they can eat more food. It is also another factor work behind extra strength. For instance, during the dry season they buy water from water trader. But this water creates stomach problem like pain in lower abdomen. The employees can't perform their job efficiently due to uncomfortable feeling.

**Extra water**

| Extra water? | Household | Percentage |
|---|---|---|
| Yes | 3 | 3.75 |
| No | 77 | 96.75 |

Table 6.7: Extra water collection (Source: field data)

In this study, socioeconomic position of each respondent is not equal. Most of them are poor. For this reason they depend on government, local, national, and international NGOs/donor agencies for getting large tank for rainwater collection. As a result, in this study 96.75% (77) of total respondents expressed their concern that they can't collect extra water due to lack of container. Even collected water is not enough for whole year. Only 3.75% (3) respondents can collect more water than they need. Moreover, they disclosed that if they had enough containers then each of them can collect enough rainwater which would sufficient to meet at least meet three family's water demand over the whole year. But this rainwater can't collect evenly during the whole period of the year. Rainfall occurs more in some specific months or period of the year. The people collect more water during this time and store it for later use over the year. The following figure shows the pattern of the possibility of extra water collection period:

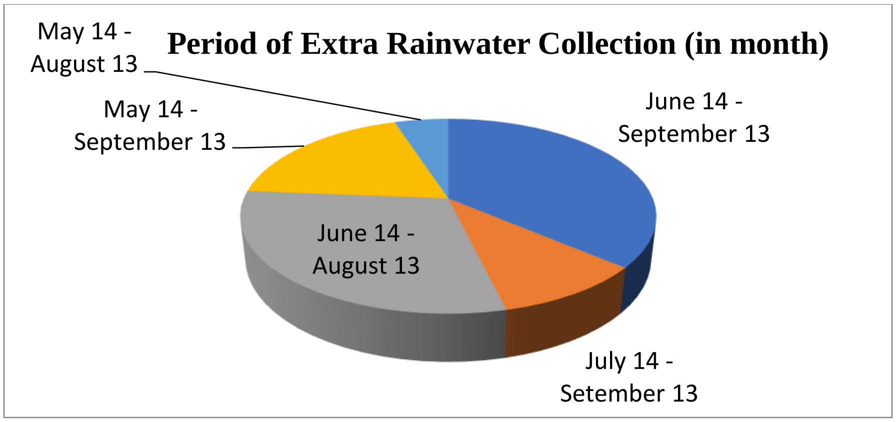



Figure 6.15: Extra water collection period (Source: field data)

Figure 6.15 shows that local people can collect extra during May 14 to September 13. Within this period, 36% of total respondents can collect extra water during June 14-September 13. However, 30% of total respondents think that they can collect extra water during June 14 – September 13. Between these two group of people one thing is similar that is extra water collection starting time (June 14). However, 19% respondents think that they can collect extra water during the period between May 14 and September 13. Additionally, 10% respondents can collect extra water in between July 14 – September 13. Among these four group of respondents one thing is similar that is ending period of extra water collection. In the study, remaining portion of the respondents (5%) think that that they can collect extra water in between May 14 – August 13. It is clear that they can collect extra rainwater in two or three months. It may differ in opinion but time almost same. Within this time frame they can collect different volume of water depending on their size of rooftop.

### Volume of extra water collection

According to survey, local respondents of the study think that if they had container they can collect extra water. The figure (shown in 6.12) shows the volume of extra water collection.

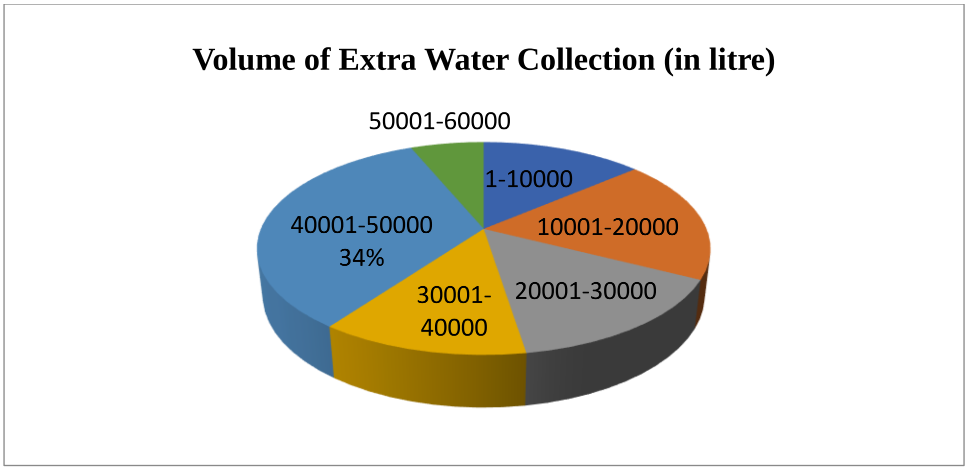



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Figure 6.16: Volume of extra water collection (Source: field data)

The survey found that if the villagers had container then 34% and 19% of total respondents can collect 40001-50000 and 10001-20000 liter of water respectively during rainy season (June 14-September 13). However, 15% of total respondents can collect 20001-30000 liter of rainwater in the same period. The study revealed that 14% and 12% of total respondents can collect 1-10000 and 30001-40000 liter of water respectively. The remaining portion of total respondents (6%) thinks that they can collect water that ranges between 50001 and 60000 liter. They can't collect same volume of water due to their catchment area and technical knowhow is not same. Catchment area depends on the size of the rooftop of the house/building. It is understandable that poor people have small building/house in size so that their catchment area is also small. As a result their water collection affect inevitably. It is clear that only one problem about extra water collection that is container. According to survey, 93.75% of total respondents can't collect enough water for whole year or extra water due to lack of container. Due to this container problem potentiality of rainwater may not utilize fully. Besides the container problem, they did not give up. They capture rainwater and store it for later use with their small container. During rainy season, they can collect extra water and use it for taking bath, washing cloth, and cooking. But only 6.00% of total respondents can use rainwater for these purposes and remaining part (94%) of the respondents wasted this ecological resource due to lack of container.

### Number of months uses rainwater per year

During rainy season, people at Chila collect rainwater continuously because they get rainfall nearly every day. For this reason, they can use collected rainwater for bathing, washing cloth, and cooking. After the rainy season (June 14-September or October 13), the river water is sweet in the following next one or two months. After that period the river water becomes salty and water poverty start and people in Chila start to use collected rainwater for drinking purpose only. If they have had enough containers to store collected rainwater they can use it over the whole year by collecting it during rainy season (June-September). As container problem persist due to economic problem and lack of government assistance they collect different volume of water and use it for different period of time. The following figure shows the number of months use rainwater by villagers in Chila.

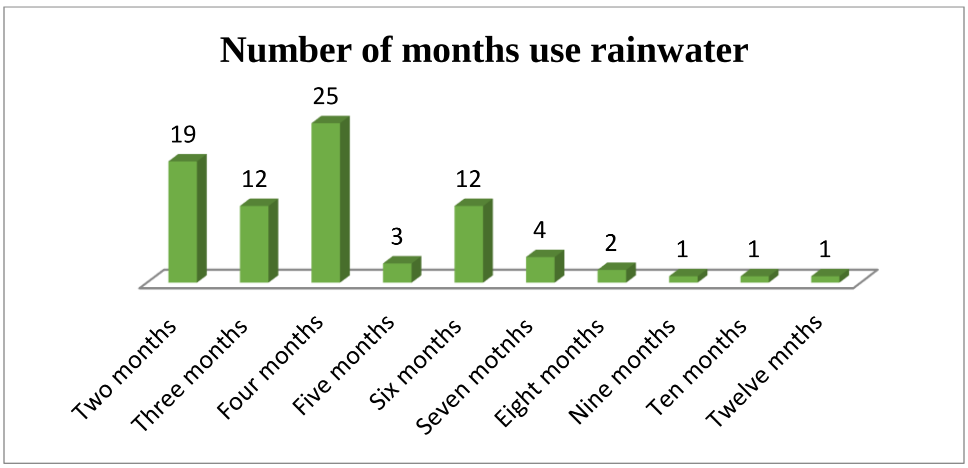


Figure 6.17: Number of months who uses rainwater in Chila (Source: field data)

Local Chila community starts rainwater use either in May or in June and lasting depends on the volume of collection. Only one villager can use rainwater during the whole period of the year from June 14 to June 13 because the respondent has enough containers to store collected rainwater for whole year. Within the community of Chila, another person has enough containers to use rainwater for ten months (June 14-April 13) and one more respondent can use rainwater for nine months (June 14 – March 13) of the year. However, two persons can use collected rainwater for eight month of the year (June 13 – February 13). Mohon Bachar, and Shohor Banu Begum informed me two people who can use collected rainwater for eight months over the year because they are technically sound about rainwater capturing and storing but their catchment area is not large and economic position is not very good. They can harvest and use rainwater efficiently. Besides these five person's financial and technical capacity nineteen of the respondents which are 23.75% of total respondents (80) at Chila can cultivate rainwater only for two months (June 14-August 13). It is understandable that they can use rainwater during most part of rainy season as rainy season long from June 14 to September 13 because they do not have container to store. Besides these group of respondents, remaining (52) respondents can use rainwater within the range of 4-6 months of the year.

**Advantages of Rainwater Harvesting**

Rainwater harvesting may contribute to reduce water poverty in Chila. Utilizing rainwater harvesting system provides specific advantages in Chila. It delivers water directly to the household and relieving the burden of women, men, and children of carrying water from kilometers of the nearest sweet pond water in Chila. Besides this benefit, other benefits include medical benefit, financial benefit, supply irrigation and domestic water, save time and so on. The advantages of rainwater harvesting summarized in the following ways:

Health Benefit: The survey found that 98.75% of total respondents (80) in Chila believe that their health status improved with rainwater harvesting by improving drinking water supply. They do not face health related problem (except physical injury) during rainy season because their water supply come from rainfall that is safe. Biswanath Bala informed that she has a daughter who can't drink and use pond water. During water poverty period (September 14 – June 13) she needs to supply rainwater to her daughter anyhow. For this reason, she collects rainwater as much as possible for her daughter. Her daughter suffered diarrhoea problem in last year (2016) due to lack of rainwater. She left the house for professional purposes but did not realize that her daughter can't collect water from large tank because her height is not enough to reach mouth of the tank. She forgot to bring water from large tank to small container. Another thing is that, pond water can't fulfill thirstiness of the people because it is not taste as much as rainwater.

Supply Irrigation Water: Agricultural activities except fish production are very few in Chila area. There are very few farmers in this area because of fresh water scarcity. The community face saline water problem all over the year except few month during rainy season. As a result, people do not try to cultivate crops in a large scale in this region. But some people grow vegetable in their homes' yard by using wasted rainwater. Biswanath Bala informed that she cultivates some crops like Brinjal, Ginger, Tulsi, and Green Chili in her home's yard. But all of these crops were died in 2007 and 2009 due to Sidr and Aila. These extreme events brought saline water which drowns those crops. Saline water kills almost all types of crops.

Supply Domestic Water: Harvested rainwater can contribute in meeting domestic water demand. If they cook rice with rainwater in the evening then the cooked rice is alright next day morning and can eat. Moreover, if they cook rice with sweet pond water then the cooked rice will turn into bad in next morning and it is uneatable. They can cultivate crops in home's yard by reusing water. They can use the water that has been used for washing their hands[72] brushing teeth, washing clothes, and dishes on the yard's vegetable garden.

Social Advantages: The community in Chila is social and they respect religious value. Rainwater harvesting helps to follow local culture like women do not need to go outside for collecting water for family. Biswanth Bala told that sometimes she faces problem during standing in queue for collecting water from sweet pond and travelling in trawler with male counterpart. She needs to collect water[73] from pond and bring it to transport from pond. After reaching village from sweet pond, she needs to transfer water from transport to residence. This kind of pressure she can't handle like male member due to age and lack of strength.

### 6.5.3 Availability of Finance

The study found that thirty one respondents got free tank, gutter, pipe, and other materials need for rainwater capturing and use. Here the figure (6.18) shows the expenditure of fifty six respondents for RH. The extra seven respondents[74] pay money for getting RHS from different NGOs. The respondents ask the respective NGOs about why they need to pay as the structure is totally free, the NGOs replied them this payment as contribution to buying structure (5), and transporter cost from Dhaka to Chila (2). Besides the finance from NGOs the respondents spent money for installing RHS and built foundation for keeping tank. The following figure shows the expenditure pattern of the respondents for RHS.

[72] Before and after eating

[73] The weight of a container depends on size. But people bring large container as it holds large volume of water.

[74] Monetary expenditure for rainwater harvesting (56) and free tank receiver (31) and total is 87 (56+31). But total respondents are 80. So, the discrepancy is 7 (87-80).

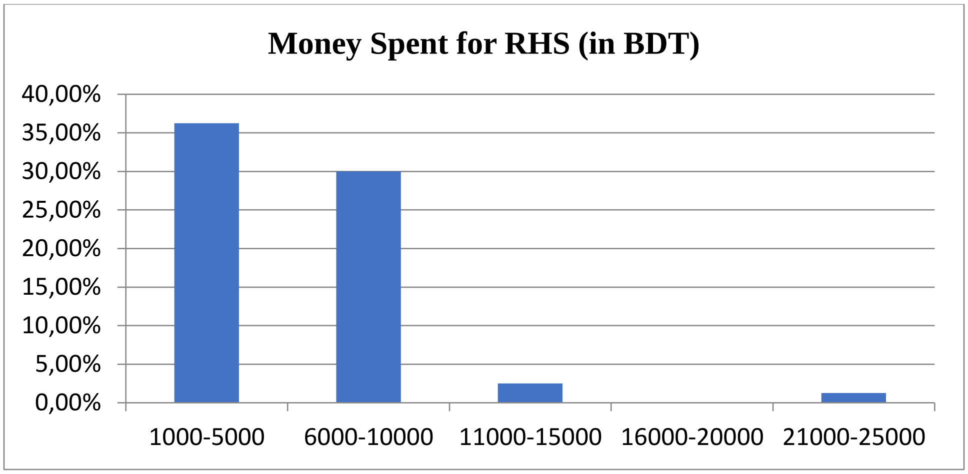

Figure 6.18: Money spent for RHS (Source: field data)

The survey revealed that 36.25% of total respondents spend money in the range between BDT 1000-5000, 30% in BDT 6000-10000, 2.5% in BDT 11000-15000 and 1.25% in BDT 21000-25000 range for RHS purposes. One respondent spent BDT 21000-25000 for RHS. This respondent does not face water poverty problem. The expenditure spent by the respondents for different purposes like buy large storage tank, small container, gutters, pipe, contribution to get tank from NGOs, foundation expenditure, and transport cost. Shohor Banu Begum, Arcona Roi, Mohon Bachar, and Dr. Bipul Chowdhury informed that if there is no natural disaster like Aila (2009) and Sidr (2007) the structure is alright more than twenty years. Keep RHS well depends on good maintenance. The structure will not damage if it maintains and operate efficiently.

| Maintenance and operation cost? | Household | Percentage |
|---|---|---|
| 1-500 | 29 | 48.75 |
| 501-1000 | 5 | 6.25 |

Table 6.8: Maintenance and operation cost (Source: field data)

Rainwater harvesting may be very simple to operate and maintain as the community in Chila maintain themselves and does not need any cooperation from other. As per survey, thirty four respondents spend money for maintaining and operation purpose of RHS. Within this expenditure group twenty nine respondents spend BDT 1-500 and BDT 501-1000. This money is spent for a number of different purposes such as cleaning tank, cleaning rooftop of house, covering mouth of tank, replace pipe, repair tank, clean pipe and replace gutter. For this maintenance purpose they use different kind of ingredients for cleaning purposes like bleaching powder[75], shampoo[76], and wheel powder[77]. The Chila community got finance from different sources for setting up RHS, maintenance, and operation purposes.

**Sources of finance**

There is 33 (41.25%) people get finance from Non-Government Organizations (NGOs) (shown in figure 6.19). This type of finance either came through either large tank or monetary benefit such as lending. The lending came from Association of Social Advancement (ASA)[78].Within this NGO beneficiary two persons got finance from ASA and remaining thirty one respondents got benefit in getting RC storage tank and materials from six different NGOs such as Tearfund United Kingdom, World Vision, Sushilon, Prodipon, Concern Worldwide and Rupantor. Within the respondents, World Vision provides nineteen large tanks and other materials need for rainwater capturing in Chila. After World Vision, Concern Worldwide provides five tank and Prodipon, Tearfund United Kingdom, and Rupantor provide two tanks each of them within the study group in Chila.

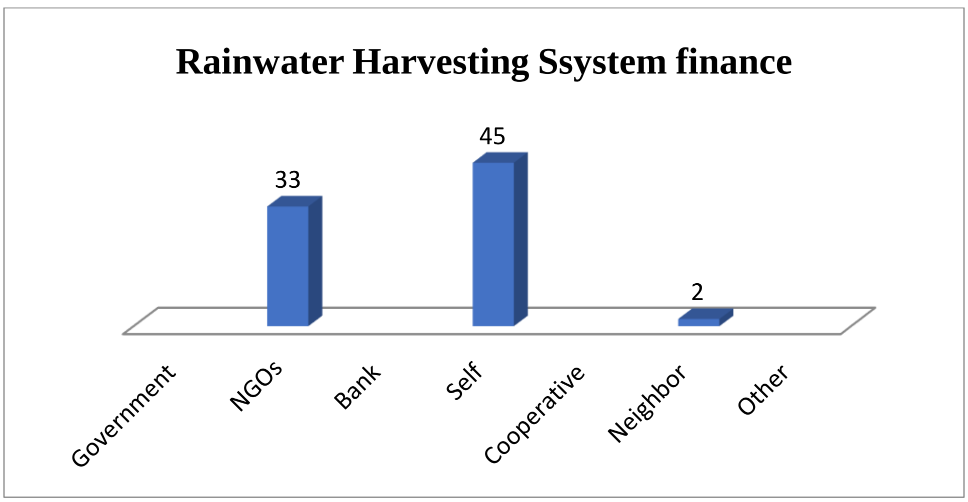


Figure 6.19: Sources of finance for RHS (Source: field data)

Besides NGOs finance forty five respondents which is 56.25% of total respondents (80) finance themselves for RHS and remaining two persons finance their system with the help from neighbor.

[75] Local cleaning powder
[76] Generally it uses for cleaning hair
[77] It is a local powder use for cleaning purpose
[78] Is a microcredit organization. It is also known as an NGO

Within respondents in the study group in Chila nobody got finance from government or bank regarding rainwater harvesting system installation.

The borrower needs to pay installment from their own earning. Neither NGOs nor bank provide loan for rainwater harvesting purposes. The community in Chila needs to show other purposes of loan and money spend for rainwater harvesting infrastructure.  According to survey result nobody face any problem for getting loan from NGOs in this study group. For instance, Kamal (fake name because he does not want to reveal his identity) took BDT 20000 as loan from ASA for small business purposes. But he bought a large tank by BDT 7500 which improve water supply to his family and business as well. He makes installment BDT 100 per thousand per month. He told that interest rate is high but it is alright as it improves safe water supply to his family which reduces health problem in his family. He needs to spend less medical expenditure as reduces illness in his family. He can cover high interest rate with saving money from reducing medical expenditure. As nobody loan provides for rainwater harvesting purposes but they provide and do not create any problem so it like something is better than nothing.

### 6.5.4 Government Roles

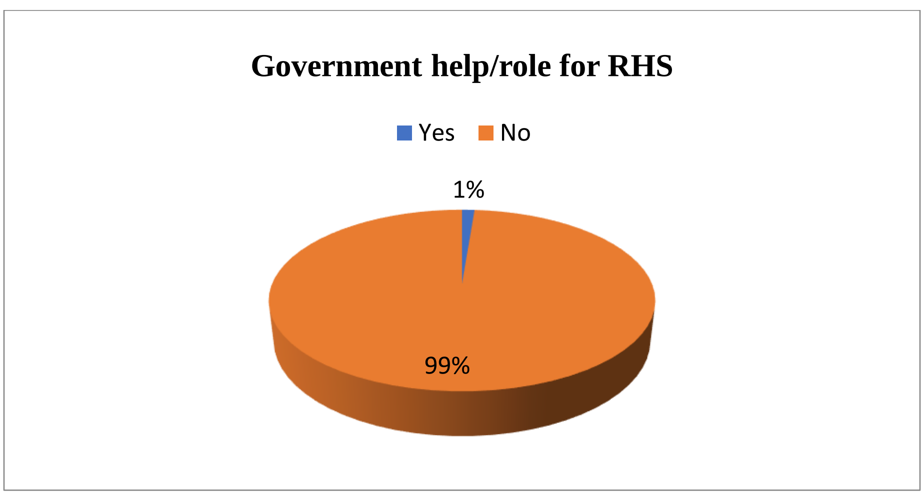


Figure 6.20: Government role for RHS in Chila (Source: field data)

A government is the system to govern the state or community. The government needs to form and execute new policy or update old policy for maintaining every matter well. The role of government regarding rainwater harvesting is testing with asking question about the support from government, awareness campaign, policy or permission and technical support about rainwater harvesting.

According to survey, 98.75% (figure 6.20) respondents said that the government does not play any role about RHS. Only one respondent heard that government provides ferro-cement tank to poor people. But the person did not get it and did not see practical application of this information. In the other hand, there is no policy about rainwater harvesting (table 6.8). Anybody can use this technique is their own way. There is no discipline about this system. As per survey all respondents (eighty) said that they do not need to get permission from anyone to set up rainwater infrastructure. In other way, there is no obligation to use rainwater for meeting water crisis in this region. It is community's own responsibility to resolve their water crisis.

**Policy/permission about Rainwater Harvesting:**

| Policy/permission? | Household | Percentage |
|---|---|---|
| Yes | | |
| No | 80 | 100.00 |

Table 6.9: Policy/permission about RHS (Source: field data)

**Technical support:**

Technical support is an important aspect for effective use of a system. Any system or product needs technical support to sustain in the market. In the same way, rainwater harvesting also needs technical support to sustain in this particular region. An important question is that who provides this technical support? The following figure shows the technical support providing by different organization to the community in Chila.

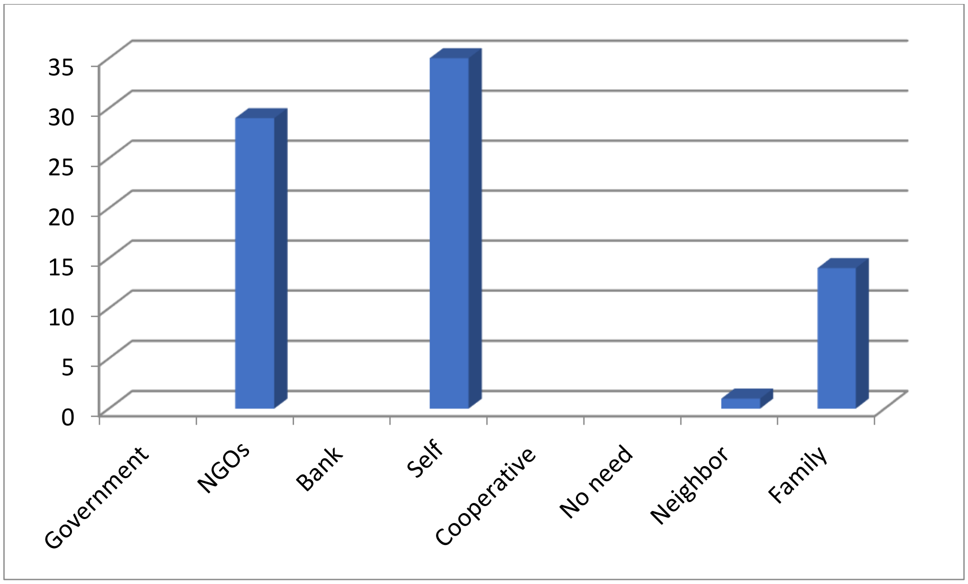


Figure 6.21: Technical supporter in Chila (Source: field data)

The above figure shows that neither government nor bank provides any technical support to rainwater cultivator. On the other hand, NGOs provide technical support to twenty nine rainwater cultivator in total respondents in Chila. But they provide rainwater harvesting material to thirty one people in Chila village. NGOs did not provide technical support to two rainwater harvesters whom they provide rainwater harvesting materials. The survey found that thirty five respondents did not get technical support from any organization. Their technical supporter is themselves. It indicates that they are creative to solve their problem and technically sound themselves without other help. Fourteen and one respondents get technical support from their family and neighbor respectively. In this region, people are supportive to each other regarding rainwater harvesting.

**Awareness campaign:**

| Awareness Campaign | Household | Percentage |
|---|---|---|
| Yes | 41 | 51.25 |
| No | 39 | 48.75 |

Table 6.10: Awareness campaign (Source: field data)

RH is an important alternative to resolve water poverty in water scarcity region and period. To use this rainwater more efficiently and effectively they need to know the advantages, disadvantages, technique of use and other aspect. For this reason awareness campaign plays important role for creating awareness among people in Chila. As per survey 48.75% of total respondent told that no awareness campaign held in Chila about rainwater harvesting. In the other hand, 51.25% of total respondents informed that awareness campaign took place in Chila by various local and international NGOs such as World Vision, Rupantor, Tearfund United Kingdom, Sushilan, Concern Worldwide, Heed Bangladesh, Prodipon, and BRAC. Awareness campaign includes rally, yard meeting, and talk to local people.

### 6.5.5 Social Acceptability

| Protest? | Household | Percentage |
|---|---|---|
| Yes | 0 | 0 |
| No | 80 | 100 |

Table 6.11: Social acceptability of RHS (Source: field data)

RH is popular as it has been using for a long period in Chila. This system of rainwater use continues from generation to generation in this region. Every family uses this practice for their freshwater supply. Social class and other norms do not create problem for using this technique in this region. As per survey result nobody complains against this method of rainwater use for domestic and irrigation purpose. Family support is an important factor to use any system for family member. If any family member does not support the system then the system is vulnerable in that particular family. But RHS may get good support within family. According to survey, 100% of total respondents (rainwater collector) said that they got cooperation from his or her family member for rainwater harvesting purposes. This cooperation can be a number of ways like collects rainwater, installation purposes, maintenance, operation purpose, transportation purposes, and cleaning purposes. Social acceptability regarding social protest and cooperation from family member is 100% as nobody protest and all rainwater collector get support from family member.

### 6.5.6 Environmental Sustainability:

**Reduce volume of saline water**

In a natural way in Chila, water flows to the Pasur River where water is saline. When rainwater cultivator collects rainwater for use in house, they reduce saline water impacts by holding water on site rather than letting it run off to Pasur River where water is saline. If it runoff to Pasur river then it will increase the volume of saline water which contribute to increase the level of water in river. When the level of water increases in river then the possibility of inundation in surrounding places by saline water increases.

### Efficient use of natural resource

Rainwater is natural resource. Every family in Chila captures rainwater and uses it for different purposes. If they do not capture this natural resource it would run off to saline water and increase the volume of saline water. If they do not collect rainwater then this natural resource will be wasted and do not bring any benefit for them.

### Tree plantation

Most plants can't grow with saline water. But saline water is available in Chila during the whole period of the year except rainy season (June – September). For this reason they do not plant trees in a large scale. They only plant number of trees which they can supply rainwater during water crisis period. Otherwise the trees will die due to lack of freshwater. Rainwater harvesting protects trees from saline water. Dr. Bipul Cowdhury, Shohor Banu Begum, and Mohon Bachar told that they lost their entire banana, mango, jackfruit, and other trees in 2007 because Sidr bring saline water in their home. But these trees absorb CO2 and leaves $H_2O$ which is helpful for environment and people. Plants may also grow faster with rainwater than any other types of water because rainwater has perfect pH balance and nitrate amount. This balance design by nature so that there is no possibility of mistake. They also told that if they do not supply water to the root of coconut trees then coconut will fall down automatically. At first the leaves of the trees will turn into red earlier than usual time. It is the first signal of lack of rainwater.

### Fish farming

Rainwater helps to do fish farming. Dr. Bipul Chowdhury informed that if he can make ratio of rainwater (80%) and saline water (20%) in the pond then he can cultivate white fish such as Rui, Grass Carp, Common Carp, Kalibause, Telapia, and Silver carp.

### Preparing food for chicken, duck, and other animals

Saline water is available all over the year in Chila. But it is not suitable in preparing food and drinking for chicken, duck, and livestock. Arcona Roi and Shohor Banu Begum informed that they can rear these animals during rainy season because rainwater is suitable for these animals. It does not create any problem for these animals.  Unfortunately Shohor Banu Begum lost ten chicken and five duck in last (2016) year because her daughter (11) prepared food for chicken and duck with saline water. Her daughter did not know that these animals can't eat food (saline water) mixed. Those animals fall into sick after eating foods. After few days all of the animals die.

**Fewer floods**

Heavy rainfall creates flood. Heavy rainfall inundates good part of whole Bangladesh every year. Coastal areas are more flood prone that created by extreme rainfall. RH reduces flood risk with holding water in house rather than entering river and so does not increase the level of water in river. For this reason it reduces the risk of floods in this region. Dr. Bipul Chowdhury told that the community at Chila does not face floods problems during the first heavy rainfall in this region during beginning of rainy season. Because during this time the entire storage tank in the village is empty. So, everyone collects rainwater in their tank and rainwater can't runoff to the river. After the first heavy rain, the region inundates with rainwater.

**Helps maintain good environment**

Local community in Chila believed that rainwater harvesting is good for them it is also good for environment. For instance, rainwater harvesting reduces diarrhoea. This diarrhoea pollutes environment. Mohon Bachar and Biswanath Bala told that they need to go to river to catch fish. Sometimes their need force them to go river with physical illness like diarrhoea. They face diarrhoea problem after passing rainwater using period. Diarrhoea forces them to leave their excreta in river and this behavior pollutes river environment. But they do not need to leave their excreta during rainwater using period as they do not face diarrhoea problem. Additionally, severe physical illness arise from pollute water use create unemployment problem for them. This unemployment problem force them to cut trees from Sundarbans, sale trees from house, and catch small and mother fish from river. These kinds of practices are harmful for environment and

Sundarbans[79] in Bangladesh. But rainwater harvesting can contribute to solving these problems from the root level by reducing polluted water use.

**Vegetable production**

It is easy to cultivate vegetable. Rainwater is good for livestock, birds, agricultural production. If the community at Chila can collect enough rainwater for agricultural purposes then their expenditure for vegetable will be reduced. They can cultivate vegetable in their house and can reduce nutrition problem and save money with not buying vegetable. Even they can do their meal with fresh vegetable as they cultivate vegetable in their own garden. It all depends on the volume of rainwater collection.

### 6.5.7 Quality

| Quality problems? | Household | Percentage |
|---|---|---|
| Yes | 5 | 6.25 |
| No | 75 | 93.75 |

Table 6.12: Quality of collected rainwater (Source: field data)

Quality is an important indicator for sustainability of RHS as collected water uses for all purposes such as drinking, bathing, cooking, and other potable purposes. According to survey, 93.75% respondents out of 80 said that they do not face any quality problem with rainwater use. Besides good quality rainwater[80]it can create health risks arise from ingestion of harvested rainwater such as contaminated with bacteriological and chemical pollutants. . But these drawbacks create by either maintenance problem of RHS or rainwater itself. This risk can be reduced with good maintenance and operation. RHS

## 6.6 Conclusion

As Chila village is near to the Pasur River and the river has direct connection with the Bay of Bengal the villagers face freshwater crisis due to salinity. In the other hand, socioeconomic position of Chila community is not very good to solve WP with wastewater treatment, river osmosis, and membrane as these techniques are expensive. Moreover, natural and climatic extreme events like storm surge, tidal wave, and other disasters deteriorate WP problem. For instance, Aila

[79] an important for environment of Bangladesh
[80]As per household survey (opinion of the respondents)

and Sidr destroyed all water supply facilities in Chila. This kind of problem is not new for them. As the problem is not new they identified their own solution to resolve their problem. For this solution NGOs has been playing important role in providing storage tank and other rainwater harvesting materials, training, awareness campaign, and finance. Moreover, the community did not find any environmental concern for this practice even they think it helps to maintain good environment and got socially acceptance. In current context of RC practice in Chila is well structured but lack of discipline in RH and lack of government intervention creates doubt about better outcome from rainwater and sustainability of RHS.

# Chapter Seven

## Conclusion and Recommendations

There are different alternatives to supply water in the study area such as buy sweet pond water, collection sweet pond water, bottle water, river water, and rainwater collection. These alternatives are not equally important to the people in Chila because of socioeconomic, sustainability, and ecological context. The present study is about to answer the questions: a. the roles are played different sources of water at coastal areas in Bangladesh, b. how climate change is responsible for WP in coastal Bangladesh, c. what is the alternative solution for reducing WP, d. advantages, disadvantages, and challenges of RHS, e. whether rainwater harvesting is sustainable or not in the context of technical feasibility, economic profitability, finance, government roles, social acceptability, environmental sustainability, and quality of harvested rainwater in Chila. The coastal people in Bangladesh heavily rely on rivers, tube wells, and ponds for cooking, bathing, and drinking. Water flow in Transboundary Rivers[81] decreased significantly due to water diversion from these rivers by upstream country[82]. Mismanagement of rainwater is another factor contributing on WP and little application of RH in local level in coastal Bangladesh. However, major part of coastal area’s groundwater is contaminated by arsenic and salinity.

Anticipated sea level rise, increasing intensity of floods, cyclone, storms surge, and tidal waves may also accomplice on saline intrusion in coastal Bangladesh by bringing saline water into fresh

[81] 57 transboundary rivers (54 out 57 come from India)
[82]Particularly India

surface[83] and ground water. Furthermore, predicted less precipitation due to climate change may also contribute on WP in coastal Bangladesh.

Rainwater harvesting may be a good approach in the context of economic, technical, and ecology to reduce water poverty in coastal Bangladesh as the country receives high seasonal rainfall[84]and can have access to rainwater for 8-10 months. But it demands to account potential health risk may arise from mineral, bacteriological, and chemical contaminants. Furthermore, technical knowhow, financing, and lack of space are also major challenges for RH. But main question is whether rainwater harvesting is sustainable alternative or not for reducing water poverty in coastal Bangladesh.

Some criteria in multiple variables under different subsystem of SES framework have used for assessing sustainability of RHS. Such criteria are: technical feasibility (U1, U4, and U5)[85], availability of finance (I5)[86], economic profitability[87] (RU4 and RU5), government role (GS1 and GS2), local socioeconomic and ecological context (U2, U3[88]), and for social performance (O1[89]) and environmental/ecological performance measure (O2[90]), social acceptability and environmental sustainability (environmental conservation) of RHS assessed.

RHS is about rainwater collection, store, and use so that it water sector[91] of resource systems[92]. The study conducted in coastal area (Chila) in Bangladesh[93]. Economic profitability of a resource unit (harvested rainwater) checked in a number of different ways. RHS reduce health related problems like diarrhoea, cholera, dysentery, stomach pain, fever, and nutrition deficiency by improving fresh water supply. The reduction of health related problems reduce medical cost and increase employment opportunity that increases income. Furthermore, RHS reduced purchasing volume of water and collection of water from far distance. Reduction of buying water saves money

[83] Pond, canal, and river
[84] average rainfall 2400mm
[85] U1 (number of users), U4 (location), and U5 (leadership/entrepreneurship) under Users subsystems of SES framework
[86]Investment is under interaction of SES framework
[87] RU4 (economic value) and RU5 (number of units) under Resource units subsystems of SES framework
[88] U2 (Socioeconomic attributes of users) and U3 (history of use) under Users subsystem of SES framework
[89] It is a variable under Outcome of SES framework
[90] It is a variable under Outcome of SES framework
[91]RS=Sector. It is a variable of SES under subsystem of resource systems
[92] It is a subsystems of SES
[93] RS9: Location. It is variable under Resource systems

and less water collection save time. The saving time can spend for earning purpose like catching fish in river, work as day laborer, and other income generating activities. It means that the resource units (volume (litre) of harvested rainwater[94]) have economic value (RU4[95]).

Better outcome from an ecological resource unit and system largely depend on the governance system. In this study, the role of government organization (GS1) and NGOs (GS2) examined in policy formulation and implementation (GS5[96] and GS7[97]), finance (I5), technical support, and awareness campaign for sustainability of RHS. The role of government is not good in these parameters as no policy has formulated for operation (GS5) and no monitoring and sanctioning process of rainwater use (GS7). Furthermore, government organizations may not finance, do not provide technical support, and did not arrange awareness campaign in Chila as the respondents did not get these facilities. Some responsibilities (e.g finance, providing and technical support, and arrange awareness campaign) are performing by different local, national, and international NGOs. But as the national government has more responsibility than NGOs and some responsibility like policy making and monitoring and sanctioning process are sole responsibilities of government in Bangladesh.

The study conducted among 80 household[98] in Chila[99] (coastal area) where people (mostly) poor and uneducated. With these 80 respondents 43 and 37 were adult[100] male and female respectively. Coastal people are frequently face climatic problems[101] as coastal areas are prone to climate change effect. With this socioeconomic[102] and local ecological context they have been using rainwater harvesting[103] for meeting up their potable water demand. It does not require specialized technical know how to operate and less than fifty percent of total respondents (80) got training from different NGOs. If it requires expert knowledge or training then this technique may not practice in this area for long time. But age of rainwater harvesting practice indicates that this system of using rainwater

[94] Number of units (RU5)
[95] Resource Units (RU) is the subsystem of SES and RU4 is the variable of this subsystem.
[96] GS5=Operation rules. It is a variable under GS (governance system) of SES.
[97] G7=Monitoring and sanctioning process. It is a variable under GS (governance system) subsystem of SES
[98]U1 (Number of users) under Users subsystem of SES framework
[99] U4 = Location
[100] Adult means over 18 years of age and mentally sound person
[101] Cyclone, floods, storm surge, tidal waves etc.
[102] U2=Socioeconomic attributes of users (poor, uneducated, gender, and adult) under User subsystems of SES framework.
[103] U5=entrepreneurship (under Users subsystem of SES)

has been practicing from generation to generation[104]. As major portion of people in Chila are illiterate it needs simplicity to manage. More specifically, 79%of 80 respondents did not face any difficulty to manage it. Even the people who faced difficulty to manage mostly could solve their problem themselves.

Chila community is not strong in socioeconomic development aspect. As major portion of population is poor, set up, maintenance and operation cost should take into account for sustainability of RHS. Rainwater harvesting may not take large volume of money as more than sixty percent of total respondents spent less than BDT 10000 for installing RHS. This finance[105] came from NGOs (33), self (45), and neighbour (2).

Finance from NGOs came in two ways: providing tank and other materials for RHS, and loan. The respondents did not get finance either from government or bank (private bank or public bank) for rainwater harvesting system setting. However, the people spend very negligible amount of money for maintenance and operation purpose[106] of RHS. Even good percentages of total respondents do not spend money for operation and maintenance purpose because they can operate and maintain it themselves.

As nobody protest against this technique and rainwater harvester gets family support so that the technique got strong social acceptability[107]in Chila. The technique has been practicing may for this reason from generation to generation. However, environmental sustainability[108] is mainly associated with either it creates environmental concern or help the environment. RH may not create environmental concern as per study conducted in Chila. Even it helps to reduce environmental concern like reduce soil erosion[109], volume of saline water[110], efficient use of ecological resource[111], tree plantation[112], fewer floods[113], surviving livestock and other animals[114].But quality

[104] U3=History of use (under Users subsystem of SES). More than 50% respondents know about this system from their parents
[105] I5=Investment(is a variable under Interaction of SES)
[106] Maximum expenditure BDT 1000 per year
[107] O1=Social performance measure (a variable under Outcome of SES).
[108] O2=environmental/ecological performance measure (a variable under Outcome of SES)
[109] Reducing runoff from rooftop on soil
[110] Reducing flows of rainwater to the river
[111] Use rainwater for different purpose
[112] Rainwater is suitable for tree plantation
[113] Reducing runoff of rainwater to the river so that it may reduce the possibility of increasing river water level and volume
[114] Rainwater is suitable for preparing food and drinking for livestock and other animals

of harvested rainwater may create concern as it depends on air quality, catchment area, maintenance and operation of RHS.

The findings from sustainability checking showed that RHS has very good possibility to reduce water poverty in the study area and bring better outcome from rainwater. But RHS has some lacking about government intervention in policy, finance, technical support, awareness campaign, and training.

## Recommendations

This study found that rainwater harvesting may be useful and sustainable system for water poverty areas as it is low cost, technically feasible, and environment friendly. For better outcome and more effective and sustainable use of rainwater the following recommendations are made based on the analysis of collected data in Chila.

The analysis can be used by the planners and decision makers and business person who are interested to make interventions in freshwater scarce areas in Bangladesh for supplying freshwater. RHS can be useful in drinking water scarce and severe groundwater depleted areas like Dhaka as an alternative source of potable water. Furthermore, it can be used as rainwater managing tool that creates water logging and flash flood in Dhaka and in coastal areas and drinking water supplier rather than draw water from ground source. It can also use for reducing pressure on groundwater which is depleting and lowering groundwater level so quickly in Dhaka[115], Bangladesh.

Poor government intervention in managing rainwater is a major drawback in governance system of rainwater in Bangladesh. Government intervention requires in the following aspect:

a. Finance: Government organization needs to provide finance for installing RHS as major people in Chila are poor. This finance can be either in providing large storage tank and harvesting materials or subsidiaries for installing RHS.
b. Training: As quality of rainwater either before or after harvesting largely depends on maintenance and operation of RHS. The government should provide training to local people particularly women who are basically responsible for supplying water to the family.

[115]It is a capital city of Bangladesh

c. Awareness campaign: As the country receives large volume of rainfall every year it can use for agricultural, potable, and industrial purposes. The government needs to create awareness among people about the use of rainwater for these purposes.
d. Policy: A system can't sustain without policy or rules. There is no such policy or rules about RHS in Bangladesh. This lacking may deter better outcome from rainwater and create vulnerability of RHS in Bangladesh. The government should prepare a policy or guidelines about RHS which should include sanctioning and monitoring process of RHS. Also, evaluation and monitoring process of policy's effectiveness.
e. Climate Change adaptation: The government can consider RHS as an adaptation tool for reducing vulnerability of climate change effect as the country one of the most vulnerable countries in the world.

The study has conducted in one village of one Upazila regarding freshwater supply for potable use particularly drinking. It should be carried out in more villages in different Upazilas with adding broader use of collected rainwater like agricultural and industrial production in coastal areas for establishing the findings more firmly. Furthermore, the study might not give enough emphasize on maintenance and operation aspect of RHS which greatly affect the quality of rainwater that may create health problems. The study carried out for over short period of time which may affect the quality of data so that it may not able to consider the finding conclusively. For conclusive findings it needs further, longer, deeper, and ethnographic study about RHS at coastal areas in Bangladesh as climate change adapter, environmental conserver, and empowering marginalize people.

**Chapter Eight**

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**Appendices**

**University of Twente**
**Enschede, the Netherlands**

Date of Interview:_______________ Questionnaire No:________________

My name is Mohammad Rafiqul Islam student of the Master of Science Environmental and Energy Management program at the University of Twente. I am here to do a fieldwork on the research topic *Reducing Water Poverty in Coastal Bangladesh: Is Rainwater Harvesting a Sustainable Solution?* for my Master's thesis. Based on your verbal consent, I would like to request you to participate in my FGD/survey that will take around 40 minutes. If you want you can ignore any question(s) or withdraw from participation of this research. I will keep your identity confidential.

**Socioeconomic Background**

(1) Name: __________________________ (2) Sex______

| | | | |
|---|---|---|---|
| 1 | Male | 2 | Female |

(3) Age (year)________________

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 20-29 | 2 | 30-39 | 3 | 40-49 | 4 | 50-59 | 5 | 60-69 | 6 | 70-79 | 7 | 80-89 | 8 | 90-100 |

(4) Marital status_________________________

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Married | 2 | Unmarried | 3 | Divorce | 4 | Separated | 5 | Others |

(5) Total number of children________________________

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1-2 | 2 | 3-4 | 3 | 5-6 | 4 | 7-8 | 5 | 9-10 | 6 | 11-12 |

(6) Ownership of cropland (bigha): ____________

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1-2 | 2 | 3-4 | 3 | 5-6 | 4 | 7-8 | 5 | 9-10 | 6 | 11-12 |

(7) (a) Primary Occupation: __________________(b) Secondary Occupation_____________

**Socioecological Problems**

(8) What types of natural disasters in 2015-16 are responsible for your freshwater crises?

| Types | Reasons |
|---|---|
| Drought | |
| Flood | |
| Salinity intrusion | |
| River bank erosion | |
| Other (specify) | |

(9) What types of challenges you encountered for irrigation and domestic water because of these natural disasters?

9 (a) You face water poverty what period of the year?

9 (b) You buy water for how many months?

9 (c) How much money spend for buying water?

(10) What are some major ways out you followed to overcome your freshwater crises?

**Technical Feasibility**

(11) How many years have you been cultivating rainwater?

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1-3 | 2 | 4-7 | 3 | 8-11 | 4 | 12-15 | 5 | 16-19 | 6 | 20-23 |

(12) How did you learn about it?

(13) How did you manage the system?

(14) Does it require specific technical skill to manage?

| | | | |
|---|---|---|---|
| 1 | Yes | 2 | No |

(15) If yes, what kind of technical skill it requires?

(16) Did you get any training for harvesting the rainwater?

| | | | |
|---|---|---|---|
| 1 | Yes | 2 | No |

(17) If yes on the question no 16, please specify the name of agency and its types of contribution about training.

(18) Do you face any difficulty to manage it?

| | | | |
|---|---|---|---|
| 1 | Yes | 2 | No |

(19) If yes, what kind of problem you face to manage it?

(20) Who help you to solve the problem?

**Economic Viability**

(21) Does this rainwater harvesting improve your drinking water supply?

| | | | |
|---|---|---|---|
| 1 | Yes | 2 | No |

(22) What other purposes you use this harvested rainwater?

(23) Does the system help to improve your family's health status?

| | | | |
|---|---|---|---|
| 1 | Yes | 2 | No |

(24) If yes, how?

(25) Can you collect more water than you need?

| | | | |
|---|---|---|---|
| 1 | Yes | 2 | No |

(26) If yes, can you collect extra water during the period and how many liters?

(27) If the answer is 'yes' on question 25 what would you do with extra water?

(28) This system can supply water for how many months?

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Jan-Feb | 2 | Mar-Apr | 3 | May-Jun | 4 | Jul-Aug | 5 | Sep-Oct | 6 | Nov-Dec |

(29) Can you tell me the advantages of this system?

**Availability of Finance**

(30) Is rainwater harvesting economically profitable for you?

| | | | |
|---|---|---|---|
| 1 | Yes | 2 | No |

(31) If yes, how?

(32) How much money (thousand) you spent to set up this system?___________

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 10-29 | 2 | 30-49 | 3 | 50-69 | 4 | 70-89 | 5 | 90-119 | 6 | 120-139 |

(33) How much money (thousand) you need to spend for maintenance and operation for this system per year? ____________________

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0-5 | 2 | 6-10 | 3 | 11-15 | 4 | 16-20 | 5 | 21-25 | 6 | 26-30 |

33 (a) You clean the structure for how many times in the year?

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 1 - 2 | 2 | 3 – 4 | 3 | 5 – 6 | 4 | 7 – 8 |

33 (b) What kinds of ingredients use for cleaning?

(34) Who finance you in setting up this system?

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Govt | 2 | NGO | 3 | Bank | 4 | Self | 5 | Cooperative | 6 | Others |

(35) If you receive loan, how would you pay back installment?

(36) Did you face any problems to receive loan?

| | | | |
|---|---|---|---|
| 1 | Yes | 2 | No |

(37) If yes, what types of problems you faced to receive the loan?

**Government Roles**

(38) What are government roles in overcoming your freshwater crises with rainwater harvesting?

(39) Did you need permission to establish this rainwater harvesting system?

| | | | |
|---|---|---|---|
| 1 | Yes | 2 | No |

(40) Who provide you technical supports in operating the rainwater harvesting?

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Govt | 2 | NGO | 3 | Bank | 4 | Self | 5 | Cooperative | 6 | Others |

(41) Is there any awareness campaign organized for rainwater harvesting?

| | | | |
|---|---|---|---|
| 1 | Yes | 2 | No |

(42) If yes, who organized it?

**Social Acceptability**

(43) Did you face any social protest to set up this rainwater harvesting system?

| | | | |
|---|---|---|---|
| 1 | Yes | 2 | No |

(44) If yes, who protest it and why?

(45) Did your household members support you in collecting and using rainwater?

| | | | |
|---|---|---|---|
| 1 | Yes | 2 | No |

**Environmental Sustainability**

(46) Is rainwater harvesting helpful for promoting environmental conservation?

| | | | |
|---|---|---|---|
| 1 | Yes | 2 | No |

(47) Give reasons for your answer in the question no 46.

(48) Do you have any environmental concerns over the rainwater harvesting system?

| | | | |
|---|---|---|---|
| 1 | Yes | 2 | No |

(49) Give reasons for your answer in question no 48.

**Quality**

(50) Did you have any quality concern over the harvested rainwater?

| | | | |
|---|---|---|---|
| 1 | Yes | 2 | No |

(51) If your answer on the question no 50 is yes, please mention some major concerns