Sustainable approaches to Drought Management: Exploratory Study on selected regions of Northwest in Bangladesh

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Submitted by

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DECLARATION

Candidate's Declaration

I hereby affirm that this thesis is a result of my own works and it has not been submitted to accept other University for a degree. The information and data from secondary sources, which I have used for the text, are acknowledged at the several sections.

Candidate---

Name:--

Date---

DECLARATION

Supervisor's Declaration

This is to confirm that the tasks and findings in the thesis "**Sustainable approaches to Drought Management: Exploratory Study on selected regions of Northwest in Bangladesh"** submitted by Mr. Md. Shafiqul Islam was carried out by himself under my supervision. The thesis represents the original research work of the candidate. External contributions for this research are acknowledged.

Supervisor--

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Date---

Joint Supervisor's Declaration

This is to certify that the results and findings in the thesis "**Sustainable approaches to Drought Management: Exploratory Study on selected regions of Northwest in Bangladesh"** presented by Mr. Md. Shafiqul Islam was completed by himself under my guidance.

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ABSTRACT

Drought is an extended deficiency of precipitation, a period of unusually dry weather. It is one of the major and complex hazards which affect peoples' livelihoods on a large scale. Drought has been identified with unusually dry weather due to lack of sufficient precipitation, and shortage of water which damages crops. The present study has been carried out with the view to discover sustainable adaptation measures to establish relationships with crop loss and factors that influence loss caused by drought. The study has been conducted in the Northwest region of Bangladesh; officially known as the Barind Tract. Household Interviews, Key Informants' Interviews, In-depth Interviews, Case Studies, and Focus Group Discussions have been conducted to collect information for this study. A total of 343 respondents were selected using the proportionate population sampling method and interviewed using a standardized questionnaire and checklist. The study findings revealed that the people in the study locations experienced different types of drought during 1976 to 2014. More frequent droughts occurred in Tanore and Shibganj, followed by Nachole, Porsha, Niamatpur and Godagari. Extreme, severe, moderate and mild droughts have been identified in the study locations. Respondents perceived drought as a natural disaster with extreme temperature and lack of rainfall. They also thought that drought is a natural occurrence and the punishment of God. Results showed that an increased frequency of drought caused huge impacts to crops, livelihoods and society. The respondents opined that the groundwater table is going down every year in respect to the seasons. Farmers are shifting from rice to low water demand crops through crop diversification. Several irrigation efficiency technologies are being practiced by the respondents. It was found that drought frequency, locations, support, occupations and agricultural land all had a significant influence on crop loss. They used animals' behaviour and a number of indications from the weather to predict droughts. Pigeons lying on the ground while spreading their feathers, the sound of wild cats, ants' upward movement from below ground, termites den and mound in dry soil, a sunny bright red colour during sunset, frequent lighting followed by thunder in the east sky at the early night were all considered as signs of drought. Common mitigation and coping measures for drought include local methods of storing water, changing food habits, field practices and the use of traditional medicine. Wild plants and animals were eaten by the rural people to sustain their livelihoods during drought. Coping and mitigation measures are often

more reactive than adaptation measures in response to drought. The sale of livestock, borrowing money from others, short term migration to other places and labour sale are a few commonly used measures to cope with short term shocks. Drought coping strategies varied from place to place and from household to household based on demography and socio-economic characteristics. Adaptation measures employed depended on the capacity of the respondents and people usually considered accessibility of livelihood options, profitability and sustainability of adaptation measures. Five different capitals are given emphasis in the study framework. People apply their best strategy to established sustainable management approaches to drought and make linkages with symbolic interaction and social exchange theory. They used their physical capital, including infrastructure, tools and technology, human capital, economic and financial capital, social capital and natural capital for managing drought risks. Land use planning is an important adaptation measures for drought. Four types of land zoning were found in the study area: *Chara*, *Char Kandur*, *Kandur* and *Jaoi*. A double cropping pattern is the common feature for *chara* land; in certain areas a triple cropping pattern was found. Farmers used their networks in managing drought risks and impacts. At first, they called upon close relatives, then friends, and then neighbouring people and elite people from the village or union. Generally they sought support for cash, food and clothes. Eventually they take loans from the samity and clubs to address drought risks. Two categories of livelihood strategies exist at individual level adaptation: a climate sensitive strategy and a non-climate sensitive strategy. The climate sensitive strategies include crop farming, poultry and egg production and livestock rearing. Most respondents were engaged in non-climate sensitive activities likely small trading, van pulling and casual labour. Other activities include collection of wild foods, bamboo slat and basket making, net and *pakha* making. At household level adaptation, respondents are performing home garden using organic manure to reduce drought impacts. At the farm level, they adopted a wide array of options including the cultivation of drought tolerant crops, crops with a low water requirement, crop diversification, changes to cropping times and patterns, raising mixed fruit orchards, relay cropping, new crops in the cropping pattern, organic practices, planting trees in the marginal lands and in the homesteads and crop land. Eventually they increased the scope for irrigation through excavation or re-excavation of ponds, canals and *kharies*. The study suggests the necessity of land use policy and drought policy for Barind Tract. There should be clear restrictions for installation of water related infrastructure.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

Glossary of Bangla Words

Aman	Rice or paddy harvested in winter. There are two types of *aman:* Broadcasted Aman and transplanted Aman
Arhar	A kind of pulse
Asha	Hope
Aus	Rice or paddy harvested in rainy season
Ayle	Bund/Dyke
Bajra/Bhura	Peral millet
Bari	Homestead
Batishak	Pechay-A kind of indigenous creeper
Beel	Swamp and marshy area
Bhang	Bhang is an edible preparation of cannabis
Bichi kola	Kind of local banana
Boishak	Name of Bangla month
Bon kochu	Wild arum
Boroi	Jujube
Chaitali	Crops in the Bengali month of Chaitra
Char kandur	Medium high land
Chara/Danga/Dying	High land

Charas	Charas is the name given to a hashish form of cannabis which is handmade in many South Asian countries
Chatok/Fatik pakhi	Common Lora bird
Chhatu	Flour made of Barly
China	Common millet
Choitra	Name of Bangla month
Dhore	Leakage
Dhul	Dust
Doila	Made of cowdung and jute stick (fuel)
Farakka	Dam constructed at Farakka which diverts Ganges water from India to Bangladesh
Fen	Rice gruel
Fitkary	Water purifier
Galagali	Slung language
Ganja	Hemp
Ghorer chala	Roof of village house
Ghute	Special type of fuel made of cowdung (dry cowdung)
Goshthi	Patrilineage (Blood relationship)
Gramer bou	Bride of village
Hathahathi	Battle

Horek mal	Different types of products
Imam	Religious leader (who leads prayer)
Jaoi	Plain land
Jhal Jau	Gruel prepared from rice, pulse and other spices
Kaj	Work
Kalboishaki	Special type of storm in the Bengali month of Boishak
Kandur	Low land
Kaun	Millet
Khal	Canal
Khari	Large canal
Khesari	A kind of pulse
Khora	Drought
Kochu	Arum
Koda	A kind of pulse
Kolai ruti	Bread made of pulse
Kolai	A kind of pulse
Kolmi	Water spinach
Lau	Gourd
Lomba	Large crowd

Maara	A kind of pulse
Macha	Platform or trellis made of bamboo
Manthal	One kind of hat made of bamboo
Mashkolai	A kind of pulse
Matir Kolshi	Pitcher made of clay
Mistikumra	Sweet gourd
Mohajan	Money lender
Mosur	Lentil
Motki	Large pitcher made from clay
Mul	Clay
Mung	A variety of pulse
Pakha	Hand fan usually made of palm leaves
Para	Neighborhood within a village
Pathkhori	Jute stick
Robi Crops	Winter crops
Roder Bachha	Bright sun light
Ros	Moisture
Sada Jau	Gruel prepared from rice and huge water
Sajna pata	Drumstick tree leaves

Sajna Tree	Drumstick tree
Santal	Ethnic people
Shaad	Taste
Shorbat	Soft drink (home made)
Sona	Gold
Taka	Bangladeshi currency
Tal gurh	Molasses made from palm juice
Tal	Palm tree
Thana	Administrative unit
Tin	Corrugated sheet
Upazila	Sub District
Van	Special type of Rickshaw
Zila	District

Abbreviations

AWD	Alternate Wetting and Drying
BADC	Bangladesh Agricultural Development Corporation
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BIDP	Bangladesh Integrated Development Project
BINA	Bangladesh Institute of Nuclear Agriculture
BMD	Bangladesh Meterological Department
BMDA	Barind Multipurpose Development Authority
BRAC	Bangladesh Rural Advancement Committee
BRRI	Bangladesh Rice Research Institute
BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
CEGIS	Center for Environment Geography information services
CSD	Center for Sustainable Development
CV	Coefficient of Variance
DAE	Department of Agriculture Extension

DASCOH	Development Association for Self-reliance
DFID	Department for International Development
DTW	Deep Tubewell
DU	University of Dhaka
FAO	Food and Agricultural Organization
FGD	Focus Group Discussion
GDP	Gross Domestic Products
HYV	High Yielding Variety
ICS	Improved Cooking Stove
IDMVS	Institute of Disaster Management and Vulnerability Studies
IGA	Income Generating Activities
IPCC	The Inter governmental Panel on Climate Change
IRRI	International Rice Research Institute
IWFM	Institute of Water and Flood Management
IWRM	Integrated Water Resources Management
KII	Key Informants' Interview
NDMC	National Drought Mitigation Center
NGOs	Non Government Organizations

OFRD	On Farm Research and Development
OLS	Ordinary Least Square
PET	Potential evapo-transpiration
PPS	Proportionate Population Sample
PRA	Participatory Rural Appraisal
SD	Standard Deviation
SLA	Sustainable Livelihood Approach
SPI	Standardized Precipitation Index
SPSS	Statistical Package for the Social Science
Sq. Km.	Square kilometer
STW	Shallow Tubewell
SWT/SWL	Static water table/Level
TV	Television
ULAB	University of Liberal Arts Bangladesh
UN	United Nations
UNDP	United Nations Development Program
UNEP	United Nation Environment Programme
WARPO	Water Resource Planning Organization
WB	World Bank

WCED	World Commission on Environment and Development
World Vision	International NGO

Chapter 1: Introduction

1.1 Introduction

Climate change has been identified as the most crucial threat that faced by the earth in this century. It was observed that the global surface temperature has changed significantly with regional dissimilarity for the last 157 years (IPCC, 2007). The global temperature has been increased to 0.35° C from 1910s to 1940s and this figure has been attained to 0.55° C from 1970s to present. This warming inflates the widespread hydrological sequences (Milly *et al*., 2002) and is subsequent to the last coolest temperature (almost 21000 years ago). Clark *et al.*, (1999) mentioned that the earth's regular surface temperature has increased in alarming rate and thus it has escalated the global average precipitation, evaporation, and run off. It has been caused the extreme climatic change in the past few decades and the world experienced severe droughts. Drought is the most complex natural disaster and it is hard to predict and lessen the impacts of multiple factors. Two major factors such as lack of specific information and data on drought externalities or issues and difficulties are involved in defining the magnitude of drought. Drought might be defined depend on the nonavailability of precipitation, leading to shortage in base flow and surface flow of water and depletion of soil moisture (Nandargi, *et al*., 2010). UNISDR (2009) identified drought as "slow onset hazard which provides time to consider and address its complex root causes". Besides, drought is a 'extended deficiency of precipitation', a 'paucity of precipitation' that causes water scarcity for all sorts of activities for a time of extremely dry weather and it extended for the shortage of precipitation to occur a severe hydrological imbalance' (Heim, 2002). The extended drought prevents any recharge to the aquifer by limiting water table and drying up all sources of natural water and channels. Several studies mentioned that drought has been placed in the first position by the number of victims among all natural disasters, (Obasi, 1994; Hewitt, 1997; Wilhite, 2000). According to the United Nations Office for International Strategy on Disaster Reduction (2004), disaster is "a serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts which exceeds the ability of the affected community or society to cope using its own resources". Droughts are often considered the cause of famine although this direct linkage has been disputed. Stephen and Downing (2001) reported that other factors also contribute famine development. Studies showed that drought occurred in the 20th century caused the most terrible impact among natural disasters (Bruce, 1994; Obasi, 1994). Drought has severe impact on the economy and society. According to Paul (1998), drought causes abnormal increase in prices as it damages agriculture, increases the unemployment and reduces food access capacity for rural people (small and landless labourers). Drought economic losses are occurred from livestocks (dairy and beef), crops, timbers, and fishery production. It collapses agro based industries reducing employment opportunities in agriculture and ultimately causes revenue loss of the local and the state financial organizations and puts them in financial hardship. In addition, it reduces the navigability of waterways and increases water and development cost (Wilhite & Glantz, 1985). After the 1984, drought in Sub Saharan Africa, the GDP for Mali, Niger, and Ethiopia fall by 9 percent, 18 percent, and 7 percent, respectively. Zimbabwe's GDP declined 3 percent after the 1983 drought (Benson & Clay, 1994). It is wellknown to all that drought in future, will pose a great threat to the climate sensitive economic sectors. Therefore, it strongly justifies the understanding and addressing the issue. The present study focuses on exploration of drought and climate scenario, elucidation of drought perception on drought related to definition, causes, symptoms and impacts, status of groundwater table and its consequences, crop loss factors due to drought, sustainable approaches for drought management (mitigation and adaptation) and how women become resilient to drought.

1.2 Statement of the problem

It was explained in the academic discussion that the Sustainable Livelihood Framework became more popular in mid 1980s as an answer to the key development talk of the 1970s, and the 'top down' approaches that had been leading within the development discussion at that times (Ellis, 2000; Scoones, 1998). Robert Chambers made critics on 'top down' approach and argued the necessity of enhanced focus on development actors and poor themselves (Chambers, 1983). The idea was to put back the 'top down' approach along with action from below (bottom up). The approach developed next to other fields and approaches in the 1980s, Chambers argues that "the sustainable livelihood thinking was formed by fusing the best environment, development, and livelihood thinking" (Chambers, 1987: 5). This gives focus on sustainability, productivity and poor peoples' livelihood. World Commission on Environment and Development (WCED, 1987) defined sustainable development as "Development that meets the needs of the present without compromising the ability of future generations to meet their needs". Sustainable livelihoods first used by WCED in 1987, and incorporated in their sustainable agriculture policy (Cahn, 2002). The livelihood issue was addressed by the Local Agenda 21 of UN Conference on Environment and Development which was held in Rio in 1992 (Schafer, 2002). Sustainable Livelihood Approach is very much helpful for understanding that households and individuals adopt during a crisis as the survival strategies. Literature of Sustainable Livelihood Approach classifies into three broad groups which includes:

i) Agricultural intensification: (e.g. food crops, cash crops, livestock)

ii) Livelihood diversification: (This includes diverse income option from both farm and non-farm)

iii) Migration: individual a few members of the family leave and earn money somewhere else and contribute to the household economy during the crisis. Migration is of three types (seasonal, circular and permanent).

Climate change increases the occurrence and severity of drought at local to a wider scale and intensifies the risk of human and economic losses. Drought may cause conflict, violence, civil wars or even wars between nations in future. This situation demands sustainable drought management approaches that will promote resilience community in future. Drought is the most common natural phenomenon in the northwest region of Bangladesh. The northwest region covers Rajshahi, Chapai Nawabganj, Naogaon and Bogra District. The northwest region of Bangladesh has become seriously drought prone due to the high variability in rainfall (Shahid & Behrawan, 2008). The average annual rainfall in this region is 1,329 mm, which is quite low compare to northeastern part of the country with 4,338 mm annual rainfall (Shahid *et al*., 2005). Several researchers have been reported that drought poses the highest risk to the northern and northwestern parts of Bangladesh. Research findings showed that the drought victims are often compelled to purchase food by selling their lands, household goods, and livestock at low prices (Reardon *et al*., 1988). The High Barind Tract, one of the agro ecological zones in the northwest has been suffering from severe drought over the decades. The Barind Tract is surrounded by Korotoya River to the east, Mahananda River to the west and Ganges River to the south. The Argo Ecological Zone of Barind Tract consist of 25 level Barind Tract, 26 High Barind Tract and 27 Northeastern Barind Tract. This study gives attention only High Barind Tract as drought prone ecosystem is much more peculiar and exceptional in High Barind Tract than the other parts of the country. The evapo-transpiration rate is higher than precipitation of five months starting from January to May, resulting in water stress or drought for the growing crops. Hence a remarkable part of High Barind Tract remains fallow in *Rabi* season. Surprisingly, there is no river system in High Barind Tract. Eventually, air temperature goes above 40^0c, sometimes exceeds 42^0c in May with dry wind prevalent from February. Most of the months it remains rain less and more than ninety percent rainfall occurs during the period of June to August. Two types of land ownership were found in the study area. Only twenty percent farmers own land and majority (70%) are absentee farmers. These cause obstruction in adopting new technologies and drought matching cultivation practices in the study area. Consequently drought leads to land degradation, desertification and water crisis in the Barind Tract. In Barind Tract, drought increases the vulnerability of local populations. However, the drought affected people are not capable enough to combat drought in effective ways. This happens due to the ever increasing frequency of drought, non resilient livelihoods, the declining of the resource base, the conflicts of resources and the changes in access to land and water. Agriculture, health, and the natural environment of these sectors are heavily affected by drought. Environmental impacts of drought lead to the mortality of fish and the aquatic resources, the loss of biodiversity, the deterioration of wetland, the dry out of rivers and the imbalance of the ecosystem. The socioeconomic impacts of drought cause poverty through the chain of consequences including the obstructing or shrinking the source of income, the loss of employment, the migration of affected people and the reducing of the livelihood options. The land degradation and the desertification are two other dimensions of drought that impact the people’s livelihood in the northwestern part of Barind Tract. Desertification refers to land degradation in arid, semi-arid, and sub humid areas due to anthropoid activities (UNEP, 1993; Darkoh, 1995). The rivers in the northern part of Bangladesh are dying gradually and creating water crisis and a potential threat to the agriculture and biodiversity in those areas. Dredging the river in dying condition is needed to reduce the impact of the Farakka barrage in the upper riparian country of the river Padma (Figure 1).

Figure 1: Low flow river in the northern region of the country (Source: Sohrab, 2015)

The Padma, region has left its impact on rivers flowing across the northern due to the huge withdrawal of the Ganges water in the upper part. The rivers with little water from upper part of the Padma have lost their flow in the dry season. The absence of the flow of water causes the deposit of sands and gradually silts up the riverbeds. The number of dying rivers in Bangladesh is increasing. There are fifty rivers that have already died in northern Districts. The river research survey identifies those as seasonal rivers. The rivers which have been silted up contain no water in the dry season. Local people grow different types of crops on the river beds. There are two sided effects of humans in land degradation such as mitigation or acceleration. According to Food and Agriculture Organization (1983) land degradation is a “process which lowers the current and/or potential capability of soil to produce goods and services”. It occurs due to the faulty land management practices (over abstraction of groundwater). Land as a means of conserving biodiversity, regulates hydrological regimes, cycles soil nutrients, and sequests carbon. Zuberi (1998) has mentioned that land degradation is about five million hectares (33%) of total land in Bangladesh that remains below the minimum threshold for sustainable cultivation. Low soil fertility is the main causes of land degradation in drier parts of Bangladesh (Zuberi, 1998).

Table 1.1: Land affected by drought

Degradation types	**Affected area (million ha)**			**Total area (million ha)**	**% National area**
	Light	Moderate	High		
Soil fertility decline	3.8	4.2	-	8.0	54
Organic matter depletion	1.9	1.6	4.0	7.5	51

Source: Hossain, 2007 (compiled by researcher).

Anthropogenic, human induced activities for land management and natural phenomena including floods, soil erosion and landslides caused land degradation in Bangladesh. In certain cases land degradation takes place as a consequence of the combined actions of human and nature. UNEP-GOB-BCAS-SACEP-NORAD (2001) have been identified following factors for land degradation and management problems: i) high rate of groundwater depletion and low efficiency of irrigation system; ii) haphazard use of fertilizer; iii) formation of ploughpan; iv) indiscriminate pesticides use; v) overexploitation of biomass from agricultural fields; vi) unplanned rural development (settlements, road, embankment and other infrastrcures related to flood control, drainage and irrigation projects) causing waterlogging; vii) more brickfields in the fertile agricultural land; viii) development of industries without consideration of land use priority; ix) uplifting and mining of gravels, sand from agricultural land; x) river bank erosion and accretions; xi) siltation and sand deposition on agricultural land; and xii) major reduction in dry season river flow. Land degradation is continuing in the sloping areas of the Barind Tract due to the faulty cultivation practice. Barind soil is clay type and heavily compacted. In these areas soil is subject to erosion during the monsoon rains when soils are loosened by ploughing. Indiscriminate use of chemical fertilizers gives seepage of chemicals into underground aquifers as well as loss through surface runoff and rain water discharge. Continuous applications of chemicals change the physical and chemical properties of the soil and deteriorate soil quality and reduce productivity (Table 1.1). Excessive and inappropriate application of chemicals pollutes nearby water bodies. High Yielding Variety (HYV) crops are being grown using chemical fertilizers without having appropriate soil management practices (little or no organic recycling). Over the years Bangladesh soils have been loosing apprppriate nutrient and cropping systems have been sufferings. However, the drought prone areas in the northwest region of Bangladesh have always been neglected. Farmers, academicians, researchers, environmentalists and NGOs are conscious about drought impacts. Prolong drought created negative consequences to the food production, human health, water supply, drinking water, water table and irrigated water, biophysical system like dead of ponds, rivers, channels and other water bodies' water stress in crop fields and consequently biodiversity is damaged. It should get priority in research agenda and so, this research essentially aims to investigate sustainable approaches to drought management by adopting socio-natural process of northwest regions of Bangladesh.

1.3 Rationale of the study

Bangladesh has experienced prolonged dry weather and insufficient rainfall during drought. Drought becomes more hazardous combining with several unusual weather patterns (less rainfall, extreme heat and others). Drought is the period of dry spell when soil moisture is less than the required amount of moisture for the satisfactory growth of crops. The records showed that the severity of drought is more severe than the floods that Bangladesh experienced almost every year. The results of the relative effects of flood and drought on rice production between 1969 to 1970 and 1983 to 1984 shows that drought is more shocking than flood (World Bank Bangladesh, 1998). Drought impacts are diverse and often damage the economy. Mainly three folds impacts (economic, social and environmental) of drought are recognized. These are often referred to as direct or indirect or these are assigned an order of propagation (Kates *et a.l*, 1985). Drought can distress human basic needs including food and water. Excessive heat creates threat to human health and makes them more susceptible to intrinsic factors including their age, gender, ethnicity, and health or extrinsic factors such as occupation and income (Parry *et al.*, 2007; Portier et al., 2010; Cal EMA and CNRA, 2012). Drought has an increased impact on agricultural production in Bangladesh. Two distinct cropping seasons faced critical drought in Bangladesh during *Rabi* (January) and pre *Kharif* in the month of May (Karim *et al*., 1990). It has been stimulated by i) cumulative effect of dry days; ii) long time high temperature during pre kharif; and iii) lack of soil moisture. Rice (High Yeilding Variety *Boro*), wheat, pulses and potatoes are affected severely. The drought during *kharif* (June/July to October) is also created by dry conditions in the northwest part of Bangladesh. The limited rainfall affects *transplanted aman* during critical growth and reproductive stage. Bangladesh has experienced an increased frequency of droughts (National Drought Mitigation Center, 2008) and observed a remarkable change of precipitation in recent years. Both high and low income people, especially the marginalized ones are affected by the drought. Currently, one forth of the world's irrigated lands is provided by groundwater of which 75 percent land is found in Asia (Shamsudduha *et al.*, 2011). During 1970s, Bangladesh agriculture was completely reliant on nature including surface water and monsoon rainfall (UNDP, 1982). In Bangladesh, 79.1 percent land is irrigated by using the underground water during *boro* season (BADC, 2010). The traditional methods were used in irrigation up to 1950s. The Barind Tract covers the area of 7727 square kilometer (Rasheed, 1998) and stands between 24°20'N and 25°35'N latitudes and 88°20'E and 89°30'E longitudes. It is built up with Pleistocene Alluvium also known as Mature Alluvium and grounded with reddish brown, muggy Pleistocene deposit; Madhupur mud (Ahmed, 2006). It was found that the physical and hydrological properties of soil (low capcity of water reatention and low infiltration rate) and high prevalence of drought is observed in the Northwestern part of Bangladesh (Rajshahi, Chapai Nawabganj and Naogaon). The Barind Tract was debarred all through 3000 Deep Tube Wells (DTWs) installation programme of BADC in Northwest Irrigation Project allowing for as low impending area for groundwater development (BMDA, 2006). Groundwater development has taken place in the Barind Tract by the BADC by creating Barind Integrated Area Development Project (BIADP) in 1985 and afterward in 1992 through the creation of Barind Multipurpose Development Authority (BMDA, 2011). Table 1.2 shows crop loss due to drought.

Table 1.2: Crop loss in percentage

Year	Crop loss in percentage
1951	31.63
1957	46.54
1958	37.47
1961	22.39
1966	18.42
1972	42.48
1979	42.04

Source: Chowdhury and Hussain, 1981

Groundwater fluctuation rate depends on season. The reduction rate of groundwater in the dry and the wet season is diverse; reduction rate in wet season is more than the rate in dry season. The study findings reveal that the groundwater level in the study area is depleting day by day at increasing rate (Rahman & Mahbub, 2012). Drought has turned into a repeated occurrence in Bangladesh and cause huge crop loss (Table 1.2). Furthermore, severe droughts were recorded in 1973, 1978, 1979, 1981, 1982, 1992, 1994, 1995, 2000 and 2006 in Bangladesh. The drought in 1979 was considered 'the worst in living memory', (Murshid, 1987). The impacts of droughts of 1994-95 in the northwestern Barind Tract caused 3.5 million tons deficit of rice production (Paul, 1995). The drought in 2006 in northwestern parts of Bangladesh affected crop production 25-30 percent. Recurrent drought episode with higher intensity, scale and ruthlessness may be attributed to climate change. Crop production was impacted due to the climate induced drought. Agrawala *et. al.,* (2003) reported that extraction of water in the upstream of main rivers flowing through neighbouring countries stresses the water catastrophe. Shahid and Behrawan (2008) reported that northwest region of Bangladesh has become seriously drought prone due to the high variability in rainfall. The rainfall variability is prevailing during the pre monsoon and the post monsoon periods. This part of the country receives low rainfall (average 1400mm per year) as against the national average of 2150 mm (Sohrab, 2015). Thus the northwestern parts (Barind Tract) are experiencing more drought than other places of Bangladesh. According to Mirza and Paul (1992), nineteen droughts have occurred during the period of 1960-1991 in Bangladesh. On an average the drought occurrence frequency is once in 2.5 years in Bangladesh (Adnana, 1993; Hossain, 1990). Water deficiency is one of the issues of drought occurrences in the northwest region of Bangladesh (WARPO, 2001). The study areas have experienced extreme drought in the year of 1994. The drought year 1994 brought a harsh outbreak in the northwest part of the districts and left the people in a shaky order. During the drought, the situation turned worse due to the extreme low level of rainfall which caused drying up surface water sources (canals, ponds, *beels* and rivers) in the districts. Under this situation, irrigation system passed a severe stress as most of the infrastructures (shallow and hand tube wells) went out of work (dry) and caused a sober warning to agricultural production (food grain). The drought caused the deficit of rice production in the northwestern parts of Bangladesh (Paul, 1995). It affects all crops, especially HYV *Boro*, *Aus*, wheat, pulses and potatoes during *Rabi* season where irrigations are limited. Low rainfall affects critical reproductive stages of transplanted *Aman* crops, reducing its yield, mainly in low soil moisture holding capacity areas. BARC has mapped drought prone areas of Bangladesh for two seasons; *Rabi*, and pre-*Kharif* (Karim *et al.*, 1990). Later on, BARC has prepared three different maps for *Rabi*, Pre-*Kharif* and *Kharif* (BARC, 2001). Table 1.2 shows drought affected areas with different crop seasons.

Table 1.3: Drought prone areas in Bangladesh by cropping seasons

Drought Class	Drought prone areas (Mha)		
	Rabi	*Pre-Kharif*	*Kharif*
Very Severe	0.446	0.403	0.344
Severe	1.71	1.15	0.74
Moderate	2.95	4.76	3.17
Slight	4.21	4.09	2.9
No Drought	3.17	2.09	0.68
Non-*T. Aman*			4.71
Total	12.486	12.493	12.544

Source: BARC, 2001

Several measures (both coping and adaptive measures) are used by the local people to reduce the drought impact on their livelihoods. The lower socioeconomic households suffer the most, receiving the least support from the national government. Therefore, sustainable approaches to drought management are essential for implementing mitigation as well as adaptation to reduce drought impact in the study areas. Now the significant and essential questions are: Are these measures sustainable or environmentally sound? In respect to drought problems in Bangladesh, the present study also proposed that livelihood intervention is very much indeed and it should be taken into consideration as an event, and the invented adaptation measures should be viable and sustainable to cope with drought situation. It is essentially important to formulation of sustainable adaptation policy with the better understanding and mind's read of local people on drought perception, causes, indigenous knowledge management in drought prediction and mitigation, drought impacts and their way to cope and adaptation to drought consequences. Several findings reveal that before the green revolution, the Barind people were not vulnerable to disasters as they were wealthy, social and dynamics. The Barind people depending on a good or bad weather condition relentlessly switched to diverse range of livelihood activities. Many communities moved advance for setting livelihood strategies which they found to in times of stress (Soja, 1968). The coping ability under challenging and changing environments in the past implied that the people in those areas had much wisdom for setting strategies to face the natural calamity. It is, therefore, important to ask them what their local livelihood strategies were, and examine why people who had previously sustained their livelihood in the absence of external options are currently suffering the ecological and the economic stress.

Social capital is functioning by mediating economic change effects on Barind households by providing access to other resources, coping mechanisms or adaptive strategies that makes it crucial, however earlier negligence of Barind Tract development were extensively documented.

Several studies although deal with generalities which musk coping and adaptive responses (Barton *et al.*, 2001; Guliver, 1951; Hogg, 1986; Oba, 2001), the necessity for a comprehensive study is important. Furthermore, comprenensive economic analysis of coping mechanisms, adaptation for livelihood strategies give us the information to understand the impact of crises only in terms of factors like wealth, mobility, education, life style and gender. The role of social relations is neglected; the reason for people choices of one coping strategy is pursued over another has not been explained in the previous study. It has been discussed that the huge crop loss occurred due to concurrent drought in the Barind Tract. Several factors lead excessive crop loss including ineffective adaptive measures, dependency on rice production and extreme weather patterns (erratic rainfall, high temperature, low soil moisture). Crop loss affects other asset that makes the community more vulnerable through the change of their livelihoods. It has been seen that the use of irrigation by pumping underground water from shallow to deeper layer, worsening the situation by depleting the underground water over times. Underground water layer is going down each and every year. Therefore finding out sustainable management options for the management of drought is required. Drought and climate scenario regarding study areas still unraveled to the farmers and eventually to other people, this provides details climate and drought scenario during the period of 1976 to 2014 mentioning drought intensity, scale, frequency. Eventually result derives from primary and secondary data gives of the study as climate scenario of the study areas which will be beneficial for planning and management of future drought. Definition and causes of drought is the matter of question. Local to national, national to international, there is no specific definition of drought, and different views were given as the causes and consequences of drought. The study provides peoples' perception level definition with casual effects and impacts at different scale. These common understandings make link with drought and climate scenario in the study areas. Eventually how local people predict drought using their local wisdom and correlate with drought and climate scenario. Based on the findings, the present study focuses on sustainable drought management using Resilient Livelihood Framework, social networks and issues related to adaptation, land use, cropping pattern, water use, drought subsidy, inputs and financial support for drought victims. There is no directive drought policy for the country as well as for the Barind Tract. The study has attempted to suggest some sustainable adaptation strategies to address drought crisis.

1.4 Drought dilemma: Concern of Barind Tract people

Frequent droughts lead to desertification, degradation of soil and pervasive falling of water tables, resulting in serious water crisis in Barind areas. Droughts have caused human sufferings and played havoc on the ecosystem. The capability of vulnerable populations to cope with drought is inadequate. This happens not only due to the frequency of drought but also to the non resilient livelihoods, the declining resource, the resource conflicts, the changes in access to land and water. Drought caused impacts not only on human life but also, increasingly economic losses (short term and long term). Sectors including agriculture, health, and the natural environment are heavily affected by drought. The intermittent drought impact across the country is rapidly getting higher. The drought situation is a consequence of local and natural climatic variability, most negatively affected livelihoods and existing land-use pattern. The economic, social and environmental impacts of droughts have increased rapidly in the High Barind Tract. In some years droughts not only can cause a greater damage to crops than a flood or cyclone, but they also affect farmers across a wider area. Drought directs to the deficiency of water and food stuffs but also boast an extensive environmental, socio-economic and health shock on the population in habituated in the areas. Water level (both groundwater and surface water) declined to an abnormally low level compared to normal and drought years. Several studies discussed earlier have showed the drought prone areas of Bangladesh in which the northwest part is pointed out clearly a tough hit area of the country. Land is the main assets of the people living in Barind, and their prime source of income is agriculture. They also raise cattle and rice is their staple food. The study essentially elicits how the Barind Tract people trying to reduce their crop loss during drought condition and the most appropriate ways they are adapting to enhance livelihood strategies. The Barind Tract people show exemplary ways of how farmers adjust to drought environment and manage numerous difficulties that extremely affect their livelihoods. As the northwest Barind Tract is an incoherent drought prone area, it has long been considered a complex place to stay alive. From the earliest verbal and recorded history, it is marked that the people of the study areas have experienced series of droughts resulting in acute deficiency of food and water for human, agriculture and livestock. The study attempts to find out new ways of reducing crop loss through improving adaptive capacities and collecting evidence from Barind.

1.5 Review of literature

Drought is a relative term and people of different regions and backgrounds may hold different viewpoints about it which has been discussed earlier. In the same locality what one farmer considers drought, another farmer may view it as normal. To some people drought is just like a chronic disease. UNDP (2004) has termed drought as a continued time spell of deficit precipitation with a low frequency of occurrence. Hudson and Hazen (1964) stated in their research that in Bali, six consecutive days without rainfall can be considered a drought, but in Libya if there is no rainfall for two years, then it is considered as drought. It is clear that there is no exact definition of drought; it varies from region to region based on the context. Drought impact depends on the interaction between low precipitation, more water demand, and human activities which may exacerbate the impacts. In terms of impacts drought can be classified into four categories: meteorological, agricultural, hydrological, and socio-economic. Drought has brought severe insecurity into the lives of Barind Tract people and because of the prevailing of the abnormal forms of uncertainty; they cannot plan to cope with it. Owing to the harsh nature of the northwest, the people in the study areas face frequent food insecurity and therefore, actions are needed for reliving or lessening their endurance. The key factors that define drought vulnerability in the social and physical contexts of Bangladesh are needed to be identified. Water scarcity, lack of soil moisture and excessive temperature with less or no rainfall are the common features of drought. The studies have been focused the impact of droughts on agriculture (Mazid *et al.,* 2005 cited in Shamsuddin & Houshang, 2008; Saleh *et al.*, 2000; Karim *et al.,* 1990; Jabber, 1990; Jabber *et al.,* 1982), production of food (Ahmed & Bernard,1989; Erickson,1994 cited in Shamsuddin & Houshang, 2008), degradation of land (Rasheed, 1998; Karim & Iqbal, 2001; Government of Bangladesh, 2005 cited in Shahid & Behrawan, 2008), economy Erickson *et al.*, 1997; World Bank Bangladesh, 2000 cited in Shahid & Behrawan, 2008), and society (Erickson *et al.,* 1997; Paul, 1998 cited in Shahid & Behrawan, 2008). High and low income households are affected by the drought but the households from the lower socioeconomic group suffer more, receiving the least support. Therefore, drought hazards, vulnerability and risk assessment are essential for adaptation and mitigation strategy to reduce drought impact in Bangladesh. Farmers, academicians, researchers, environmentalist and NGOs are aware about impacts of drought. Prolong drought created negative impacts to the food production, human health, water supply, drinking water, water table and irrigated water, biophysical system like dying of ponds, rivers, canals and other water bodies' water stress in crop fields, and loss or damage of biodiversity. Therefore these issues should get priority in research agenda. The present study is essential in this context to investigate sustainable approaches to drought management through adopting socio-natural process of northwest region of Bangladesh. Water scarcity and drought (irrigated water deficit) may increase risks for agricultural sustainability and food security in varied regions (Kijne *et al.,* 2001). Drought is a harsh restraint to crop production throughout Asia (Wade *et al.,* 1999), and is also considered important in some intensively cropped, irrigated farming systems such as on the Indo Gangetic plain (Kataki *et al.,*2001). The excessive soil moisture shortage reduce crops yield and it can be totally lost if a severe water shock occurs during reproductive and vital stages of the crops. Water is the most crucial element needed for growing food as we have already observed that human induced climate change is resulting in less and more erratic rainfall, especially in regions where food security is very minimal. Increasing temperatures and unpredictable rainfall will exacerbate conflicts over water allocation and existing critical state of water availability (Thomas *et al.,* 2007). Water scarcity also affects food supply. It takes 1,000 tons of water to produce one ton of grain and food production has been artificially inflated by unsustainable water abstractions (Brown, 2002). Already, water deficits have led to heavy grain imports in numerous countries such as Iran, Egypt, Morocco, Yemen, Algeria, and Saudi Arabia (Brown, 2002). In China, approximately 85 percent of all water is used for irrigation. It is estimated that China suffers from an annual water supply shortfall of 40 billion m^3, which equates to 5 to 7 times the amount used in Southern California (Hays, 2008). On the consequence, 20 million hectares of farmland are affected by drought, cutting grain production by 20 million tons (Hays, 2008). Drought transpires in advent of monsoon season when the potential evapo-transpiration (PET) is higher than the available moisture due to uncertainty in rainfall, while in post-monsoon season it is due to prolonged dry periods without appreciable rainfall (Karim *et al.*, 1990). According to Barind model (Ali *et al.*, 2007), homestead vegetable was cultivated at Nachole and Shapahar. However, production was less compared to other areas due to late start in *Kharif*-II season and subsequent six months acute *Rabi* and *Kharif*-I drought.

1.6 Barind Livelihood

The cocept of social networking has been clearly mentioned in sociological and anthropological literature (Davern, 1997; Putnam, 1994). This study describes the writings of different authors in understanding how the concept works for the crisis in Barind Tract. According to Davern (1997), social networks is the direct and indirect straps from several actors, regardless of whether the central actor is an aggregation of individuals (households); kin and place of the origin may be the foundation of reciprocal relationship as defined by Moser (1989). Personal or family relationship formed social network that characteristically combine remote kin as well as close family which one focused by Ellis (2000). According to Johnson (1982), the networks are the links with the past, present and future, when the family is extend over a different choice of areas and can take action when past help necessitate to reciprocated. Johnson disagrees with the idea of relationship by mentioningthat family tie or kinship tends to loosen or disintegrate during food crisis or food insecurity and the victims tie up with those who can provide them with material support. The aim of this study is to understand how Barind Tract people use their social networks as an essential role in supporting rural livelihood. Drought generally occurs in two seasons: from June to October known as *Kharif* drought and pre-*Kharif* drought. *Kharif* drought affects the transplanted *aman* crops in low soil moisture areas at the stage of flowering, whereas

Rabi drought affects transplanted *boro*, pulses, wheat, potato and other crops (Ramamasy & Baas, 2007). Brammer (1999) estimated in his study that, the severe drought of 1978-1979 directly affected 42 percent cultivable land and reduced 2 million tones rice production. The drought of 1994-1995 resulted in a 3.5×10^6 tones decrease in rice and wheat production (Rahman & Biswas, 1995) and the 2006 drought caused 25-30 percent crop yield reduction in north-western part of Bangladesh (Rahman *et al*., 2008). Drought and water paucity (irrigated water deficit) may increase risks for agricultural sustainability and food security (Kijne *et al.*, 2003). Drought is a barrier to crop production throughout Asia (Wade *et al.*,1999) and is also considered important in some intensively cropped, irrigated farming systems such as on the Indo Gangetic plain (Kataki *et al.*, 2001). 20 million hectares farmlands are affected by drought, reducing grain production by 20 million tons (Hays, 2008). In Bangladesh, the continued drought in the northwestern districts led to 3.5 tons shortfalls rice production (Rahman & Biswas, 1995). Crop is affected during *Rabi* and *Kharif* season due to drought resulting in crop failure/ low yield and loss of other livelihood factors in Barind Tract (Brammer, 1999).

1.7 Research Objectives, Research questions and Hypotheses of the study

Research question, objectives and research hypotheses have been discussed in this section. How did local people perceive drought (in relation to causes, scale, risks and other impacts)? Are drought parameters (rainfall, temperature and water table) changing over time? What are the losses caused by drought? What are the hazards, vulnerabilities and risks to use of underground water? Can the change of cropping pattern mitigate drought impacts? How does drought influence the social processes (Vulnerability, inequalities, conflicts, exploitation, asset losses and migration)? How can indigenous knowledge help in drought prediction and extreme weather management? How Barind people use the concept of resilient and sustainable livelihood framework and Symbolic Interactionsm Theory (social networks) in their livelihood during crisis? What are the approaches being practiced in adaptation (scales, effectiveness and vulnerable occupational groups) and in response to longer-term drought risks? What are the options available to drought management? How do local people cope with drought? What are the available livelihoods opportunities? And what are the existing adaptation strategies for drought (for both women and men)?

To set the objectives of the research, research problems and background have been discussed in the problem statement and in research gaps in the context of Barind peoples' vulnerability to disasters. It has been done by reviewing literature, and how they adjust challenges and crises such as migrating, splitting of families in their social context. Elementary findings have been obtained from literature review is that typical adaptive measures are taken during economic hardship. The adaptive measures are determined by environmental, social and physical resources are available and how that plays role for their survival during crisis. Both individual and group capacity determines the survival strengths as discussed in the second chapter. The knowledge has been gained through literature review and secondary information leads to the stating following hypotheses for this study as follows:

i) Accessible economic and social resources to starved Barind people will increase degree of adaptive responses through Sustainable Livelihood Framework

ii) There is an increasing trend of crop loss with increased drough frequency, rainfall & temperature variability and declined trend of groundwater table

The details conceptual framework and method of hypotheses testing has been discussed in the theoretical and methodology section (see chapter two and chapter three). The broad objective of the study is to explore sustainable adaptation practices of drought management in the study areas

Specific objectives of the study are to:

1. know the socioeconomic background of study populations, drought and climate scenario of the study areas
2. elicit perception on drought and its impacts on agriculture and livelihoods and how local people manage drought and weather extreme using indigenous knowledge
3. know the negative consequences of groundwater table depletion and what are factors associated with crop and drought losses
4. findout sustainable adaptation measures and women's contribution in drought management

Hence, chapter Two has been discussed in details about the theoretical framework of the study.

Summary and conclusion

This chapter has been discussed about climate change and occurrence of natural disasters. Drought is one of frequent and concurrent natural disasters in the world as well as in Bangladesh. Drought impacted on livelihoods and society especially in the north-western Barind and caused huge damage to agricultural production. It also affected human health, poultry, livestock, fish and biodiversity. The study focuses on sustainable approaches to drought management.

Chapter 2: Theoretical Framework

2.1 Insight of Sustainable Livelihood Framework

This section describes insight of sustainable livelihood framework and make linkages with the chapter One and the conceptual and study framework, rationale, research questions, set objectives for this study and sustainable livelihood framework outlined in section, 2.1.1 (Adapted from Juma, 2009: 43; Ellis 2000: 30)

2.1.1 Understanding of sustainable approach for the study

In understanding livelihood it is pre requisite to know about "stress and shocks" and be able to "maintain and enhance" capabilities and assets in future. 'Resilience' to stress is the key focus and "shocks" is the diversification of component that consists of 'livelihood'. Carney (1998) gives a simple definition of livelihood and sustainability.

"*A livelihood comprises the capabilities, assets (including both material and social resources) and activities for a means of living.*"

"*A livelihood is sustainable when it can cope and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and the future, while not undermining the natural resource base.*"

The World Commission on Environment and Development (WCED) defined sustainable development as "Development that meets the needs of the present without compromising the ability of future generations to meet their needs". WECD used ustainable livelihoods term at first in a report in 1987, and included in sustainable agriculture policy (Cahn, 2002). The livelihoods issue was accounted into Local Agenda 21 during the UN Conference on Environment and Development in Rio in 1992 (Schafer, 2002). The concept of sustainable livelihood gives a functional guideline to know survival strategy at households' and individuals level. Literature on Sustainable Livelihood Approach classifies into four broad categories such as households trail: i) Agricultural intensification: (e.g. food crops, cash crops, livestock) ii) Livelihood diversification: (diverse income option from both farm and off-farm) iii) Improved irrigation system and management: supplementary irrigation system using groundwater and surface water and efficient irrigation management (pre paid meter system, AWD etc) iv) Migration: Some time individual or a few family members go away somewhere and earn money else and contribute to the family economy. This can be short term or permanent. Four type livelihood strategies (agricultural intensification, improved irrigation management, diversification of livelihood and migration) contribute in searching how Barind people acclimatize livelihoods throughout crisis as they are used to cope with drought. The approach of Sustainable Livelihood provides focus on social factors to understanding the implication of household livelihood strategies (Ellis, 2000). This statement is relevant to the Barind context as food stuff production in the area is primarily, although not entirely, dependent on local peoples' social networks. At a macro level social structures and processes, have a significant impact on livelihoods. The macro level has to be coupled with micro level wherever several actors run individuals and households deploy initiatives for changes. In analyzing, different aspects of Sustainable Livelihood Approach are incorporated in this study. The study supports Sustainable Livelihood Approach which accents on the household and its assets as a unit of social change and development. Hence, it is better to observing what sorts of strengths and capabilities people do have, is more valuable than searching at their needs or what they are lacking. In reducing poverty, this is a way of thinking about objectives and priorities for development. This is an important approach that helps poor people to achieve improvement against poverty indicators (Ashley & Carney, 1999). This approach sets people and their central notion in the analysis. It represents an understanding of poor peoples' views towards the world and their condition to find opportunities and challenges in achieving sustainable livelihood (Chambers, 1983, 1987). Barind peoples' perception and definition of their status is considered as they mean their status in this study. Sustainable Livelihood Approach is holistic in nature and requires diverse focus. The factors influencing households and Sustainable Livelihood Approach differ from mother approaches to developments which pay attention on integrated objectives and indicators. This framework gives the foundation for investigation of the livelihood strategies in greater scale and gives scopes for reflection of diverse factors driving livelihood sustainability in the study area. The Sustainable Livelihood Approach plays key role to identify the significance of resilience, adaptability and sustainability (Scoones, 1998:6). Sustainable management, coping and adaptability are the main concern of this study. A rural livelihoods analytical framework has been developed by Ellis (2000). The framework believes that diverse factors contribute in livelihood strategies and sustainability. This framework is structured to holds the livelihood complexity, understanding poverty drivers and knowing where interventions can help poor people to cut poverty. Many development agencies, donors and other organizations have been applied it widely in formulating policies, strategies and projects through participatory planning (Ashley & Carney, 1999:10). The framework which has been developed by Ellis (2000) is presented here in figure 2a. This 'assets mediating process activities' framework start with the access points and critical process and helps in prioritizing means for change. Ellis Framework (2000) for micro policy analysis of rural livelihood has been discussed with the different context of rural livelihood strategies. Linking this scenario to drought risks and sustainable livelihood strategies, drought adaptation practices depend on livelihood platform (natural capital, social capital, human capital, financial capital and physical capital), access modifying factors (Demography, types of institutions and organizations), context (trends & shocks), results (livelihood strategies), composition (natural & non natural resource based activities) and effects (livelihood security and environmental sustainability).

A	B	C	D	E	F
Livelihood platform	Access modified by	In context of	Resulting in	Composed of	With effects on
Assests: Natural capital, Physical capital, Human capital, Financial capital, Social capital	**Social relations:** Gender, Class, Age, Occupation Institutions: Rules and customs, land tenure, markets in practice **Organizations:** Associations, NGOs, Local administration and state agencies	**Trends:** Population, Migration, Technical change, Relative prices, Macro policy, National economic trends, World economic trends. **Shocks:** Drought, Floods, Pests, Diseases’ Civil war	**Livelihood strategies**	**Natural resource based activities:** Collection, cultivation (food), cultivation (non food), livestock, non- farm NR **Non natural resource based activities:** Rural trade, rural manufacture, remittances	**Livelihood security:** Income level, income stability, seasonality, Degree of risks **Environmental sustainability:** Soil and land quality, Water, Range lands, Forests, Biodiversity

Figure 2a: A framework for micro-policy analysis of rural livelihoods

Source: Juma (2009: 43). Adapted from Ellis (2000: 30)

2.1.2 Elucidation the sustainable livelihood Framework

The main component of Ellis framework is assets, given in figure 2a. Ellis mentioned "assets status of poor individual is as basic to understanding the options available to (the rural poor), the strategies they adopt for survival and their vulnerability to difficult inclination and proceedings" (Ellis, 2000: 28). It is easy to understand that assets can be both tangible and intangible resources that the household accumulate through ownership, direct, allege or by any means, and can be used directly or indirectly to lead livelihoods. There is a close relationship with assets and livelihoods. Those who have more and diverse assets can lead better secure livelihoods with diverse options and resilient level of sustainability. Assets can be grouped into several forms of 'capital'. Ellis has classified assest into several categories such as, natural, physical, human, financial and social capital. *Natural capital* means natural resource stocks covering land, water, trees, crops, fish, pasture, wildlife and environmental services including hydrological cycle and pollution sinks through which resource flows and services for livelihoods are derived (DFID, 2001; Ellis, 2000; Scoones, 1998 cited in Juma, 2009). The output of these resources may enhance or declined by human management (DFID, 2001; Ellis, 2000). The capital that can be created by deploying economic production process is known as the *physical capital*. Physical capital includes infrastructure (roads, ponds, canals, electricity supply, and water supply) and producer goods (tools and machinery). The *financial capital* refers to reserves of money or other deposits in liquid form. *Human capital* refers to the quantity (productive individuals) and the quality (how hard they are able to work) of labour accessible in the household level; hence it depends on household size, education, skills and health of household members. *Social capital* denotes to the social resources including contact networks, social claims, social relations, affiliations, associations and mutual trust, upon which people depends in pursuing different livelihood strategies (Scoones, 1998; Ellis, 2000; DFID, 2001; and Juma, 2009). Several factors that are influenced in accessing these assets are: i) social relation as class, gender and ethnicity; ii) institutions, which refers types, rules, and code of behaviours; and iii) organizations, dedicating groups of individuals to achieve certain objectives (DFID, 2001). Livelihoods are influenced by both endogenous and exogenous factors. The above mentioned endogenous factors additionally affected by exogenous factors like as trends and shocks. The existing modified assets in a specific context, contribute to the livelihood strategies of a household. Such types of set activities are pursued by the households to generate means of survival for their livelihood strategies (Ellis, 2000). The livelihood strategies are categorized in different way by the scholars and researchers. According to Ellis (2000), strategies are divided into two categories including natural resources and non natural resource based activities, on the other hand Scoones (1998) mentioned three broad livelihood strategies including agricultural (intensification of existing agricultural activities); diversification by adopting additional productive activities; and migration to productive activity elsewhere. Migration is the part of combined activities for the diverse livelihood strategies. Livelihood strategies determine households' livelihood security, measured considering income level, seasonality and degree of risks. The activities performed by the households as the individual strategies also affect environmental sustainability of the household's resources and surroundings on which they relies.

2.1.3 Assessment of Sustainable Livelihood Framework

Although Sustainable Livelihood Framework is also very much helpful in analysis of Barind peoples' livelihood strategies inside broader circumstances of transform, the study subject is to a critique. The key limitations of this approach is that it is enormously extensive and common, and grasp different aspects including micro to macro level by accounting many considerations that affecting livelihoods of the poor. So, it is not possible to evaluate the lively relationships that appears all through disaster (drought) in the Barind Tract in the attempt to stay alive. Few livelihood behaviours remain dormant in the most times and only become observable in inflated forms only during the time of needs. The approach may not able to analyze this behaviour change in methodically either acceptable mode. There are few limitations of this approach, which limit the analysis in details, especially reciprocity and symbiotic relationship during livelihood crisis. The sustainable livelihood approach framework is not enough to pinpoints and significantly evaluate of these variables inside the framework. This framework reveals the major livelihood strategies (agricultural intensification, diversifications and migration) and the situation (in which they are applied and at what capacity) to prove how and why people would prefer those strategies. In choosing livelihood strategies during crisis, the Barind people read their own minds, judge their perception and definition of situation and environment, and the meaning the diverse strategies available for them. These issues may term away from the scale of sustainable livelihood approach. Cahn (2002) reported that it was impractical for Ellis (2000) to show the livelihood framework is linear, with valid argument or other relationship. In this study this argument is applicable due to the way of Barind people attain and continue their livelihoods during crisis have a response mechanism. Several organizations (DFID, FAO, Action Aid and Practical Action) attempted to establish linkages with risks and disasters. DFID framework provided focus on five livelihood assets (Human capital; Natural capital; Physical capital; Finanacial capital and Social capital). These assets are affected by the vulnerability context such as short term shocks (droughts) and long term sresses (climate change). Practical Action emphasized on vulnerability to resilience framework for increasing the resilience of community.

Food and Agricultural Organization (FAO) developed Resilience Livelihood Framework paying attention on Capacity development; Knowledge management & communication; Strategic partnership and Gender Equity for developing countries. Livelihood Framework of Action Aid provided focus on empowerment; solidarity and campaigning. Christian Aid developed Resilient Livelihood Framework through participatory approach. In this connection, Nasreen (2015) assessed some of the existing livelihood frameworks in the context of Bangladesh and developed a Resilient Livelihood Framework and variations of different climatic regions.

2.2 Symbolic Interactionism Theory and adjustment

Symbolic Interactionism Theory comes in two theoretical forms: Symbolic Interaction theory and Social Exchange theory. Symbolic Interaction argues that society is tranquil of still present among individuals who share symbols and their meanings. The theory is very much useful for understanding other people in cross-cultural relations including improving communications and crisis management. Symbolic Interactionism is very powerful in helping people to understand each other. According to social scientist, it is mentioned that adjustment behaviours during earlier period of drought extended into the field of social psychology. It is essentially important as because Ben Wisner had mentioned: "Man does not act directly from his surroundings, but rather indirectly through a perpetual and cognitive filter composed of culture, personalities, childhood experience, recent experience and even immediate bodily states" (Wisner, 1978: 119). The approach reflects adjustment behaviour which using withinasocial perspective and weighted by forbidden, philosophy, values and individual perceptions. This constructs highly based on symbolic interactionist theory. The symbolic interactionist theory is a prototype and originated from the work of the psychologist. Blumer (1986) and Schutz (1970) are the leading intellectuals of symbolism. After realizing individuals by their social natures very symbolic with one another, then you begin to understand how to persuade your friends and family, how to understand others' points of view and how to resolve misunderstanding or crisis. The Thomas Theorem is often called the "Definition of the situation" which is basically if people perceive or define something as being real then it is real in its consequences. This theorem is very much applicable in the crisis situation likely caused by drought. The central principles of the symbolic interactionist theory are that human beings works together on the basis of the meanings those things they have in the course of interaction and that definition characteristically go through adjustment and re-enactment in the procedure of interaction itself. The key element of the theory is that in a varying situation, behavior is never accidental and aimless, but careful and objectively verifiable. Unknown environments note for their meaning by the interacting individual to outline the frame of his act. According to Sheldon and Stryker the theory is likely: "When one enters a situation in which his behaviour is problematic, that is, in which pure habit will not suffice, he must find some way to represent himself in symbolic terms. If he is not to behave randomly, if he is not to select arbitrarily from range of acts in his repertoire of possible actions, he must, in short, define the situation. The products of his behavior are definitions of the situation" (Stryker, 1973). Hence, human living state is symbolic, physical, biological, and social world that drives as a stimulant to shape their behaviours. The notions of 'role' and 'expectations' are essential for this theory. An individual come into an interacting system, he or she presumes define role and assign definite other roles to members of their group, and by doing so raises role expectations. People need to define again the changing phenomenon as the fundamentals for cogent selection of adjustment preferences (Stryker, 1973 cited in Juma, 2009). Thus people depend on the available options they have during crisis and do accordingly for the necessary adjustment. In due experience of polish migration in America, researchers found that poles adjusting themselves to the fresh environment abroad had to face consequence in which they found themselves a description which in the process molded their adaptive behaviours (William & Znanieki, 1974 cited in Juma, 2009). In the Barind Tract, people adjusted their behaviours within individuals or in the group context to cope with the drought and its consequences for their livelihoods. Thus their motivation and awareness of the change situation is considered as the roots of their innovative behaviours. In the light of literature, the Barind people's collective drivers of economic privation allow and even legitimize' otherwise anti-social conduct such as begging, stealing, human trafficking (women and children), taking up paid employment and *chorachlani.* Such types of indications are definitely abnormal behaviours, which are not allowed Barind people in normal situations. Though, symbolic interaction theory inflates the evaluation of adjustment behaviours, it does not confines firm aspects of Barind peoples' adjustment strategies (reciprocity and symbiosis) which are the focus of this study. These focuses are addressed by the social exchange theory.

2.3 Social Exchange Theory

Second theory of Symbolic Interactionism is Social Exchange Theory. Social Exchange states that society is composed of ever present interactions among individuals who endeavor to make best use of incentives as reducing costs. Assumptions in this theory are alike to Conflict theory assumptions yet have their interactistic underneath. Essentially, human beings are coherent individuals, competent of building sound choices once the details of the choice are understood. The study may look at options available for the community and weigh as the best they can how to maximize their rewards and minimize their losses. Sometimes they get it right and other times they make a bad choice. Homans (1961) and Blau (1964) have explained the social exchange theory at their best. This theory deals with human behaviour. In achieving rewards, it seems to be that people always behave logically. It is human nature to find out the maximum or higher gain when competing choices. This rewards may be (materials or social or psychological such as prestige, acceptance, sympathy, praise or satisfaction). Values, beliefs, ideology, social interactions, goals and expectations are the motivating factors in all situations. Eagerness to work elicits the prospect that relating individual’s target will be achieved or interest served. Therefore, the situation is the case, the reality what's left that Barind communities are co-dependent, one increasing the chances of survival of the other. Such strategy is a two way connection which is reciprocally valuable. Hence, finding the best implication of these theories (Sustainable livelihood approach, symbolic interaction theory and social exchange theory) are important to the adaptive strategies of Barind people during the crisis period.

2.4 Conceptual Framework for the study

With the view to better understanding how Barind people lead their livelihood and adjust during crisis, a framework is developed and presented in figure 2b. The knowledge through literature review in the previous section and knowledge gain from the study area were used explaining the situation. This study has been brought together sustainable livelihood approach, the symbolic interaction theory, and the social exchange theory in practice. The apporach has been used to analyse Barind peoples’ adaptation measures to manage drought and its consequences. Two issues including access to assets and assets transformation for a better livelihood; and local people’s capabilities to make their living more meaningful are used. This study paid special attention to the significance of sustainable management options and social networks as a negotiator through which Barind people are able to extend their access to other resources during crisis period. This framework describes the significant role of social networks in the Barind people livelihood relationship during drought crisis. Crop loss could be managed by using social networks (support), sustainable management options (crop diversification, use of surface irrigation, increasing irrigation efficiency), livelihood diversification (alternative employment) and migration to other places. The study starts with the hypothesis that sustainable drought management is the results of interaction of various determinants (local people innovate sustainable options for drought management over times). Sustainable livelihood framework as discussed by DFID (2004), vulnerability covers the trends (population, resources, technological change), shocks (economic shocks, natural shocks and conflict), and seasonality (health, of prices and employment). Scoones (1998) argued that vulnerability includes historical and present socioeconomic trends like policy setting, politics, history, climate and socioeconomic condition. Within the framework, several factors are responsible to affect resource flows for livelihood sustainability in the Barind Tract by extremely upsetting resources of the local people during drought. Generally people adapt measures either individually or as a group to cope with crisis or adopt sustainable adaptation measures in managing drought. At first, they define and affirm their problem based on crisis and view using their own values, norms, taboos and roles and finally sought meaningful insights before adopting livelihood strategy. Several literatures differentiate between coping and adaptation terminology. Coping is a term which means temporary adjustment to the livelihoods in tackling crisis but never brings change in livelihoods inevitably. The term adaptation' means long-term adjustment which bring long time change in the usual practices and proper system followed by community people to secure their livelihoods and to reduce live risks (Scoones, 1998; Sinclair & Ham, 2000). The respondents for this study made argument to the opposite that though they are conscious that they are live in highly vulnerable system, they are pursuing adaptive strategies apart from coping strategies, whereas looking for all existing options. Social network is the important strategy of Barind people for their survival during crisis. In these networks, family, kin and neighbours contributed significantly in providing social security and other services (Nasreen, 1995: 86-87). Three important groups: kinship, neighbourhoods and patron-client relationship are contributing in social networks. These are interlinked with the socio-cultural structure of Barind people likely gender subordination and socioeconomic background of different households. The Barind household settlement is patrivirilocal and men got instant kinsupport from their male line but women lacking her natal village to live with her husband's kin. It is due to existing patrilocal society structure and *ghosthi* relationship was with their marital kin. Barind people mentioned that they managed close relationship with *ghosthi* people and good neighbourhood relationship with inter *ghoshthi*. Fictive kinship with neighbouring households played great role in Barind. The more chance of obtaining favours through stronger fictive relationships. It was mentioned that the fictive kinship relationship were built up by women and among neighbours (Nasreen, 1995: 87). The women's neighbourhood relationships were non political, not patriarchal or patron-client relationship as opposed to men's. It was observed that buying and mortgaging of land, sharing equipment and cattle for ploughing and weeding and harvesting were found among kin members (Feldman & McCarthy, 1983 cited in Nasreen, 1995: 88). According to Chen (1991:218) and Jansen (1986:122-125), mortgaging and land sale takes place intra *ghosthi* or patrilineage. The price paid by kin members might be lower than market prices and this business limited within the kin group. Some time sales of land or mortgaging might take place outside the kin, but the relationship with non kin members was formal and not the basis of lifetime network as were the *ghosthi* relationships. The reciprocal relationships between patrons and clients played significant role in facilitating adjustment to crises. Economic and political patron-client relationship prevailed in the society (Chen, 1991 cited in Nasreen, 1995: 88). Economic relationships were built between employers and labourers, landowners and tenants, shopkeepers and customers, mortgagors and mortgagees, money lenders and receivers. Political relationships were established between factional leaders and their supporters. This was evident in Barind, as Van Schender mentioned his study that the ties between poor and landowners or between patron and client are decreasing with the increase of poverty (Nasreen, 1995: 89).

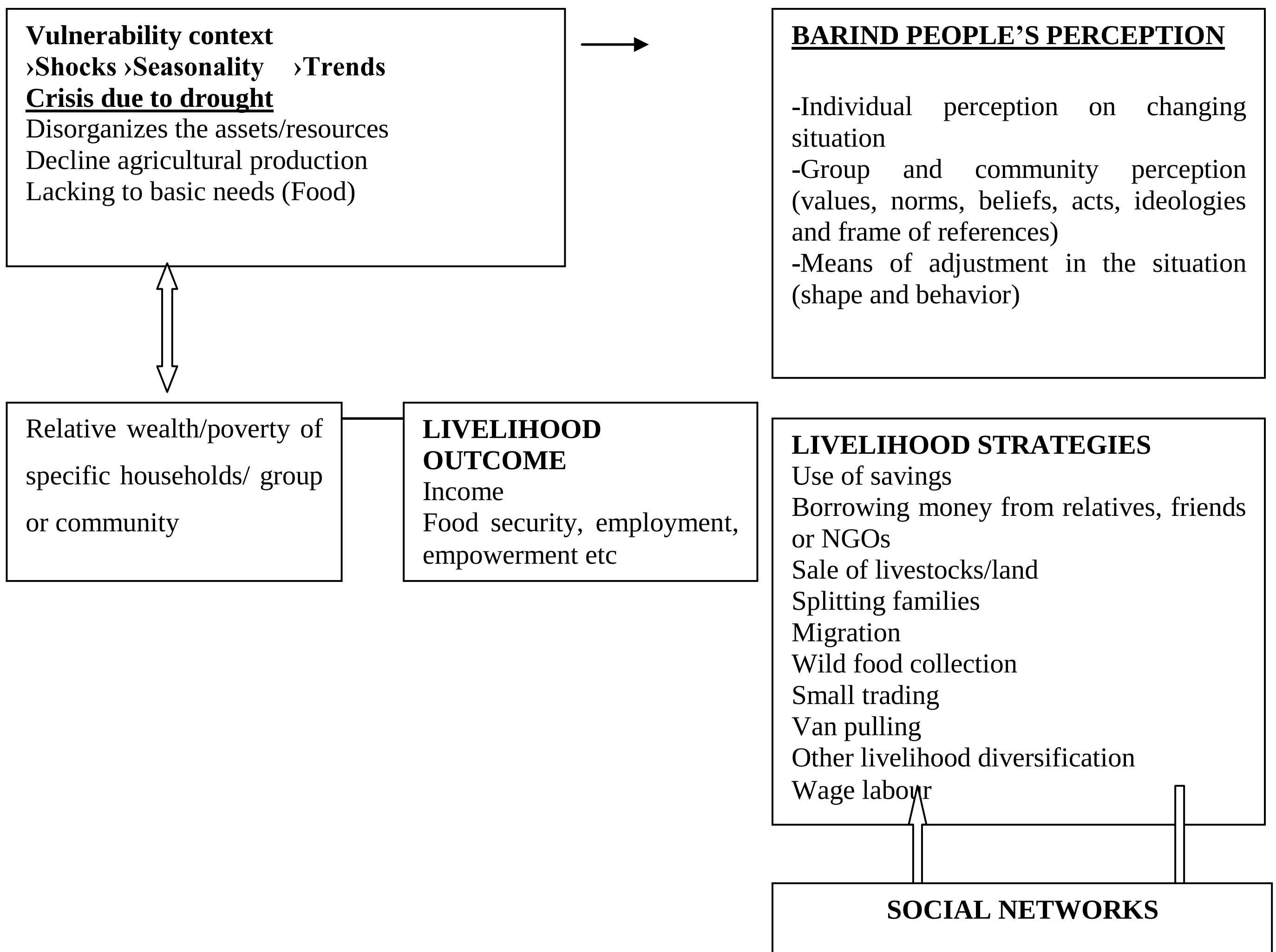


Figure 2b: The Conceptual Framework for the study

In the light of earlier discussion the following key concepts have been drawn and shaped the Conceptual Framework of the study:

- Members of households have the main responsibilities for adaptation practices in managing drought crisis through livelihood strategies. However, their perception and engagement in drought management are not well understood because earlier no or less attention has been paid on these practices.
- Vulnerability due to drought has multi dimentional impacts on livelihood, health, agriculture, assets and pshyco-social life.
- Poverty is the common issue among study villages; as rural households have fragmented and heterogenous characteristics in terms of economic status, land holdings, assets, capacity, behaviour and services. This makes them difficult to sustainable drought management practices.
- Diverse livelihood strategies are limited to the disadvantaged group in terms of cash income, income generating activities, employment opportunities during drought hardship.
- Understanding of social cohesion for effective social networks essentially important for this study within sustainable livelihood framework.

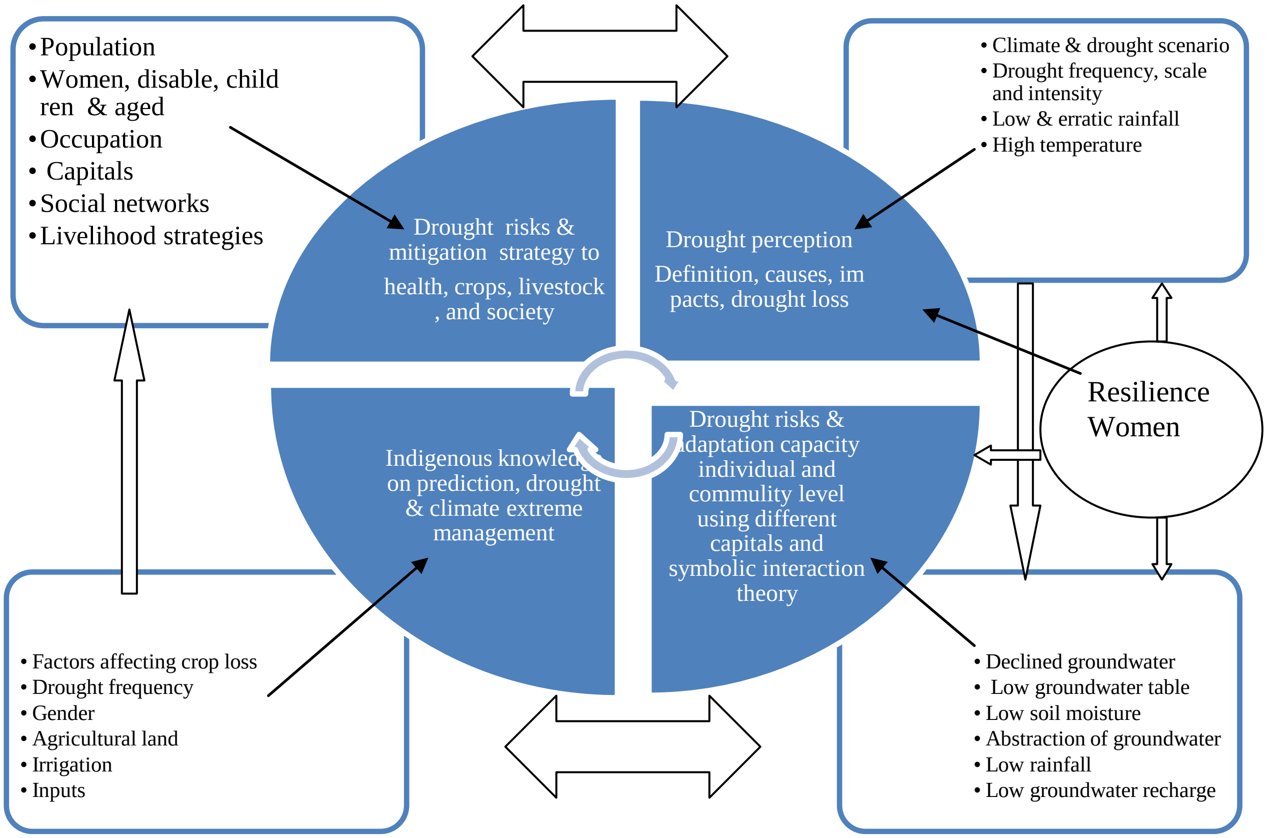


Figure 2c: A study framework for analyzing Barind peoples' adaptation strategy to drought

Figure 2c outlines the study framework elicits from the conceptual as well as the key gaps in the literature concerning sustainable approaches to drought management or adapting capacity to drought risks and vulnerability:

a) Agricultural production technology associated with irrigation, cropping pattern and intensity, organic technology, resistant cultivar and use of compost:

b) Health issues related to heat stroke, skin diseases, diarrhea, dysentery and health care services

c) Social capital associated with the education, support and networking

d) Drought loss related to rainfall, water and soil moisture issues:

- Loss of crops

- Loss of livestock
- Loss of fisheries
- Loss of poultry
- Lack of water (irrigation, drinking & domestic water)

e) Environmental issues linked with drought and extreme weather (high temperature, less rainfall, low groundwater table and low soil moisture)

f) Barind people characteristics related to vulnerabilities of persons with disability, aged person, women and children to drought

g) Livelihood strategies for alternative income generation associated with the scope, availability and diversity in the study areas

h) Government policy on drought, land degradation and desertification

i) Households' financial necessities and adaptation capcity to cope loss and drought crises management

j) Sustainable livelihood options for adaptation based on access to the options, availability and profitability of the measures

k) Empowerment is linked with capacities of the disadvantaged groups (elderly people, persons with disability, children, women and poor people in drought management)

The above framework forms the basis for analyzing the sustainable approach asan effective management system for drought adaptation in the northwest region of Barind Tract. Drought is primarily an agricultural phenomenon that refers to conditions where plants can survive to certain levels of moisture stress that affect both the vegetative growth and yield of crops. Several context of the vulnerability are recognized such as shocks, seasonality and trend of crisis due to drought. These cused huge losses in resources declined agricultural productionand unavailability of food. The vulnerability is also related with the relative wealth and poverty of households or community causing impacts on livelihood. As the the respondents perceived causes, impacts and strategies of drought adaptations they select their strategies through diversified livelihood options and social networks to manage drought risks (Figure 2a). The conceptual framework provide detail linkages among several issues, Barind people vulnerability, crop loss, adaptation capacity, social & natural capital and alternative agricultural production technology for sustainable livelihood strategies (Figure 2b). Water is the most crucial element needed for producing food. In fact, soil moisture deficit can cause drastic reductions of crops yield, which can be completely lost if a severe water stress occurs during vital crop stages. As we are already seeing, human induced climate change is resulting in less and more erratic rainfall, especially in regions where food security is very minimal. Increasing temperatures and unpredictable rainfall exacerbates conflicts over water allocation and already existing critical state of water availability (Thomas *et al.,* 2007). Water scarcity also threatens food supply. Water scarcity has a huge impact on food production. Without water people do not have other means of watering their crops and, therefore, to provide food for the fast growing population. Szep *et al*., (2005) found in his study that local soil moisture conditions in East Hungary became drier in the 20th century, parallel to the hemispherical changes. In fact, Bangladesh faced severe droughts in the years 1951, 1957, 1961, 1972, 1976, 1979, 1986, 1989 and 1997. Most of these droughts primarily occurred in pre-monsoon and post-monsoon seasons, but in some extreme cases the pre monsoon droughts had extended into the monsoon season due to delayed onset of the monsoon rains, e.g. the 1979 drought (Choudhury, *et al.,* 2003). The agriculture sector contributes 22.7 percent to GDP in Bangladesh alone (BBS, 2010). As like as many natural disasters, droughts distress the country at least as frequently as do others disasters, averaging about once in 2.5 years (Adnan, 1993; Ericksen, 1993; Hossain, 1990). Few years droughts cause a greater damage to crops than a flood or cyclone, eventually affect more farmers transversely a wider area (Paul, 1995). Drought is interlinked with climate change and both climatic factors and climate stressors. Several factors are associated with the crop loss during drought including drought frequency, cultivated land, livelihoods options (alternatives including nursery, van pulling), family income, adaptation measures (dismalting of housing structure, migration) and support. Drought affects rice crop in three different seasons. One forth of world's irrigated lands is provided by groundwater, of which 75 percent of lands are to be found in Asia (Shamsudduha *et al.,* 2011). Bangladesh Agriculture was completely reliant on nature including surface water and monsoon rainfall in earlier 1970s (UNDP, 1982). In Bangladesh, 79.1 percent lands are irrigated using underground water during Boro season (BADC, 2010). Bangladesh Agriculture was led and irrigated by traditional means up to 1950s. Study findings revealed that groundwater level is depleting in an accelerating rate over the time (Rahman & Mahbub, 2012). The groundwater table in High Barind Tract is depleting continuously over the time especially in dry season due to over exploitation of groundwater by tubewell (Islam, 2013). Careful monitoring on groundwater level for agriculture is essential; there is an immediate need of study on irrigated crops and groundwater table suction limit (Adhikary *et al.,* 2014). Indigenousknowledge is espoused in this research. Bangladesh has a long history of traditional and indigenous knowledge which are well documented in folk literature e.g. *Khanar vachan* (Islam, 2012; Sen, 2008). Different studies observed a number of interesting soil and water conservation techniques undertaken by local people (Chowdhury *et al.,* 1996; Islam, 1996). Successful local adaptation is quite necessary to reduce vulnerability to drought affected people (Havone & Hansen, 2009). Resilience is the capacity to cope with or adapt to hazards like drought. There are different adaptive measures but most of the adaptation studies consider climate change and variability (Gebrehiwot & van der Veen, 2013; Tessema *et al*., 2013) rather than specific adaptation strategies of drought. However, Reilly *et al.,* (2003) has identified several measures, for example changing of crop varieties and planting dates, using drought resilient crop etc, as means of adjusting to drought. Belay *et al.*, (2005) investigated coping strategies focusing on offsetting the negative effects of droughts after their occurrence among pastoral and agro-pastoral communities in eastern Ethiopia. As a result of 1994-1995 droughts, various adjustment measures were taken by farmers (Paul, 1998) which included household level adjustments and supports from both formal and informal sources (Olaleye, 2010). Some employed irrigation, gap-filling and inter-culture of some crops. As a non agriculture adjustment, people sale their belongings (livestock, land, poultry, housing structures etc) to reduce vulnerability of drought (Paul, 1998).

Based on the facts discussed above, the present study demands to explore climate scenario related to drought in the study areas. From the same perspective, this research aims to elicit farmer's perception on drought and its impacts (economic, health and social), state of groundwater table, factors associated with crop loss due to drought, indigenous knowledge used in drought prediction, drought mitigation measures and sustainable adaptation measures to drought.

Summary and conclusion

It has been observed that people in the vulnerable areas used livelihood strategies for the crises management. Livelihood approach is very much crucial for disasters like drought management. The chapter has discussed about different capitals and theory related to social behavior, social networks, social support as social security. The present chapter discussed about the Conceptual Framework of the study. The conceptual farmework highlighted on social networks and livelihood strategies.

Chapter 3: Methodology of the study

3.1 Overview of Methodology

The methodology chapter represents the details methods of research used for this study, and described design summary (including data collection, management and analysis). It was planned to acquire general idea of the vulnerability context in the study areas, and investigate the complicated nature of the Barind Tract. The framework provided conceptual idea from which the research questions were prepared. It was also used as the key tools in guiding and developing the methodology and the real questions asked. The analysis of the Barind Tract peoples' livelihood has been done by using several concepts of assets, perceptions, and impacts. The investigation has been deployed fieldworks (going to rural study villages) in the Barind Tract (three Districts), discussing with the men and the women having first hand experience of the crises and documenting their voices and views.

The study was conducted using the mixed methods (a combination of quantitative and qualitative methods). Both the primary data and the secondary data were used in this study. The qualitative research strategy has been applied to know the perceptions and collect the rigorous information of specific issues, and concentrate on the issues of livelihood and the issues of the changing of livelihood responses responsible for the growth of complexity at individual, household level and community level. The Quantitative data were collected from the field using several tools including surveys, In-depth Interviews, Key Informants Interviews, Focus Group Discussions and Case Studies. In selecting study locations, multistage (cluster) sampling was followed. Six Unions from six Upazillas in three Districts from Barind Tract were selected based on priority and vulnerability ranking (Appendix 1). Before selecting individual people at random, it has been decided to focus on certain 'areas', e.g. Upazila and Unions—selecting these by a method of random sampling. Total 343 respondents (70% men and 30% women) were selected randomly. Quota sampling was followed during selection of respondents (men and women) and proportionate population sample (PPS) in each village from study areas. Details on determination of sample size were given in Appendix 2. In collecting quantitative data, structured questionnaire were administered for household survey.

To get qualitative data and details information, diverse tools were administered. Thirty (30) In-depths Interview (5 from each Upazila) were carried out using semi-structured questionnaire, twelve (12) Focus Group Discussion (One FGD with male group and one FGD with female group from each Upazilla), six (6) case studies (1 from each Upazila) were carried out on success adaptation measures and twelve (12) Key Informants' Interview (two from each Upazila) were carried out to get success stories on drought adaptation measures.

The climatic data including monthly rainfall, temperature and static water level were collected from Bangladesh Water Development Board (BWDB), Barind Multipurpose Development Authority (BMDA), Department of Agriculture Extension (DAE) and Department of Meteorology from the study Upazila. There is no station of BWDB at Niamatpur Upazila of Naogaon District. Manada Upazila is the nearest station of Niamatpur Upazila and rainfalldata of Manda station is considered for Niamatpur Upazila. The six Upazilas were represented the study area, hence the saying that Northwest Region in the Barind Tract. The data obtained for the period of 1976 to 2014 and the study area was grouped into six. Statistical analyses were performed to measure significant difference among six Upazilas in realtion to weather parameter. Several graphs were prepared to describe the results in relation to months and years for the study. The measure of central tendency (mean, range, etc) and dispersion (SD., CV, etc) were calculated for recognizing rainfall trend data, the statistical analysis of linear regression was used. Rainfall data were used in calculation of Standardized Precipitation Index (SPI) and compare among six Upazila considering three, six and twelve months' rainfall for 30 years.

A survey on socio-economic losses and drought management options of respondents' of Chapai Nawabganj, Rajshahi and Naogaon District were carried out over a period of four years from February 2015 to August 2018 in four phases. The first phase of field work that was started in May 15, 2015 and in July14, 2015 covered the introduction with study areas, reconnaissance field visit, and stakeholder consultation, field testing of questionnaire with different occupational groups, study area selection and survey on economic losses, health hazards and migration. The second phase of field work (August 2015 to January 2016) focused on respondent selection for Key Informant's Interview and individual interview with sample population, preparation of questionnaire and field test of the questionnaire with the respondents. The third phase (February 2016 to August 2016) focused on group interview, Focus Group Discussion with respondents and other stakeholders about drought and its consequences, risks and vulnerabilities of drought, adaptation options and management options for drought. The last phase of the study focused on data analysis, document of the findings, preparation of report and submission from September 2016 to August 2018.

3.3 The Study Locations

It is a well known fact that the Barind Tract has experienced serious economic loss due to drought. Therefore more research should be carried out to support the resilience of the local people to drought. The observation has been made that this could be attained through research on Barind Tract. Hence, it is not easy to describe the impact of drought on peoples' livelihoods across the district or region, because the circumstances and problems tend to be varying from location to location.

Based on geographical settings, drought severity and ranking, three districts (Rajshahi, Chapai Nawabganj and Naogaon) were selected from northwestern region of Bangladesh. According to the study of Khan and Islam (2013), six Upazilas were selected based on drought severity ranking (two Upazila from each District). Finally Tanore (2) and Godagari (12) from Rajshahi District, Nachole (3) and Shibganj (9) from Chapai Nawabganj District and Niamatpur (1) and Porsha (4) from Naogaon District were selected for this study (Annex 1). Six Unions from six Upazila (each union from each Upazila) were selected considering agricultural production loss and affected livelihoods (Fig 3.1).

3.3.1 Rajshahi District

Rajshahi District locates between 24°07′to 24°43′ north latitudes and between 88°17′to 88°58′ east longitudes. Total area of the district is 2,425.37square kilometers. The District is surrounded by Natore District on the east, Naogaon District on the north, Kushtia District on the south and Chapai Nawabganj District on the west. The Barind Tract of the District consists of *Diara* and *Char lands*. Rajshahi town (City Corporation) stands on the bank of river the Padma. It was a part of Pundruvardhana. The District consists of one City Corporation including 4 metropolitans *Thana*, 30 Wards, 170 Mahallah & 9 Upazilas, 71 Unions, 1678 Mauzas, 1727 Villages, 14 Paurashavas, 126 Wards and 306 Mahallas. According to the Population Census 2011, the total number of households of Rajshahi District was 6, 33,758 and total enumerated population was 25, 95,197. Among the nine Upazilas, Bagmara had the highest population of

355 thousand whereas Mohanpur had the lowest population of 170 thousand. Annual average temperature of this District varies from maximum 37.8°C to minimum 11.2°C and annual average rainfall is 1862 mm. The main rivers of the District are the Padma (Ganges), Mahananda, Baral and Barnai (BBS, 2011).

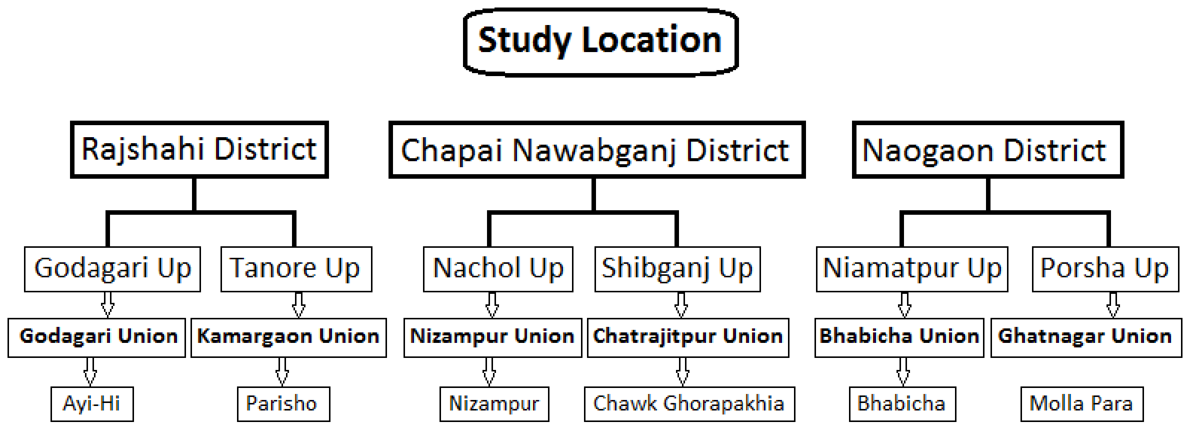
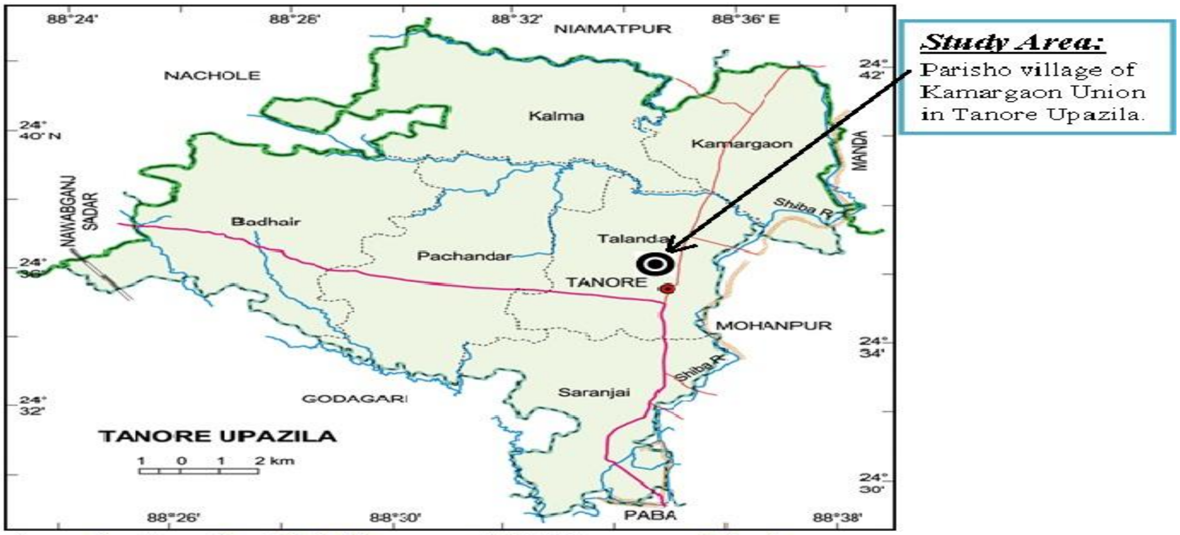


Figure 3.1: Study Location

3.3.1.1 Tanore Upazila

Tanore *Thana* appeared into existence in the year of 1869. Still it is unknown about the origin of the Upazila name. It is assumed that the Upazila might have derived its name from the Mauza where it's headquarter is situated. It covers an area of 295.40 Sq.km and situated between 24°29' and 24°43' north latitudes and between 88°24' and 88°38' east longitudes. The Upazila is enclosed by Niamatpur and Manda Upazilas of Noagaon Zila on the north, Paba and Godagari Upazila on the south, Manda Upazila of Naogaon Zila on the east and Nachole Upazila and Nawabganj sadar Upazila of Nawabganj Zila on the west (Fig 3.2).



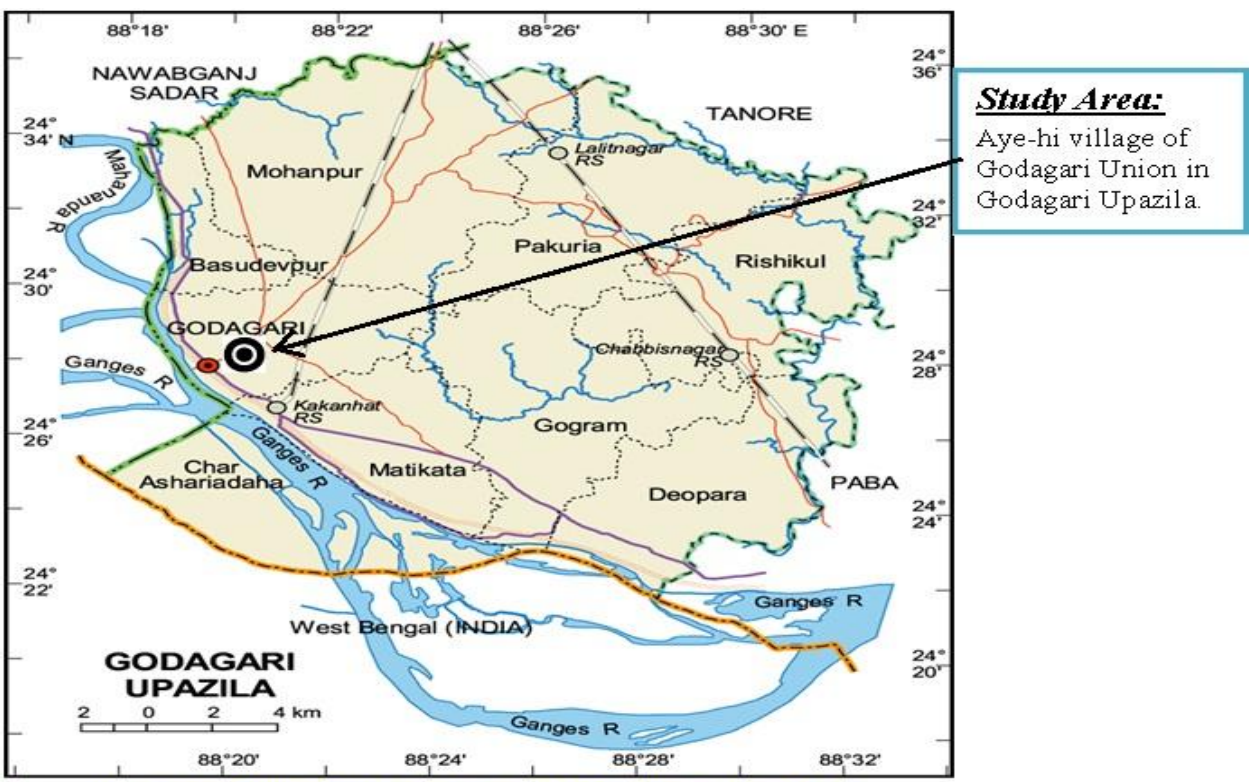
Source: http://mapofbangladesh.blogspot.com/2011/12/tanore-upazila.html

Figure 3.2: Study location: Parisho Village

According to Population and Housing Census 2011, the total population of the Upazila is 191330 of which 94041 are males and 97289 are females. The sex ratio of the Upazila is 97. The population density is 648 person per sq. km. The Upazila consists of 7 Unions, 157 populated Mauzas and 169 Villages. In the Upazila, there are 47425 households. The average household size at the Upazila is 4.03 persons. The literacy rate of the Upazila in 2011 is 48.8 percent for both sexes, 51.1 percent for male and 46.7 percent for female. The major crops in the study areas are paddy, wheat, jute, sugarcane, turmeric, oil seed, onion, garlic, potato, and betel leaf. Few crops are extinct or nearly extinct such as linseed, sesame, indigo, mustard seed, sweet potato, *kaun*, *bajra*, *arahar* and *aus* paddy. Main fruits are mango (*Mangifera indica*), jackfruit (*Artocarpus heterophyllus*), black berry (*Syzygium cumini*), betel nut (*Areca catechu*), coconut (*Cocos nucifera*), palm tree (*Borassus flabellifer*), guava (*Psidium guajava*) and lime (*Citrus grandis*) and papaya. Tanore experiences an average temperature of 38^0c with very limited rainfall 4637.mm for most of the year. The reasons for choosing Tanore as a study site are many folds: firstly, it is a severe drought prone area in Rajshahi; secondly it is very dry compared to other areas; thirdly, its geographical location and remoteness from any other major population centre has made it an ideal site for observing on how people cope to drought on their own way with little initial outside help.

3.3.1.2 Godagari Upazila

In 1865, Godagari came into existence as the *Thana*. The history about the origin of the Upazila name is still unknown. It is heard that long back ago there lived an influential washer man named Godagari. The people believed that the Upazila might have derived its name from the name of the washer man. It covers an area of 475.26 square kilometers of which 0.28 square kilometers are under forest. It is located between 24°21' and 24°36' north latitudes and between 88°17' and 88°33' east longitudes. The Upazila is 31 kilometers away from Rajshahi (district headquarters). The Upazila is encircled by Tanore Upazila on the north, Paba and Boalia on the east, by the river Padma on the south and Nowabganj sadar Upazila on the west (Fig 3.3).



Source: http://mapofbangladesh.blogspot.com/2011/12/godagari-upazila.html

Figure 3.3: Study location: Aye Hi Village

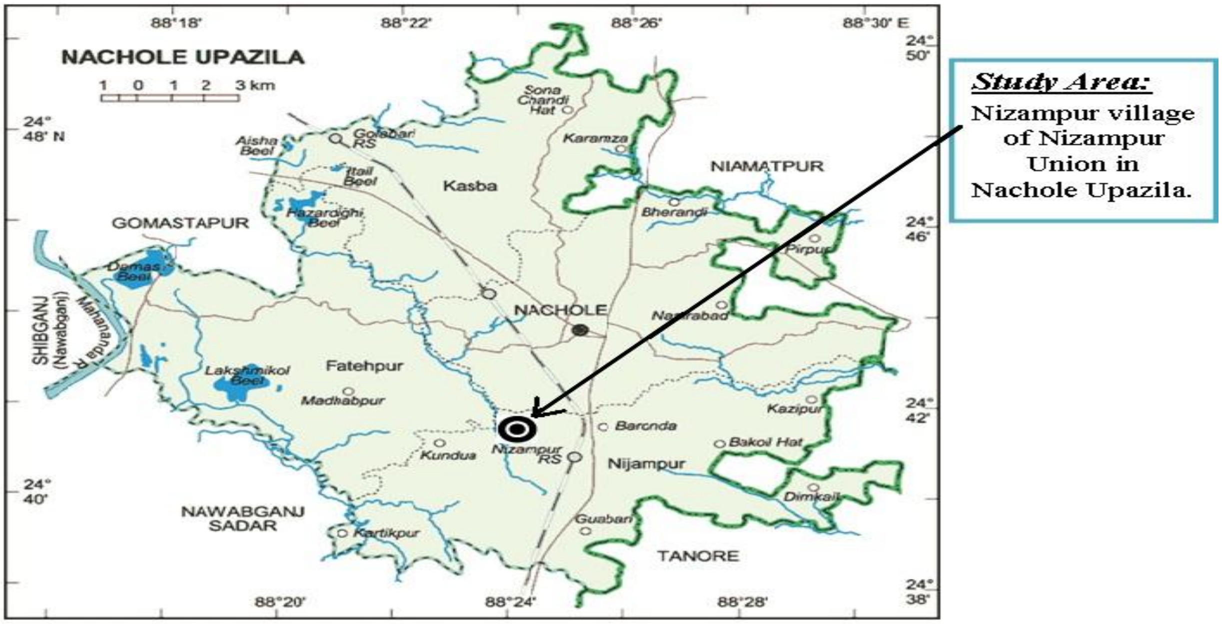
According to Population and Housing Census 2011, total population of the Upazila is 330924 compose of 166260 are males and 164664 are females with the sex ratio of the Upazila is 101. The population density is 696 person per sq. km. The Upazila combines 9 Unions, 316 populated Mauzas and 396 villages. In the Upazila, there are 72,186 households. The average household size for the upazila is 4.57 persons. The literacy rate of the Upazila in 2011 is 46.3 percent for both sex, 46 percent for male and 46.6 percent for female. Paddy, wheat, jute, sugarcane, turmeric, oil seed, onion, garlic, potato, betel leaf and mulberry plants are the major crops. Linseed, sesame, indigo, mustard seed, sweet potato, *kaun*, *bajra*, *arahar* and *aus* paddy are in the state of exintinction or nearly extinction. The main fruits are mango (*Mangifera indica*), jackfruit (*Artocarpus heterophyllus*), black berry (*Syzygium cumini*), betel nut (*Areca catechu*), coconut (*Cocos nucifera*), palm tree (*Borassus flabellifer*), guava (*Psidium guajava*), lime (*Citrus grandis* and papaya. Godagari exhibits maximum temperature of 38 degrees celsius and minimum 5.8^{0}c with total rainfall of 4637.3mm in a year. Godagari has been selected as the study site based on drought severity ranking and remoteness.

3.3.2 Chapai Nawabganj District

Chapai Nawabganj locates in northern part of Bangladesh as a part of the Rajshahi Division. Peviously it was a sub division under Maldah (India) district. Tthis was divided from Maldah and was given to East Pakistan as a sub-division of Rajshahi District in 1947. Again, this District became a separate district of Bangladesh in 1984. It is commercially very much important place due to its location at the connection of rivers the Mahananda and the Ganges. Chapai Nawabganj District is surrounded on the north by India, on the east by Naogaon and Rajshahi District, on the south and west by India. The District covers the area of 1702.54 square kilometers. The District stands between 24˚25´and 24˚58´ north latitudes and between 88˚01´ and 88˚30´ east longitudes. Annual average temperature of the District varies from maximum 37.8°C to minimum 11.2°C and annual average rainfall is 1862 mm. The main rivers of the Districts are the Ganges, Mahananda, Pagla, Moraganga and Punarbhaba. Chapai Nawabganj District consists of 5 Upazilas, 45 Unions, 785 Mauzas, 1135 Villages, 4 Paurashavas, 42 Wards and 156 Mahallas. The Upazilas are Bholahat, Gomastapur, Nachole, Chapai Nawabganj Sadar and Shibganj (BBS, 2011 and Banglapedia, 2015).

3.3.2.1 Nachole Upazila

In 1918, Nachole *Thana* came into existence. The origin of the Upazila name is unkwon to us. It is known that this area was hoarders and not suitable for movement from one place to another on foot in the past. The people of this area used to identify this area as Na Chal (Na means not and chal means easily accessible in Bengali). It is believed that the Upazila might have derived its name from the above mentioned two words. The Upazila covers an area of 283.67 sq. km and is located between 24°38’ and 24°51’ north latitudes and between 88°15’ and 88°21’ east longitudes. Nachole is located approximately 30 kilometers away from Chapai Nawabganj (district headquarters). The Upazila is encircled on the north by Gomastapur and Niamatpur upazilas of Naogaon Zila and Tanore Upazila of Rajshahi Zila, on the south by Tanore Upazila of Rajshahi Zila and Nawabganj Sadar Upazila and on the west by Gomastapur, Nawabganj Sadar and Shibganj Upazilas (Fig 3.4).



Source: http://www.hellobangladesh.biz/Bangladesh/District-Map/Thana_Upazila_Map/nachole_upazila.gif

Figure 3.4: Study location: Nizampur Village

Nachole Upazila consists of 4 Union and 191 Villages. Total Population (Enumerated) of the Upazila is 1, 46,627 of which 72,895 are male and the rest 73,732 are female. Population density is 517 persons per square kilometer. The ratio of male and female is 99. The number of total households of the Upazila is 32,922 and the average household size is 4.45. Literacy rate is 45.5 percent; among them 44.9 percent male and 46 percent are female. Annual average temperature lies between maximum 37.8°C to minimum 11.2°C; annual rainfall 1862 mm. Paddy, jute, sugarcane, wheat, betel leaf, oil seeds and pulses are the major crops in the area. The following crops such as Indigo, *koda*, *maara* (one kind of pulse), *china* (common millet) are nearly in the state of extinction. The main fruits of the area are mango (*Mangifera indica*), jackfruit (*Artocarpus heterophyllus*), black berry (*Syzygium cumini*), betel nut (*Areca catechu*), coconut (*Cocos nucifera*), palm tree (*Borassus flabellifer*), guava (*Psidium guajava*), lime (*Citrus grandis*) watermelon and *boroi*.

3.3.2.2 Shibganj Upazila

It is found that the formation of the Shibganj *Thana* came into existence in 1903. There is no specific information about the origin of the Upazila name. The previous name of the Upazila was Sherganj which was named after the name of emperor Sher Shah. Subsequently the name was changed into Shibganj by the Hindu community to commemorade the honour and respect of their God Shiba. The Upazila covers an area of 525.42 square kilometers and locates between 24°34' and 24°54' north latitudes and between 88°1' and 88°18' east longitudes. It is 28 kilometers away from Chapai Nawabganj (district headquarters). The Upazila is bounded on the north Bholahat Upazila and India, on the east by Gomastapur, Nachole and Nawabganj Sadar Upazilas, on the south by Nawabganj Sadar Upazila and India and on the west by India (Fig 3.5).

Source: http://wikimapia.org/16598558/Shibganj-Upazila-HQ

Figure 3.5: Study location: Chakghorpakhia Village

Shibganj Upazila consists of 15 Union and 407 Villages. Total Population (enumerated) of the Upazila is 591178 of which 295338 are male and the rest 295840 are female. The population density of this Upazila is 1125 persons per sq. km. The ratio of male and female is 100. The number of total households of the Upazila is 124899 and the average household size is 4.73. Literacy rate is 39.4 percent, of which 38 percent male and 40.8 percent are female. Annual average temperature of this area varies from maximum 37.8°C to minimum 11.2°C; annual rainfall 1862 mm. Paddy, jute, sugarcane, wheat, betel leaf, oil seeds and pulses are the major crops in the study area. Few crops such as indigo, *koda*, maara (one kind of pulse), *china* (common millet) are the state of extinction. mango (*Mangifera indica*), jackfruit (*Artocarpus heterophyllus*), black berry (*Syzygium cumini*), betel nut (*Areca catechu*), coconut (*Cocos nucifera*), palm tree (*Borassus flabellifer*), guava (*Psidium guajava*),lime (*Citrus grandis*) watermelon and *boroi are the major fruits*. The average temperature of Shibganj is 38.3 degrees celsius and limited rainfall 1477 mm for most of the year. The Upazila has been selected for the study considering remotetness and drought severity.

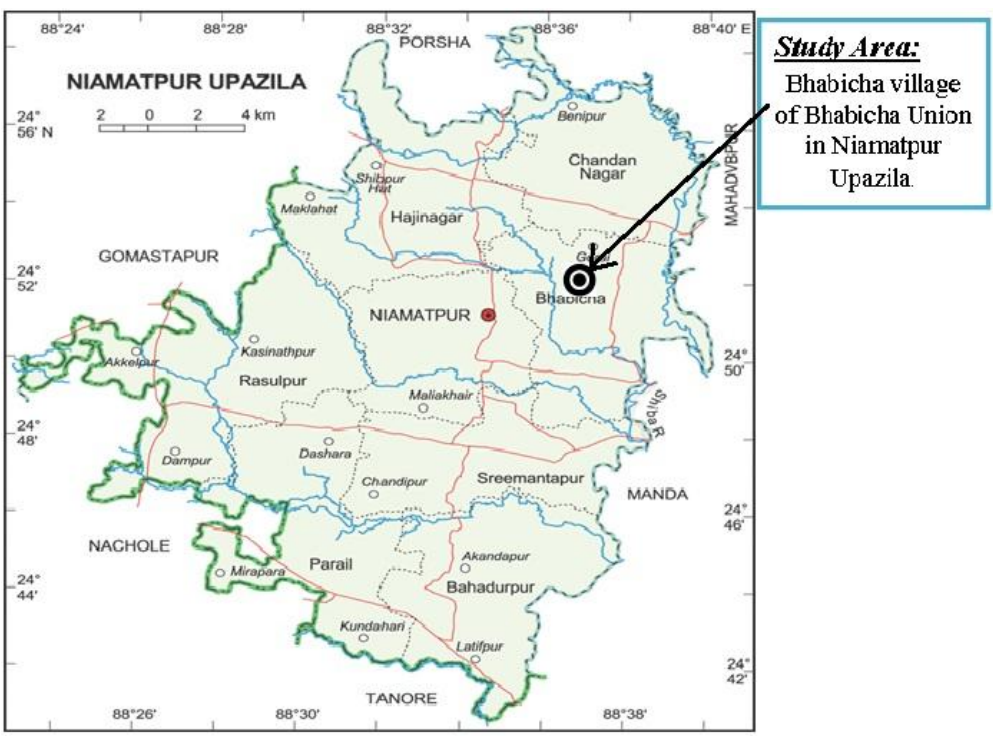
3.3.3 Naogaon District

Naogaon District is enclosed on the north by the West Bengal State of India, east by Joypurhat District and Bogra district, south by Natore and Rajshahi Districts and on the west by Chapai Nawabganj District and West Bengal State of India. It locates between 24º32’ and 25º13’ north latitudes and between 28º23’ and 89º10’ east longitudes. The total area of the District is 3435.65 square kilometers. The District consists of 11 Upazilas, 99 Unions, 2497 Mauzas, 2780 Villages, 3 Paurashavas, 27 Wards and 92 Mahallas. The Upazilas are Naogaon Sadar, Atrai, Badalgachhi, Dhamoirhat, Manda, Mahadebpur, Niamatpur, Patnitala, Porsha, Raninagar and Sapahar. The annual average temperature of the Zila varies from maximum 37.8°C to minimum

11.2°C and the average annual rainfall of the Zila is recorded 1862 mm. The Atrai, Punarbhaba, Little Jamuna, Nagar, Chiri and Tulsi Ganga are the main rivers of this District (BBS, 2011).

3.3.3.1 Niamatpur Upazila

Niamatpur *Thana* appeared in the year of 1918. It was upgraded to upazila in 1984. It is the biggest Upazila of Naogaon Zila in respect of area. The origin of the upazila name is unkown. There is hearsay that previously the name of this area was Hokmadanga. Subsequently, it was renamed as Niamatpur at the desire of the Saint. The Upazila occupies an area of 449.09 sq. km. It is located between 24041' and 24059' north latitudes and between 88023' and 88040' east longitudes. The Upazila is bounded on the north by Porsha Upazila, east by Manda Upazila and Mahadebpur Upazila, south by Tanore Upazila of Rajshahi Zila and west by Gomostapur Upazila and Nachole Upazila of Chapai Nawabganj Zila (Fig 3.6).



Source: http://mynaogaon.blogspot.com/2009/02/niamatpur-upazila-naogaon.html

Figure 3.6: Study location: Bhabicha Village

Total population of the upazila is 248351 of which 122578 are males and 125773 are females (BBS, 2011). The sex ratio of the Upazila is 97. The Upazila consists of 8 Unions, 321 populated Mauzas and 344 Villages. The average size of population of each Union, Mauza and Village are 31044, 774 and 722 respectively. In the Upazila, there are 61811 households. The average household size for the Upazila is 4.0 persons. The literacy rate of the Upazila in 2011 is 44.7 percent for both sex, 46.5 percent for male and 42.9 percent for female. The annual average temperature of the this area varies from maximum 37.8°C to minimum 11.2°C and the average annual rainfall is recorded 1862 mm. Major agricultural products comprise of *aus, aman, boro*, jute and wheat. Among rice crops, *aman* covers by far the largest area followed by boro and aus. Rice covers 85.25 percent of the gross cropped area of this Zila. *Rabi* (summer) includes mustard, *khesari*, *masur*, potato, sesame, spices, barly, maize, tobacco, sugarcane, etc. *Tal* (palm) is abundant in the Barind portion of the Zila. Besides, the cultivation of hemp plant (*Cannabas sativa*) is a speciality of this area. The plant yields three narcotic products called *ganja*, *charas* and *bhang*. The homestead flora represents different species of commonly planted trees. These are mango (*Mangifera indica*), jackfruit (*Artocarpus heterophyllus*), black berry (*Syzygium cumini*), betel nut (*Areca catechu*), coconut (*Cocos nucifera*), palm tree (*Borassus flabellifer*), guava (*Psidium guajava*) and lime (*Citrus grandis*). Niamatpur experiences an average temperature of 37.8 degrees celsius with very limited rainfall 1862 mm for most of the year. In selecting Niamatpur as a study site, several factors were considered including drought severity, homogeneous community and remoteness.

3.3.3.2 Porsha Upazila

Porsha Upazila came into existence as a *Thana* in 1933 and was upgraded to Upazila in 1984. It is the second smallest Upazila of Naogaon Zila in respect of population. It is unraveled about the origin of the Upazila name. It is said that in the past, a group of Persian people came here and settled at the present place of the Upazila headquarters where a village grew up in the name Porsha. It is generally believed that the Upazila might have originated its name from the name of that village. The Upazila occupies an area of 252.83 sq. km. Including 0.5 sq. km. river area. It is located between 24°54’ and 25°05’north latitudes and between 88°24’ and 88°39’east longitudes. It is located approximately 58 kilometers away from Naogaon (district headquarters). The Upazila is bounded on the north by Sapahar Upazila, east by Patnitala Upazila and Mahadebpur Upazila, south by Gomastapur Upazila of Chapai Nawabganj Zila and Nimatpur Upazila and west by West Bengal State of India (Fig 3.7).

Source: http://lib.pmo.gov.bd/maps/images/naogaon/Porsha.gif

Figure 3.7: Study location: Mollapara Village

The Upazila holds 132095 population of which 66299 are male and 65796 are female. The sex ratio of the Upazila is 101. The Upazila consists of 6 Unions, 155 populated Mauzas and 246 Villages. The average size of population of each Union, Mauza and Village are 22016, 852 and

537 respectively. In the Upazila, there are 30773 households. The average household size for the Upazila is 4.2 persons. The literacy rate of the Upazila in 2011 is 42.5 percent for both sex, 43.2 percent for male and 41.9 percent for female. The annual average temperature of this area varies from maximum 37.8°C to minimum 11.2°C and the average annual rainfall is recorded 1862 mm. It has been seen that *aus*, *aman*, *boro*, jute and wheat are the main crops in this Upazila. Among rice crops, *aman* covers huge area followed by *boro* and *aus*. Rice covers 85.25 percent of the gross cropped area of this Zila. Rabi (summer) includes mustard, *khesari*, *masur*, potato, sesame, spices, barly, maize, tobacco, sugarcane, etc. *Tal* (palm) is plenty in the Barind portion of the Zila. The plant yields three narcotic products called *ganja*, *charas* and *bhang*. The homestead flora represents different species of commonly planted trees. These are mango (*Mangifera indica*), jackfruit (*Artocarpus heterophyllus*), black berry (*Syzygium cumini*), betel nut (*Areca catechu*), coconut (*Cocos nucifera*), palm tree (*Borassus flabellifer*), guava (*Psidium guajava*) and lime (*Citrus grandis*). Porsha experiences an average temperature of 37.8 degrees celsius with very limited rainfall 1862 mm for most of the year. Porsha has been selected for this study due to remoteness, drought severity and community characteristics.

Summing up, the choices of the six sites were selected to find out affected households' experience to get answer of the research objectives for this study. Special care was taken for the survey considering rural environments and purposes of comparison.

3.4 Selection of Study Population

For Quantitative Survey

3.4.1 Sampling

Sampling may be defined as the process of selecting a representative set of cases from a much larger set. There were three types of respondents required in this study including Household Surveys, In-depth Interviews and Key Informant Interviews. A random sampling method was used to select the respondents.

3.4.2 Sample Households

Large numbers of households were living at each site and therefore, the multistage sampling method was chosen for respondents' selection. The unit of analysis was the household. The households were listed as they appeared in the records of Union Parishad and sampled accordingly. The aim of this method was to eliminate bias in selecting sample, and to steer the resercher to households throughout the research sites. Households were selected randomly. Figure 2 showing details on household and sample size. Total 343 household respondents were selected from six Villages using PPS for the survey (Appendix 3).

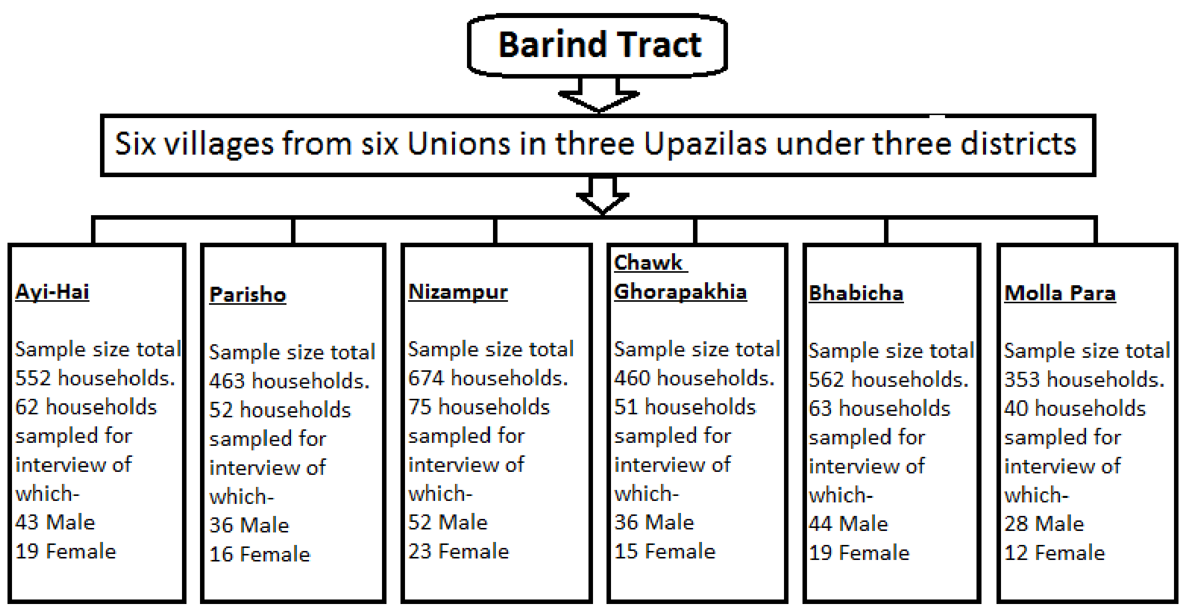


Figure 3.8: Total Households and sample size

Tanore

There are seven Unions in Tanore Upazila having 42784 households. People were living at the site in seven Unions.

Sampling stage 1: The seven Unions were given number from 1 to 7. One of the numbers was drawn using simple random online calculator and the random number was 7 (Kamargaon union).

Sampling stage 2: The 36 villages were given number from 1 to 36. One of the numbers was drawn using simple random online calculator and the random number was 8 (Parisho village).

Sampling stage 3: All the households (463) in Parisho Village from Kamargaon Union which had fallen into the sample were listed as they appeared in the register held at the Union Parishad office and put number accordingly. After readiness of sample frame, respondents were selected for the study (random numbers were drawn using simple random method). The fifty two numbers were drawn for the survey. The study began by assigning numbers (1-463) to the sample frame. The numbers were drawn using simple random online calculator (*https://www.random.org/integers/*). A random sample of 52 households (36 male and 16 female) were drawn at Parisho Village.

Godagari

There are nine Unions in Godagari Upazila having 60181 households. They were living at the site in nine Unions.

Sampling stage 1: The nine Unions were given number from 1 to 9. One of thenumbers was drawn using simple random online calculator and the random number was 2 (Godagari Union).

Sampling stage 2: The 46 villages were given number from 1 to 46. One of the number was drawn using simple random online calculator and the random number was 32 (Aye Hai Village).

Sampling stage 3: All the households (552) in Aye Hai Village from Godagari Union which had fallen into the sample were listed as they appeared in the register held at the Union Parishad office and put number accordingly. Once the sample frame was ready, respondents were selected for the study (random numbers were drawn using simple random method). The sixty two numbers were drawn for the survey.

The study began by assigning numbers (1-463) on the sample frame. The numbers were drawn using simple random online calculator (*https://www.random.org/integers/*). A random sample of 62 households (43 male and 19 female) were drawn at Aye Hai Village.

Nachole

There are four Unions in Nachole Upazila having 29142 households. They were living at the site in four Unions.

Sampling stage 1: The four Unions were given number from 1 to 4. One of the number was drawn using simple random online calculator and the random number was 1 (Nizampur Union).

Sampling stage 2: The 58 Villages were given numbers from 1 to 58. One of the number was drawn using simple random online calculator and the random number was 34 (Nizampur Village).

Sampling stage 3: All the households (674) in Nizampur Village fromNizampur Union which had fallen into the sample were listed as they appeared in the register held at the Union Parishad office and put number accordingly. Once the sample frame was ready respondents were selected for the study (random numbers were drawn using simple random method). Seventy five numbers were drawn for the survey.

The study began by assigning numbers (1-674) on the sample frame. The numbers were drawn using simple random online calculator (*https://www.random.org/integers/*). A random sample of 75 households (52 male and 23 female) were drawn at Nizampur Village.

Shibganj

There are fourteen Unions in Shibganj Upazila having 60181 households. They were living at the site in fourteen Unions.

Sampling stage 1: The fourteen Unions were given number from 1 to 14. One of the number was drawn using simple random online calculator and the random number was 2 (Sutrajitpur Union).

Sampling stage 2: The 8 Villages were given numbers from 1 to 8. One of the number was drawn using simple random online calculator and the random number was 1 (Chakghorpakhia Village).

Sampling stage 3: All the households (460) in Chakghorpakhia Village from Sutrajitpur Union which had fallen into the sample were listed as they appeared in the register held at the Union Parishad office and put number accordingly. Once the sample frame was ready, respondents were selected for the study (random numbers were drawn using simple random method). Fifty one numbers were drawn for the survey.

The study began by assigning numbers (1-460) on the sample frame. The numbers were drawn using simple random online calculator (*https://www.random.org/integers/*). A random sample of 51 households (36 male and 15 female) were drawn at Chakghorpakhia Village.

Niamatpur

There were eight Unions in Shibganj Upazila having 61811 households. They are living at the site in eight Unions.

Sampling stage 1: The nine Unions were given number from 1 to 8. One of thenumbers was drawn using simple random online calculator and the random number was 7 (Bhabicha Union).

Sampling stage 2: The 39 Villages were given number from 1 to 39. One of the number was drawn using simple random online calculator and the random number was 27 (Bhabicha village).

Sampling stage 3: All the households (562) in Bhabicha Village from Niamatpur Union which had fallen into the sample were listed as they appeared in the register held at the Union Parishad office and put number accordingly. Once the sample frame was ready, respondents were selected for the study (random numbers were drawn using simple random method). Sixty three numbers were drawn for the survey.

The study began by assigning numbers (1-562) on the sample frame. The numbers were drawn using simple random online calculator (*https://www.random.org/integers/*). A random sample of 63 households (44 male and 19 female) were drawn at Bhabicha Village.

Porsha

There were six Unions in Porsha Upazila having 30773 households. They were living at the site in six Unions.

Sampling stage 1: The six Unions were given number from 1 to 6. One of the number was drawn using simple random online calculator and the random number was 2 (Ghatnogor Union).

Sampling stage 2: The 55 Villages were given number from 1 to 55. One of the number was drawn using simple random online calculator and the random number was 9 (Molla para Village).

Sampling stage 3: All the households (353) in Molla para Village from Ghatnogor Union which had fallen into the sample were listed as they appeared in the register held at the Union Parishad office and put number accordingly. Once the sample frame was ready, respondents were selected for the study (random numbers were drawn using simple random method). Forty numbers were drawn for the survey.

The study began by assigning numbers (1-353) on thesample frame. The numbers were drawn using simple random online calculator (*https://www.random.org/integers/*). A random sample of 40 households (28 male and 12 female) were drawn at Molla para village.

Qualitative data collection

3.4.3 Selection of Key Informants

In selecting Key Informants, the study built connection with many people and officials through observation, informal meetings, interaction and discussion with various groups ofpeople. Twelve Key Informants were identified during stakeholder consultation. There is no sample frame prepared for the selection of Key Informants. The Key Informants are people supposed to have particular insight or opinions about the topic under the study. The Key Informants may be ordinary people and not necessarily the specialists, the better educated, those in power or the officials (Mikkelsen 2005). In this study, the main criteria for selecting the Key Informants were those who had a wide spread knowledge about the Barind cultural practices related to drought and livelihoods both in the present and the past, their engagement in relevant works at the study site, and their latest role in the policy. Total of twelve Key Informants were selected from the study areas on the basis of the aforesaid criteria. Two Key Informants were interviewed from each site (one official from DAE and one from BMDA). In formulating strategies to drought, one high official from BMDA, one high official from DAE and one high official from Ministry of Disaster Management and Relief were interviwed. They were relevant in getting in-depth information on the cultural history of the Barind, and the traditional modes of management to drought.

3.4.5 Selection of Respondents for In-depth Interview

In-depth information regarding drought and its impacts, local practices for adaptation and drought management options were required for the study. The interview was conducted with 30 respondents from six Upazilas (5 respondents from each Upazila). To get diverse and authentic information related to drought perspectives, one Sub Assistant Agriculture Officer, One elected person (member of Union Parishad)/ local school teacher, two farmers (one famer who cultivated own land and one lease farmer) and one fisherman from each Upazila were selected.

3.4.6 Selection of participants for Focus Group Discussion (FGD)

12 Focus Group Discussions (FGDs) were carried out with the male and female group separately to get in-depth information on drought, causes of drought, drought severity, drought hazards, and impact of drought, local practices and drought management options. Two Focus Group Discussions (FGDs) were carried out in each Upazila (one FGD with the male group and one FGD[1] with the female group). 6-10 participants were participated in each Focus Group Discussion. The participants were invited to come to any place at any time that was convenient for them. The occupational homogeneous groups were selected for the session to gather relevant

[1] [FGD demotes to Focus Group Discussion where a homogeneous group of people are selected to address the targeted research queries. Informants are informed about topic, purpose, time, date, and venue of the meeting. Participants organized the meeting by themselves].

information on drought history, drought impacts and drought management options. The session was conducted by the researcher with the help of a note keeper and a gate keeper. Documentation was done using both voice recorder and in written forms.

3.5 Data collection procedure and data analysis

The study has been used a set of data collection techniques and different sources of information to collect both qualitative and quantitative data. Several methods were deployed to ask people the same questions in different settings for triangulation. It reduced the biased interpretations. The study required to use four main sources with an understanding that the collected data would help in answering the research questions. The main data sources were: secondary document search, observation and informal interviews, Key Informant Interviews, household surveys, In-depth Interviews, Focus Group Discussion and Case Studies and mapping. The study has been applied in multiple strategies, or triangulation.

In order to achieve the research objectives and explore the answer to the research questions, both secondary and primary data were collected from relevant sources. The secondary data were collected from secondary sources including reports, printed materials and from different institutions including concerned departments, research organizations, universities and Barind Multipurpose Development Authority. All of the background information and secondary data were collected from different sources and through personal contact of the related organizations namely, Institute of Disaster Management and Vulnerability Studies, University of Dhaka, Institute of Water and Flood Management, Bangladesh University of Engineering and Technology other secondary sources including journal articles and Library from different Universities. The primary data were collected from the primary stakeholders of the study area.

The primary stakeholders include small, medium and large farmers. Other groups of primary stakeholders were landless and farm laborers. Another category of primary stakeholders were women from small and medium farms' households and landless people. Several methods and techniques were deployed for primary data collection. Few PRA Tools such as Focus Group Discussion and Transect Walk along with case study and observation were made for the study.

3.5.1 Documentation of data

The secondary data were collected from different sources including published and office documents from different sources. The main source of secondary data was library and archival research. Library search was carried out at Institute of Disaster Management and Vulnerability Studies, University of Dhaka, Institute of Water and Flood Management, Bangladesh University of Engineering and Technology. Several resource centers including Department of meteorology, Department of Environment, Department of Agriculture and Extension, Office of the On Farm Research and Development, Ministry of Disaster Management and Relief and office of the Barind Multipurpose Authority were also visited by the researcher. Documents studied in the libraries included books, journals, newsletters, newspapers, manuscripts, theses, and magazines.

3.5.2 Observation and informal interviews

Informal interviews and observation were made prior to the household surveys of the study by visiting the selected sites. This was necessary to make the researcher conceptualize the problem on the ground, and consequently to plan for intensive formal interviews. The local NGOs and village leaders from six sites accorded researcher all the necessary help. They personally took the researcher around their respective areas of jurisdiction and introduced him to the locals and other influential people within those areas. A quite numbers of households were visited by the researcher. The study was introduced researcher to the people as a PhD student from the Institute of Disaster Management and Vulnerability Studiesat University of Dhaka, Bangladesh,doing research on drought, and how the people coped on their own. The villagers didn't have any difficulty in welcoming the researcher. The most of the time was spent by the researcher with the villagers, talking to them and making observations during the study. The study has been identified two person (one male and one female) from each of the study site, who could speak both Bengali and local language to help researcher in interpreting some of the words. Familiarization and observation is crucial to shape the study. The key issues to be examined through questionnaire interviews were selected from the experiences gained during this early period. The method had few limitations. Firstly, the respondents were not systematically selected. We just happened to live together and talk. Secondly, the issues discussed were never entirely controlled. A topic would come up and be discussed spontaneously and was discussed there and then. Therefore, data generated in this way left alot of gaps in the subject of response to drought management. Thirdly, the data generated through observation and informal interviews was not enough to bring out completely, the Barind people cultural interpretation of drought its management, and how they currently cope with such conditions on their own within their capacity. There was then a need for a more systematic data collection technique specifically designed to explore the drought management phenomenon.

3.5.3 Preparation of questionnaire and checklist

Survey questionnaire on several aspects including economic losses and health hazards due to drought and checklist for In-depth Interviews, Key Informants Interview and Focus Group Discussion were developed and tested at the field level and finalized for the study. Structured questionnaire was prepared for household survey and semi-structured questionnaire for In-depth Interviews.

3.5.4 Pilot survey

At first pilot survey was carried out to pre-test the questionnaire. This was done with the guided structured questionnaire in advent of actual survey. The pre-testing interview task was done on at the Aye-Hi Village under Godagari Union of Godagari Upazilla in Rajshahi District. The site (Village homesteads) has been visited by the researcher and selected five households randomly. The household heads of those five selected households were interviewed using drafted structure questionnaire. It took two days to complete the interviews. From the result of the pre testing interviews, few necessary adjustments were made in the questionnaire for its effectiveness and applicability. Few difficulties were identified during pilot survey. Interviews should be made in such a way that they could be conducted at different times of the day, depending on the availability of the respondents avoiding too long questionnaire. The interview was expected to take less than one hour per household, but it took more than one hour. Therefore, necessary adjustments were required in the questionnaire (had to be shortened). The study has been given lot of opportunity to learnt some questions that were never answered at all by anybody, while at the same time; particular questions were popular with everybody. It was also noted that some questions were not relevant in answering my research question. The questionnaire was therefore streamlined by removing those questions which were ineffectual. Key questions were identified that had generated useful data from all the five respondents during the pilot survey. The questions were designed in a structured manner through necessary adjustment.

3.5.5 Households Survey

Pilot survey was carried out to ascertain important parameters of the study with a draft structured questionnaire. Based on pilot survey the study instruments were revised and necessary amendments were made. The survey were designed to gather information related to education, sex, income, occupation, total land holdings, total family sizes with their age, sex, educations, losses from drought, drought adaptation techniques and health hazards for this survey. After pilot survey, the survey parameters on drought and socio-economic condition and potential value for the study were reviewed for large, medium and small farmers group considering land holdings. A structured questionnaire was prepared covering issues related to economic loss, health hazards due to drought and migration perspectives. This was guided interview and started with examining the different management issues for which respondents' opinions were expected. This study preferred the household interview method to recognize that the informants are individual actors with different experiences, status, needs, and motives. The study also aligned within research realm, it was important to categorize individual people experiences, practices, and values to be able to say something general about the specific group of people, the study was researching their livelihood. Household is a complex term, the specific forms and characteristics of households often depend on context, a combination of social and cultural norms and economic incentive (World Bank, 2000). The most frequent definition of the household is relatives who live under the same roof, and regularly eat their main meals together (Eriksen 1994). Total 343 households interview were carried out with the structured question (Appendix 4)

3.5.6 Key Informants' Interview

To generalize methodical information on the history of drought, drought impacts, local practices on drought management and modes of adaptation and management inthe past and present, twelve Key Informants were identified and interviewed in-depth. The interview was conducted with the guided checklist. This study asked several follow up questions in order to get a deeper understanding of local people's practices for drought management during data collection. Flexible questions were asked according to guided checklist. The interviews were anticipated to generate expert information about the six research sites based on the research objectives. At the end of an interview session, study requested the respondent if he or she wanted to add something and also ask for permission to come again in case the study needed more information. This question gave the respondent an opportunity to discuss things they considered important for them to focus on.

3.5.7 In-depth Interview

This was more informal interview with the respondent to get case by case details information. Total 30 respondents were interviewed with the semi-structured questionnaire (Appendix 5) covering issues of drought, causes of drought, drought severity, drought impacts, and available drought management options at the community.

3.5.8 Focus Group Discussion

The study used Focus Group Discussion to get more qualitative data rather than quantitative. Total 12 FGDs were conducted using guided checklist from six study sites. Six Focus Group Discussions were made with the homogenous female group to get relevant information on drought management and gender perspectives. Similarly another six Focus Group Discussions were carried out with the homogenous male group to get details information on drought and its management.

3.5.9 Case Study

During the survey and interview, several cases were identified on adaptation and drought management options those were very interesting for the study. Based on case histories, the study was made six case studies on several issues of drought management. Six case studies were made with relevant information and data.

3.6 Notes and data recording

In this study, three different documentation techniques were used to collect the data:

Note keeping: Note keeping was the most used method to document data. The notes included the names and ages of the informants and the dates and places of interviews. Key notes were taken during both formal and informal interviews and elaborated later. A double cross checking of interpretations was done to ensure accuracy of the information. After each interview session, research team (researcher with research assistants) would sit down together and review what they recorded and saw. In addition, the study would revise daily work and write down full notes at the end of each day. This included what they observed in relation to this study, and their comments on the interviews and/or interviewees.

Audio recording: The study used audio recording as a method, but it was employed cautiously so as not to affect the progress of research. In advent of audio use, the team requested permission to use it to record the interview. This device gave researcher an opportunity to record for many hours continuously, and to catch up with what they had missed during the interview session. Interviews were only recorded with a few of the Key Informants and Focus Group Discussion.

Photography: The study eventually used still camera to capture key issues and respondents activities related to drought impacts, livelihoods and drought adaptation and drought management options. This was done with the prior permission from the respondents and authority.

3.7 Testing of hypothesis

The chi-square tests of relationship wherever there are sets of variables for comparison are used for determines homogeneity of baseline indices. The study was to elicit there is significant variation in the indices having similar milieu. The problem can be solved as a 5 x 4 contingency problem utilizing the rather normal chi-square test formula. The use of the conventional x^2 formula involves the calculation of the expected frequencies using the formula.

Fe = FrFc/N

Where:

Fe = Expected frequency

Fr = Total row frequency

Fc = Total column frequency

N = Total frequency

The complete elements of the usual chi-square test are given below as;

$X^2 = (O-E)^2/E$

Where,

O = Observed frequency

E = Expected frequency

n = Number of categories

3.8 Analysis of regression

Actually time sequence data are not bivariate data, simple regression analysis technique was used to draw linear trend line (Udofia, 2004; Okoko, 2006). In this study, the independent variable is time in years (x) and rainfall/ temperature/ humidity/Static Groundwater Table is dependent variable (y).

The least square model is presented as;

$Y = a + bx + e$ where;

Y = Dependent variable (Static groundwater level in feet)

X = Independent variable (time in years).

A= A constant and y – intercept

b = Regression coefficient

c = Error random term

Time in years was the only considered cause of the fluctuations as the meteorological controls of the annual rainfall vary in their positions and intensities periodically.

3.9 Drought identification by using Standardized Precipitation Index (SPI)

The SPI was calculated using 3month SPI for four times for the year and 6 month SPI for two times, 9month SPI for one time and 12 month SPI for one time, The SPI was calculated using the formula which was developed by Komusco (1999). This study used following formula:

$$SPI = \frac{X - \overline{X}}{\sigma}$$

Here,

X = Actual Rainfall

$\bar{X}$= Mean Rainfall

σ= Standard Deviation

3.10 Data processing and analysis

The study was used combination of quantitative and qualitative tools to collect, organize, analyze, interpret and present findings of the study objectives. The field data were first organized and categorized for thorough analysis to eliminate any errors after data collection. This included the selection of rationalized data and collection of evidence through the validation of sources to determine accuracy and soundness of information. The data were checked for reliability and accuracy of the system. All information has been assessed to determine its usefulness in answering the research questions. The opinions and essentials gathered from the Informants are presented as well as author's own observations. Finally all of the collected data were analyzed and presented in the paper in the graph and also draw inference in each section to ease the reader perception. Data were analyzed using Statistical Package for the Social Sciences (SPSS).

3.11 Organization of the study

The study has been organized into twelve chapters. Chapter One has been provided overview of all chapters including introduction and background of the study, context and contextual situations. Subsequent, the first chapter has been explored the research idea; research objectives and research question and formulating research hypothesis. Chapter Two has been outlined the theoretical structure and conceptual framework for the study. The livelihood approach has been decribed in such a way that is holistic, sustainable and people centered. Considering the constraint of the theory, additionally two theories including symbolic interaction theory and social exchange theory has been included in this study. The chapter has been synthesized the study frame work. Chapter Three has been discussed details about the methodology including selection of study area, details description of the study area, sampling procedures, data collection systems, selection of respondents, preparation of questionnaire, data management and other methodological aspects. Chapter Four has been represented socio-economic background of the study area, details about respondent's family structures, their age, education, occupation, assets and income. Chapters Five to Twelve has been described about the findings of the study based on primary and secondary data. The information has been gathered trough the questionnaire, focus group discussion and case studies. Chapter Five has been elicited drought and climate scenario of the study areas based on secondary data over the periods of 39 years. In chapter Six, people's perception on drought including their own definition of drought, causes, symptoms, frequency and impacts of drought has been clearly mentioned. Chapter Seven has been presented status of groundwater in the study areas and depleting water with the expanded irrigated agriculture. In Chapter Eight, what are the factors influencing crop loss due to drought: prospects and challenges has been described. Chapter Nine has been explored how local people use their indigenous knowledge in drought prediction and weather extreme management. In chapter 10, how Barind people cope with the drought crisis using social safety networks has been clearly mentioned. Chapter Eleven has been discussed about the adaptation and sustainable approaches to drought management following sustainable livelihood strategies and social exchange theory. Chapter Twelve has been provided evidence case by case on how women combat drought in their real life. Chapter Thirteen has been provided details discussion on study findings and made linkage with the previous relevant field studies. Finally Chapter Fourteen has been drawn concluding remarks and future recommendation for drought management and implication of the study.

Summary and conclusion

Mixed method (quantitative and qualitative) has been applied for this study. Total 343 sample respondents (240 men and 103 women) have been selected for households' survey. Key Informant Interview, In-depth Interview with the sample respondents have been carried out to get in-depth information on drought related issues and demography of the study populations. Qualitative information has been gained through Focus Group Discussion (6 male groups and 6 female groups). Additionally six Case Studies were obtained throughout the study.

FINDINGS OF THE STUDY

The study findings is divided into nine chapters that derived from the study framework which include: Demography of study populations; Climate and drought scenario of study locations; Peoples’ perception on drought and its consequences; Declined groundwater and its impacts; Factors influencing crop loss due to drought; Indigenous knowledge used in drought & weather extreme management; Coping mechanism to drought risk mitigation; Sustainable adaptation practices to drought management and finally women as the drought resilience.

Chapter 4: Socio-economic and Demographic Information about study population

This chapter shows both quantitative and qualitative results from the Household survey, In-depth Interviews, Key Informants as well as field observations. The quantitative data analysis is mainly based on Household survey results, whilst the qualitative data analysis is based on the Focus Group Discussions, direct observations and interview results from Key Informants. The qualitative data are not presented in isolation from the quantitative data but these are combined in such a way as to triangulate, and supplement the quantitative data.

4.1 Socio-economic background of the respondents in the study area

4.1.1 Age group of the respondents

The study was conducted interviewing total 343 respondents from six Villages. Table 4.1 showed that 21.87 percent respondents (n=75) are distributed in Nizampur followed by 18.37 percent respondents (n=63) in Bhabicha, 18.08 percent respondents (n=62) in Aye-Hi, 15.16 percent respondents (n=52) in Parisho, 14.87 percent respondents (n=51) in Chokghorpakhia and 11.66 percent respondents (n=40) in Mollapara Village. The Household survey result showed that the maximum number of respondents (n=157) belong to the age category of ≥30<45, among them 33.2 percent respondents (n=114) are male and 13.7 percent respondents (n=47) are female. The second largest age category is ≥15<30 and there are 84 respondents in this category of which 15.5 percent are male (n=53) and 10.8 percent are female (n=37). Eighty respondents found in the ≥45<60 age category in which 18.1 percent respondents (n=62) are male and 4.1 percent respondents (n=14) are female. There are 19 respondents found above 60 years old. Among them 2.6 percent respondents (n=9) are male and 1.7 percent respondents (n=6) are female. On the other hand only one male respondent (0.3%) is found in <15 age category (Table 4.1).

Table 4.1: Age and sex of the respondents

Age (in years)	Sex	Study location and sex distribution (%)						Total (%)
		Rajshahi		Chapainawabganj		Naogaon		
		Parisho n=52	Aye-Hi n=62	Nizampur n=75	Chokghorpakhia n=51	Bhabicha n=63	Mollapara n=40	
<15 n=1	Male n=1	(100)						(0.3)
	Female n=0							
≥15<30 n=84	Male n=53	(9.43)	(28.30)	(9.43)	(7.55)	(22.64)	(22.64)	(15.5)
	Female n=37	(10.81)	(16.22)	(16.22)	(10.81)	(27.03)	(18.92)	(10.8)
≥30<45 n=157	Male n=114	(16.67)	(16.67)	(24.56)	(14.91)	(17.54)	(9.65)	(33.2)
	Female n=47	(21.28)	(21.28)	(17.02)	(17.02)	(12.77)	(10.64)	(13.7)
≥45<60 n=80	Male n=62	(12.90)	(12.90)	(27.42)	(22.58)	(17.74)	(6.45)	(18.1)
	Female n=14	(14.29)	(21.43)	(42.86)	(14.29)	(7.14)		(4.1)
≥60 n=19	Male n=9	(33.33)	(11.11)	(22.22)	(11.11)	(11.11)	(11.11)	(2.6)
	Female n=6			(50)	(16.67)	(33.33)		(1.7)
Total N=343		(15.16)	(18.08)	(21.87)	(14.87)	(18.37)	(11.66)	(100)

N= Total Number, n=number, Figure in parenthesis indicates percent value, Source, Field data 2015

4.1.2 Family size of the respondents

This part reflects the information related to the distribution of household members. Table 4.2a shows that the total family member are 1396 of which majority of them are male (53.9%) and the rest (46.1%) is female. Among the family, it was found that 34.5 percent members are belong to the age category of 15 to 30 years in which 17.3 percent are male and 17.2 percent are female. The second highest family members are belong to the age category of 30 to 45 (26.7%) in which 13.9 percent are male and 12.8 percent are female. Only 22.6 percent respondents are less than 15 years of which 12.8 percent are male and 9.8 percent are female. Very small number of respondents (4%) is found above 60 years old.

Table 4.2a: Status of household members based on age and biological identity

Age (in years)	Male (%)	Female (%)	Total (%)
<15	(12.8)	(9.8)	(22.6)
≥15<30	(17.3)	(17.2)	(34.5)
≥30<45	(13.9)	(12.8)	(26.7)
≥45<60	(7.5)	(4.7)	(12.2)
≥60	(2.4)	(1.6)	(4)
Sub Total	753 (53.9)	643 (46.1)	1396 (100)

Figure in parenthesis indicates percent value
Source, Field data 2015

Table 4.2b represents the average family member of Aye-Hi Village is 4.48 with the minimum numbers of 2 and maximum numbers 10 per household followed by Nizampur (4.35), Parisho (4.21), Chokghorpakhia (3.92), Mollapara (3.79) and Bhabicha (3.57). The minimum family members are 2 in all the villages and the maximum family members are found in Parisho (10) followed by Nizampur and Mollapar (9).

Table 4.2b: Status of household members

Numbers	Study location and household members distribution					
	Rajshahi		Chapainawabganj		Naogaon	
	Parisho	Aye-Hi	Nizampur	Chokghorpakhia	Bhabicha	Mollapara
Mean	4.21	4.48	4.35	3.92	3.57	3.79
Minimum	2	2	2	2	2	2
Maximum	10	7	9	7	6	9

Source, Field data 2015

4.1.3 Occupation of the respondents

58.3 percent respondents mentioned that agriculture is their primary occupation followed by housewife (14.9%), business (10.5%), day labour (9.3%), van/ rickshaw pulling (1.7%), small trading (1.5%) and teaching (1.2%) respectively (Table 4.3). On the other hand, total 28.9% (n=99) are also found to be involved in secondary occupation including agriculture (8.5%), business (7.9%), day labour (3.8%), small trading (3.5%), house wife (2.9%) etc. Among the Villages, it was found that 75 percent respondents of Mollapara engaged in agriculture as a primary occupation followed by Aye-Hi (61.3%), Bhabicha (58.7%) and Nizampur (57.3%). In Chokghorpakhia, 31.4 percent respondents are engaged in business as a primary occupation followed by Nizampur (9.3%). 30.8 percent respondents in Parisho said that their primary occupation is housewife followed by Aye-Hi (25.8%). Furthermore, 6.3 percent respondents of Bhabicha also engaged in teaching as their primary occupation. On the other hand 40 percent respondents of Mollapara village engaged in secondary occupation followed by Nizampur (34.7%), Chokghorpakhia (31.4%), Bhabicha (23.8%), Parisho (23.1%) and Aye-Hi (22.6%) Village.

Table 4.3: Occupations of the respondents (primary and secondary)

Occupation		Rajshahi		Chapainawabganj		Naogaon		Total (%)
		Parisho n=52	Aye-Hi n=62	Nizampur n=75	Chokghor Pakhia n=51	Bhabicha n=63	Mollapara n=40	
Primary occupation	Agriculture	(55.8)	(61.3)	(57.3)	(45.1)	(58.7)	(75)	(58.3)
	Business	(1.9)	(3.2)	(9.3)	(31.4)	(6.3)	(15)	(10.5)
	Small trade		(1.6)	(2.7)	(2)		(2.5)	(1.5)
	Labour	(9.6)	(4.8)	(13.3)	(7.8)	(12.7)	(5)	(9.3)
	Van/R puller		(1.6)	(4)		(3.2)		(1.7)
	Driver(A/N)	(1.9)			(2)			(0.6)
	House wife	(30.8)	(25.8)	(13.3)	(7.8)	(6.3)	(2.5)	(14.9)
	Fishing	-	(1.6)	-	-	-	-	(0.3)
	Student	-	-	-	(2)	-	-	(0.3)
	Migrant	-	-	-	-	(4.8)	-	(0.9)
	Milkman	-	-	-	-	(1.6)	-	(0.3)
	Doctor	-	-	-	(2)	-	-	(0.3)
	Teacher	-	-	-	-	(6.3)	-	(1.2)
	Sub-Total	(100)	(100)	(100)	(100)	(100)	(100)	(100)
Secondary occupation	Agriculture	(5.8)	(3.2)	(5.3)	(11.8)	(9.5)	(20)	(8.5)
	Business	(7.7)	(9.7)	(5.3)	(7.8)	(6.3)	(12.5)	(7.9)
	Small trade	(3.8)	(6.5)	(4)	(2)	-	(5)	(3.5)
	Labour	(5.8)	-	(12)	-	-	(2.5)	(3.8)
	Van/ rickshaw pul	-	-	(4)	-	-	-	(0.9)
	Driver(A/N)	-	-	-	(2)	-	-	(0.3)
	Mechanics	-	-	-	-	(1.6)	-	(0.3)
	House wife	-	(3.2)	(2.7)	(7.8)	(3.2)	-	(2.9)
	Fishing	-	-	(1.3)	-	-	-	(0.3)
	Student	-	-	-	-	(3.2)	-	(0.6)
	Sub-Total	(23.1)	(22.6)	(34.7)	(31.4)	(23.8)	(40)	(28.9)

Source, Field data 2015, Figure in parenthesis indicates percent value

4.1.4 Marital status of the respondents

This part depicts the information about the marital status of the respondents of the study area. According to the table 1.4 the highest (46.9%) married personnel found between age group

≥30<45 followed by ≥15<30, ≥45<60, ≥60 and less than 15 years respectively. More than ninety percent respondents are married and 5.54 percent is unmarried. Only 0.87 percent is widow (Table 4.4).

Table 4.4: Marital status of the respondents

Age (in years)	Sex	Marital status of the respondents (%)			Total
		Unmarried	Married	Widow	
<15	Male (n=1)	0	(100)	0	(0.3)
	Female (n=0)	0	0	0	
≥15<30	Male (n=53)	(16.98)	(77.36)	(5.66)	(26.2)
	Female (n=37)	(16.22)	(83.78)	0	
≥30<45	Male (n=114)	(1.75)	(98.25)	0	(46.9)
	Female (n=47)	0	(100)	0	
≥45<60	Male (n=62)	(3.23)	(96.77)	0	(22.2)
	Female (n=14)	0	(100)	0	
≥60	Male (n=9)	0	(100)	0	(4.4)
All N=343		(5.54)	(93.59)	(0.87)	(100)

Source, Field data 2015, Figure in parenthesis indicates percent value, n=number

4.1.5 Education of the respondents

Among the study population only 13.70 percent people are illiterate. Majority people have had their primary education followed by junior schooling, secondary, higher secondary and university level education respectively (Table 4.5). The higher percent of university education found among female respondents of the age group 45 years to less than 60 years. Only one respondent was interviewed under 15 years. The higher percentage of illiterate person was found from female respondents having age over 60 years.

Table 4.5: Educational status of the respondents

Age (in years)	Sex	Educational status (%)						
		Literate					Illiterate	Total
		Primary	High school	SSC	HSC	Graduate		N=343
<15	Male (n= 1)	(100)						(0.3)
	Female (n= 0)							
≥15<30	Male (n= 53)	(39.6)	(22.6)	(7.5)	(3.8)	(1.9)	(24.5)	(15.45)
	Female (n=37)	(43.2)	(32.4)	(8.1)	(5.4)		(10.8)	(10.79)
≥30<45	Male (n=114)	(46.5)	(19.3)	(12.3)	(7)	(1.7)	(13.2)	(33.24)
	Female (n=47)	(44.7)	(19.1)	(19.1)	(4.2)	(2.1)	(10.6)	(13.70)
≥45<60	Male (n= 62)	(37.1)	(35.5)	(11.3)	(3.2)	(3.2)	(9.7)	(18.08)
	Female (n=14)	(42.8)	(14.3)	(7.1)	(21.4)	(14.3)		(4.08)
≥60	Male (n= 9)	(33.3)	(44.4)		(11.1)		(11.1)	(2.62)
	Female (n= 6)	(16.7)	(16.7)	(16.7)			(50)	(1.75)
Total		(42.27)	(24.48)	(11.37)	(5.83)	(2.33)	(13.70)	(100)

Source, Field data 2015, Figure in parenthesis indicates percent value, n=number, N=Total

4.1.6 Households' mean income

The highest mean monthly income was recorded from Nizampur followed by Mollapara, chokghorpakhia, Aye-Hi, Parisho and Bhbicha Village (Table 4.6a). The respondents from Nizampur were mentioned that their monthly average income BDT 12097.30 with the range of (BDT 3000.00 to BDT 65,000.00). The lowest monthly average income was recorded from Bhabicha Village with BDT 6031.75 (minimum BDT 1000 to BD 20,000). Among the female respondents, the highest monthly average income (BDT 13533.33) was recorded with the minimum BDT 4000 and maximum BDT 40,000 from Mollapara village. The lowest monthly average income (BDT 4263.16) was recorded from Bhabicha Village among the female respondents. On the other hand, the highest monthly average income (BDT 12817.65) was recorded from Nizampur village among the male respondents. Like female respondents, the male respondents from Bhabicha village were recorded the lowest monthly average income (BDT 6795.45).

Table 4.6a: Average income of the respondents

Village:		Income (BDT)	Male income (BDT)	Female income (BDT)
Parisho	Mean	8817.31	9125.00	8125.00
	Minimum	4000.00	4000.00	5000.00
	Maximum	30000.00	30000.00	30000.00
Aye-Hi	Mean	9411.29	10639.53	6631.58
	Minimum	3000.00	3000.00	3000.00
	Maximum	65000.00	65000.00	15000.00
Nizampur	Mean	12097.30	12817.65	10500.00
	Minimum	1200.00	1200.00	4000.00
	Maximum	33000.00	33000.00	20000.00
Chokghorpakhia	Mean	10431.37	9138.89	13533.33
	Minimum	5000.00	5000.00	6000.00
	Maximum	28000.00	20000.00	28000.00
Bhabicha	Mean	6031.75	6795.45	4263.16
	Minimum	1000.00	2000.00	1000.00
	Maximum	20000.00	20000.00	15000.00
Mollapara	Mean	11450.00	10642.86	13333.33
	Minimum	3000.00	3000.00	4000.00
	Maximum	40000.00	30000.00	40000.00

Source, Field data 2015

4.1.7 Households' expenditure

The highest mean monthly expenditure (BDT 10865.38) was recorded in Chokghorpakhia followed by Nizampur, Mollapara, Aye-Hi, Parisho and Bhabicha (Table 4.6b) respectively.

Table 4.6b: Households' expenditure of the respondents (BDT)

Village:		Household	Education	Other	Total
Parisho	Mean	3824.53	2636.36	1717.95	6349.06
	Minimum	200.00	500.00	100.00	2500.00
	Maximum	25000.00	15000.00	21000.00	22000.00
Aye-Hi	Mean	4950.00	1871.43	2555.56	6669.36
	Minimum	400.00	100.00	500.00	3000.00
	Maximum	15000.00	6000.00	10000.00	18000.00
Nizampur	Mean	6135.14	2612.07	1549.02	10035.71
	Minimum	1000.00	500.00	500.00	4000.00
	Maximum	15000.00	10000.00	10000.00	21000.00
Chokghorpakhia	Mean	8846.15	2264.71		10865.38
	Minimum	2500.00	1000.00		5000.00
	Maximum	90000.00	6000.00		75000.00
Bhabicha	Mean	4023.44	1716.67	1666.67	5048.39
	Minimum	1000.00	500.00	1000.00	1000.00
	Maximum	20000.00	10000.00	4000.00	20000.00
Mollapara	Mean	4779.49	2662.07	1673.68	8466.67
	Minimum	1000.00	200.00	300.00	1500.00
	Maximum	15000.00	6000.00	8000.00	27000.00

Source, Field data 2015

The respondents reported different heads of expenditure including household expenditure, educational expenditure and others. The highest mean household expenditure (BDT 8846.15) was reported from Chokghorpakhia followed by Nizampur, Aye-Hi, Mollapara, Parisho and Bhabicha. In case of educational expenditure, the highest mean monthly expenditure (BDT 2662.07) was recorded from Mollapara followed by the lowest mean monthly educational expenditure (BDT 1716.00). The highest mean monthly other expenditure (BDT 2555.16) was reported from Aye-Hi Village.

4.1.8 Land ownership and holdings

Respondents provide information related to the land ownership and types. Table 4.7a shows that 100 percent respondents of Parisho, Aye-Hi, Chokghorpakhia and Mollapara Village have own land property followed by Bhabicha (98.41%) and Nizampur (96%) respectively. It was found that 59.68 percent respondents of the Aye-Hi village have leased property followed by Nizampur (54.67%), Mollapara (35%), Parisho (5.77%) and Bhabicha (4.76%).

Table 4.7a: Land ownership

Owner of land	Rajshahi (%)		Chapainawabganj (%)		Naogaon (%)	
	Parisho	Aye-Hi	Nizampur	Chokghorpakhia	Bhabicha	Mollapara
Own property	(100)	(100)	(96)	(100)	(98.41)	(100)
Leased property	(5.77)	(59.68)	(54.67)	(1.96)	(4.76)	(35)
Mortgaged in property	(15.38)	0	(2.67)	0	(1.59)	(17.5)
Mortgaged out property	(3.85)	0	0	0	0	(2.5)

Source, Field data 2015, Figure in parenthesis indicates percent value

Beside these, 17.5 percent respondents of Mollapara village have mortgaged in property followed by Parisho (15.38%). 3.85 percent respondents of Parisho has mortgaged out property followed by Mollapara (2.5%). Table 4.7b showed that average 118.63 decimals own land area is operated by each family of Parisho village followed by Bhabicha (112.98 decimals), Mollapara (108.28 decimals) and Nizampur (71.48 decimals). The respondents of Nizampur operate the highest (124.72 decimals) lease land compared to Mollapara (108.21 decimals), Aye-Hi (76.49 decimals), and Parisho (44 decimals).

Table 4.7b: Land holdings in decimal

Village:		Own	Lease	Mortgage in	Mortgage out
Parisho	Mean	118.63	44	37.88	26.50
	Minimum	1.50	33	6	20
	Maximum	830	66	66	33
Aye-Hi	Mean	72.88	76.49	0	0
	Minimum	2	10	0	0
	Maximum	1099	264	0	0
Nizampur	Mean	71.48	124.72	111.50	0
	Minimum	3	5	66	0
	Maximum	825	990	157	0
Chokghorpakhia	Mean	73.73	66	0	0
	Minimum	4	66	0	0
	Maximum	350	66	0	0
Bhabicha	Mean	112.98	50.33	33	0
	Minimum	3	33	33	0
	Maximum	668	85	33	0
Mollapara	Mean	108.28	108.21	63.86	66
	Minimum	3	17	15	66
	Maximum	472	330	120	66

Source, Field data 2015

Respondents of Nazimpur Village owned the highest average of mortgage in land (111.50 decimals) followed by Mollapara (63.86 decimals) while the respondents of Mollapara Village operate the highest average of mortgage out land (66 decimals) followed by Parisho (26.50

decimals). It was found that the maximum own land area operated by each family in Parisho (830 decimals) followed by Nizampur (825 decimals) and the minimum land area owned by each family in Aye-Hi (2 decimals) followed by Bhabicha and Mollapara (3 decimals). The highest mortgage in land area was found in Nizampur (157 decimals) followed by Mollapara (120 decimals) while it was minimum in Aye-Hi and Chokghorpakhia (no mortgage out land). The maximum mortgage out land were found in Mollapara (66 decimals) followed by Parisho (33 decimals) while Aye-Hi, Nizampur, Chokghorpakhia and Bhabicha village it was not identified.

4.2 Description of assets

4.2.1 Livestock

Livestock rearing is an important income generating activity of the respondent's family. They usually do it for cash income as well as for their own consumption. Table 4.8 represents that 83.97 percent respondent households were found to rear cow of which it was the highest in the Aye-Hi Village (29.1%) and lowest in Chokghorpakhia (24%) followed by hen (72.60%) of which highest in Mollapara (29.5%) and lowest in Parisho (19.5%), goat (65.60%) of which highest in Chokghorpakhia (29.6%) and lowest in Mollapara (15.5%), duck (59.18%) of which highest in Parisho (27%) and lowest in Chokhgorpakhia (5.6%), pigeon (12.83%) of which highest in Chokghorpakhia (11.2%) and lowest in Nizampur (1.9%). It was found that on an average 18 numbers of pigeons are found in Mollapara followed by Aye-Hi (17) of which the maximum number were found in Nizampur (200) and the minimum number were found in Chokghorpakhia and Bhabicha (2). On an average 13 hens were recorded in Mollapara followed by Parisho (12) with the maximum numbers in Mollapara (40) and minimum in Parisho, Aye-Hi and Chokghorpakhia (1).

Table 4.8: Ownership of livestock

Name of livestock	Rajshahi (%)		Chapainawabganj (%)		Naogaon (%)		Total (%)
	Parisho n=52	Aye-Hi n=62	Nizampur n=75	Chokghorpakhia n=63	Bhabicha n=51	Mollapara n=40	
Cow	(88.5)	(85.5)	(92)	(47.62)	(100)	(82.5)	(82.21)
Buffalo		(6.5)	(8)				(2.92)
Goat	(71.1)	(46.8)	(84)	(58.7)	(76.5)	(50)	(65.60)
Sheep	(9.6)	(3.8)	(2.7)	(1.6)		(10)	(4.08)
Duck	(90.4)	(64.5)	(76)	(11.1)	(47)	(70)	(59.18)
Hen	(65.4)	(72.6)	(89.3)	(57.1)	(56.9)	(95)	(72.60)
Pigeon	(9.6)	(14.5)	(6.7)	(22.2)	(9.8)	(15)	(12.83)

Source, Field data 2015, Figure in parenthesis indicates percent value

The respondents from Mollapara village had on an average 3 cows followed by Chokghorpakhia (2) of which the highest number of were found in Mollapara (10) while the lowest in Parisho (1).

4.2.2 Other moveable properties

All respondents have more or less moveable properties (Table 4.9). 58.31 percent respondents had (n=200) TV in their own followed by motorcycle (13.99%), sewing machine (10.2%), shallow (9.62%) and power lifter (6.41%). Among the Villages, it was found that 81.33percent respondents of Nazimpur had own television followed by shallow (9.33%). In Parisho 78.85

percent respondents had television followed by shallow (28.85%). On the other hand in Chokghorpakhia Village, only 25.49 percent respondents had television followed by motorcycle (11.76%).

Table 4.9: Other moveable properties

Properties	Rajshahi		Chapainawabganj		Naogaon		Total (%)
	Parisho n=52	Aye-Hi n=62	Nizampur n=75	Chokghorpakhia n=63	Bhabicha n=51	Mollapara n=40	
Shallow	(28.85)	(4.84)	(9.33)	(1.96)	(7.94)	(5)	(9.62)
Power tiller	(3.85)	(1.61)	(6.67)	0	(4.76)	(27.5)	(6.41)
Motor cycle	(17.31)	(11.29)	(9.33)	(11.76)	(15.87)	(22.5)	(13.99)
Television	(78.85)	(48.39)	(81.33)	(25.49)	(46.03)	(65)	(58.31)
Sewing machine	(7.69)	(17.74)	(8)	(5.88)	(3.17)	(22.5)	(10.2)

Source, Field data 2015, Figure in parenthesis indicates percent value, n=number

4.3 Housing pattern of the respondents

Respondent's residence status was considered in terms of construction materials. The result showed that around 72 percent respondnts' houses were built with clay walls and a tin roof in the study locations followed by 18.08 percent houses made of semi concrete (tin roof), 7 percent houses made of concrete, 1.46 percent houses made of thatched wall with a *tin* roof and another 1.17 percent houses were made of cottage materials. Among the Villages, 90.3 percent houses of Aye-Hi Village was built clay wall and a *tin* roof, followed by concrete, thatched wall with a *tin* roof and cottage (each of 2%). On the other hand, in Chokghorpakhia Village 78.4 percent houses were built with semi concrete (*tin* roof) followed by concrete (19.6%) and clay wall with a *tin* roof (2%) respectively (Table 4.10).

Table 4.10: Type of residence

Residence type	Rajshahi		Chapainawabganj		Naogaon		Total (%)
	Parisho n=52	Aye-Hi n=62	Nizampur n=75	Chokghorpakhia n=63	Bhabicha n=51	Mollapara n=40	
Concrete	0	(3.2)	(10.7)	(19.6)	(3.2)	(5)	(7)
Semi concrete (*tin* roof)	(17.3)	0	(5.3)	(78.4)	(11.1)	(5)	(18.08)
Clay wall with a*tin* roof	(80.8)	(90.3)	(78.7)	(2)	(84.1)	(90)	(72.01)
Thatched wall with a *tin* roof	0	(3.2)	(4)	0	0	0	(1.46)
Cottage	(1.9)	(3.2)	0	0	(1.6)	0	(1.17)

Source, Field data 2015, Figure in parenthesis indicates percent value, n=number

4.4 Agricultural activities performed by household members

Several agricultural activities performed by the household members' such as planting, weeding, irrigation or watering, compost preparation, mulching, crops harvesting, per-boiling, cultivation of vegetables, homestead gardening, fishing and fish farming, keeping cows and goats and raising of poultry. Most of the men (90.36%) performed rice transplanting followed by mulching, homestead gardening, watering, weeding, planting, harvesting, threshing, composting, fishing and fish farming, cultivation of vegetables, keeping cows and goats, raising poultry and per-boiling (Table 4.11) respectively. Most of the women (90.10%) performed per-boiling followed by raising of poultry, keeping cows and goats, vegetables cultivation and composting.

Table 4.11: Agricultural activities performed by household members

Agricultural activity	Women	Men	Son	Daughter	Total (N=1396)
Planting crops/seeds	(1.75)	(86.63)	(9.62)		(24.57)
Weeding	(2.96)	(86.98)	(10.06)		(24.21)
Irrigation	(1.20)	(84.94)	(13.55)	(0.30)	(23.78)
Composting	(17.92)	(74.52)	(7.55)		(22.78)
Transplanting	(0.36)	(90.36)	(9.28)		(20.05)
Mulching	(2.47)	(87.04)	(10.49)		(11.60)
Harvesting	(6.10)	(83.73)	(10.17)		(21.13)
Per-boiling	(90.10)	(6.14)	(0.68)	(3.07)	(20.98)
Threshing	(7.14)	(82.33)	(10.53)		(19.05)
Cultivation of vegetables	(31.55)	(59.11)	(8)	(1.33)	(16.11)
Homestead gardening	(4.08)	(88.78)	(6.12)	(1.02)	(7.02)
Fish farming/fishing	(7.84)	(74.51)	(13.72)	(3.92)	(3.65)
Keeping cows and goats	(58.53)	(34.36)	(5.21)	(1.89)	(30.30)
Raising Poultry	(85.55)	(10.40)	(0.29)	(3.76)	(24.78)

Source, Field data 2015 (Multiple response), Figure in parenthesis indicates percent value

4.5 Non-agricultural activities performed by household members

Non agricultural activities like cooking, cleaning, clothing, handicrafts production, sewing, house repairing and marketing are the most common. All these activities except marketing were performed by the women (Table 4.12). These activities are dominated by women. There is little contribution of men in non agricultural household activities in the study locations.

Table 4.12: Non- agricultural activities performed by household members

Household activity	Women (%)	Men (%)	Son (%)	Daughter (%)	Total (%) N=1396
Cooking	(93.96)	(0.27)	(0.55)	(5.22)	(26.07)
Cleaning	(93.09)	(1.66)	(0.55)	(4.70)	(25.93)
Clothing	(94.40)	(1.12)	(0.56)	(3.92)	(25.57)
Handicrafts production	(55.55)	(22.22)		(22.22)	(0.64)
Sewing	(74.30)	(17.14)	(2.86)	(5.71)	(2.51)
House repair	(16.58)	(77.72)	(5.16)	(0.54)	(26.36)
Marketing	(7.12)	(82.99)	(9.64)	(0.25)	(28.22)

Source, Field data 2015 (Multiple response), Figure in parenthesis indicates percent value

4.6 Drinking water related information

Several sources were reported by the respondents during interview and focus group discussion. Both sources (Surface and underground water) are used by the respondents. The water source includes Deep Tubewell, Tubewell, Pipeline, Dug well, River and ponds were mentioned by the respondents.

4.6.1 Sources of drinking water

The respondents were asked to know about their drinking water sources. Most of the respondents (57.43%) mentioned that tube well is the main source for drinking water. The second source of drinking water is deep tube well (31.78 %).

Table 4.13a: Sources of drinking water

Sources	Rajshahi (%)		Chapainawabganj (%)		Naogaon (%)		Total (%)
	Parisho	Aye-Hi	Nizampur	Chokghorpakhia	Bhabicha	Mollapara	
Own source	Yes (52)	Yes (26)	Yes (79)	Yes (100)	Yes (40)	Yes (75)	Yes (60.64)
Deep Tube well	(7.7)		(96.2)	(100)	(3.1)	(3.2)	(31.78)
Tube well	(90.4)	(96.7)	(3.8)		(85.9)	(54)	(57.43)
Tap water/pipeline	(1.9)	(1.6)			(10.9)	(28.6)	(7.87)
Dug well		(1.6)					(0.29)
River/pond						(14.3)	(2.62)

Source, Field data 2015, Figure in parenthesis indicates percent value

7.87 percent respondents mentioned that tap water/pipeline is another source of drinking water and 2.62 percent respondents reported that they used river/pond water for drinking (Table 4.13a). Among the villages, it was seen that there was no tube well in the village of Chokghorpakhia. All the respondents of this village were dependent on deep tube well followed by Nizampur (96.2%). On the other hand, 96.7 percent respondents from Aye-Hi village said that tube well is the main source of their drinking water followed by Parisho (90.4%) and Bhabicha (85.9%) respectively. In Mollapar village, 14.3 percent respondents mentioned that theyused river and pond water for drinking. 60.64 percent respondents of the study locations had own source of drinking water and 39.36 percent respondents had no own source of drinking water. They c reliant on others completetly for drinking water such as neighbor's tubewell, nearest Deep tubewell, dug well and other sources (Table 4.13a). Among households, women and girls are responsible for water collection (details have been discussed in Chapter Thirteen). Boys and men have little contribution in water collection as mentioned by FGD participants. Among the Villages, all the respondents of Chokghorpakhia village have their own sources of drinking water followed by Nizampur (79%), Mollapara (75%), Parisho (52%), Bhabicha (40%) and Aye-Hi (26%).74 percent respondents of the Aye-Hi village have no own source of drinking water followed by Bhabicha (60%), Parisho (48%), Mollapara (25%) and Nizampur (21%).

3.6.2 Time required to collect drinking water

The respondents were also asked to know about the time required in collecting drinking water. 38.78 percent respondents (n=133) from the study locations reported that they need nearly 30 minutes in drinking water collection. 74.19.59 respondents from Aye-Hi Village, 60.32 percent from Babicha, 48.08 percent from Parisho and 20 percent fromMollapara mentioned that they need less than 30 minutes in drinking water collection. On the other hand, 61.22 percent respondents (n=210) said that they need around 30-60 minutes to fetch drinking water from faraway and crowded situation (4.13b).

Table 4.13b: Drinking water collection time (%)

Time (in minute)	Rajshahi (%)		Chapainawabganj (%)		Naogaon (%)		Total (%)
	Parisho	Aye-Hi	Nizampur	Chokghorpakhia	Bhabicha	Mollapara	
Less than 30 minutes	(48.08)	(74.19)	(21.33)		(60.32)	(20)	(38.78)
30-60 minutes	(51.92)	(25.80)	(78.67)	(100)	(39.68)	(80)	(61.22)

Source, Field data 2015, Figure in parenthesis indicates percent value

3.6.3 Distance of drinking water source from homestead

It was mentioned by the respondents that they collect drinking water from different sources and faraway from their home. Women and girls usually collect water from distant places. About 29.45 percent respondents (n=101) from the study areas reported that the sources of drinking water is very close (100 meter away) to their home (Table 4.13c).

Table 4.13c: Distance of water sources

Distance (in meter)	Rajshahi (%)		Chapainawabganj (%)		Naogaon (%)		Total (%)
	Parisho	Aye-Hi	Nizampur	Chokghorpakhia	Bhabicha	Mollapara	
Less than 100	(15.4)	(48.4)	(16)	(9.8)	(39.7)	(52.5)	(29.45)
100-500	(46.2)	(22.6)	(8)	(13.7)	(22.2)	(2.5)	(19.24)
More than 500	(38.5)	(29)	(76)	(76.5)	(38.1)	(45)	(51.31)

Source, Field data 2015, Figure in parenthesis indicates percent value

Another 19.24 percent respondents (n=66) told that drinking water sources arearound 100 meters to 500 meters away from their home. Among the villages, 52.5percent respondents (n=21) from Mollapara village said that drinking water source is near (100 meters away) to their homes followed by Aye-Hi (48.4%). In Parisho, 46.2 percent respondents (n=24) reported that the sources of drinking water is away (100-500 meters) from their houses followed by Aye-Hi (22.6%). On the other hand, 51.31 percent respondents (n=176) said that the drinking water source is more than 500 meters away from their home.

Summary and conclusion

Maximum number of respondents under the age groups ≥30<45 years with the primary occupation agriculture (58%, n=200), primary education (42%, n=145). Most of the respondents having clay wall with tin roof houses (72%, n=247), chicken (73%, n=249), own drinking water source (61%, n=208) and the source is tube well (57%, n=197). Diverse occupation (both primary and secondary) was observed in the study areas. Several life stock resources and other moveable resources were owned by the respondents. All the respondents have had several capitals including human, economic, physical, natural and social capitals.

Chapter 5: Climate and Drought scenario in the Barind Tracts

5.1 Climate

The study area has three seasons including *rabi* (from November through February), *kharif-1 (*from March through May) and kharif-*2* (from June through October). Generally, temperatures are the highest in April and May, decline to some extent during the monsoon and increase in September or October when the rain begins to diminish. Mean daily minimum and maximum temperatures, recorded over the period of 1976-2014, ranged from 34-38°C and 10-15 °C, respectively. Rains begin in March-April and end in October, averaging 1,144.8 mm per year in study areas. Southwest monsoon influences the climate during June to October, and during the winter the climate is controlled by the northeast monsoon from November to March. The mean annual humidity in 2014 was 78.2% with a maximum humidity 100% and minimum 15% in January. Rainfall, temperature, humidity and other parameters are very much associated with drought. Chapter 5 explores the drought & climate scenario and its perspectives by analyzing climatic data like precipitation, temperature and humidity.

5.2 Drought Perspectives

Several weather parameters are interlinked with drought and climate scenario. These parameters such as rainfall, temperature, humidity and soil moisture are interlinked to explain drought scenario. This section represents results of the following sections by using long term rainfall, temperature and humidity data set for the period of 1976-2014. The relevant data were collected from secondary sources including Bangladesh Meteorological Department (BMD), Bangladesh Water Development Board (BWDB) and Barind Multipurpose Development Authority (BMDA). The data have been analyzed using different formulae to elicit drought and climate scenario in the study areas. The previous section (Chapter Four) is also contribute in this section (Chapter Five) for the understanding of the study locations by providing climatic data and water use pattern in the study locations.

5.3 Drought identification by using Standardized Precipitation Index (SPI)

Different types of drought have been identified in the study areas using 3months, 6 months, 9months and 12 months SPI. It has been found that different types of drought occurred in the study locations. The results (local drought) varied from locations and time. The results have been discussed in the following subsections.

5.3.1 Drought Identification by using twelve months SPI

After analyzing 39 years (1976-2014) data, results revealed that several types of drought occurred over fifty percent years of study periods at different scale and magnitude. Results have been drawn using 12 months SPI from January to December. Frequent drought occurred in Tanore and Shibganj, followed by Nachole, Porsha, Niamatpur and Godagari. Different droughts including extreme, severe, moderate and mild droughts have been occurred in different locations in rlations to time (figures 5.1, 5.2, 5.3, 5.4, 5.5, & 5. 6). Different magnitudes of drought were observed including frequencies, time scale percentage and pattern of drought. The scale of drought has been determined by SPI value. Extreme drought (SPI value ranges from -2 and less), severe drought (-1.5 to -1.99), moderate drought (-1 to -1.49) and mild dryness (0 to -.99) scales were utilized in this study. These scale also varied from country to country and location to location. The Barind Tract is very much prone to drought over the periods causing huge loss the crops and assets.

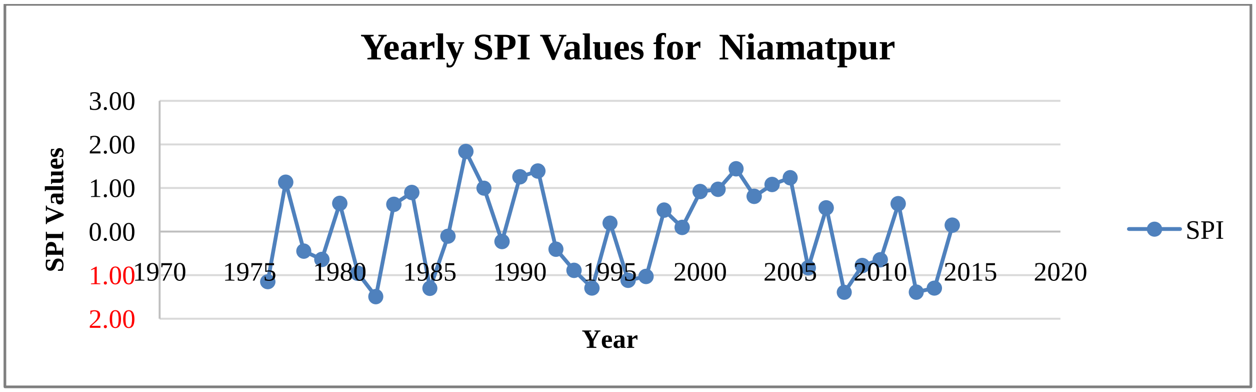


Figure 5.1: SPI values for Niamatpur using twelve months

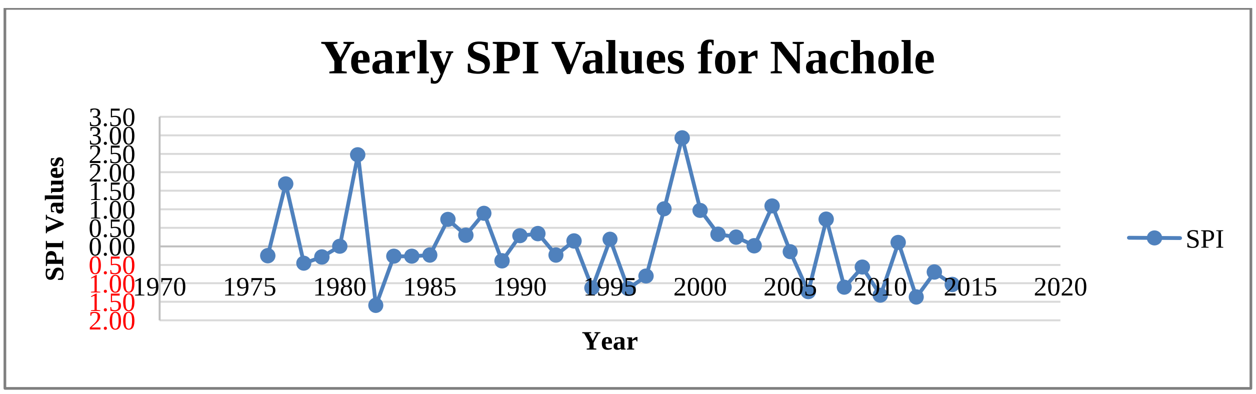


Figure 5.2: SPI values for Nachole using twelve months

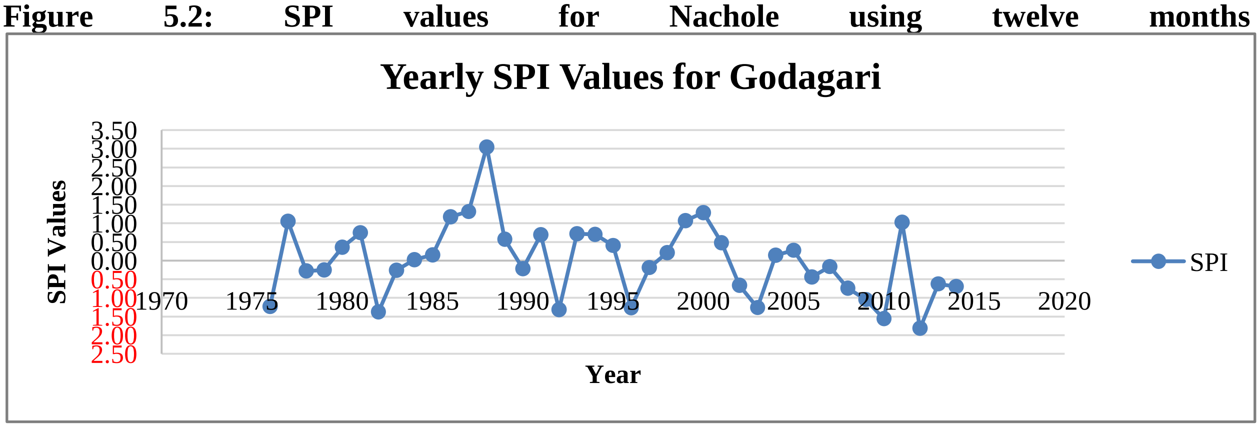


Figure 5.3: SPI values for Godagari using twelve months

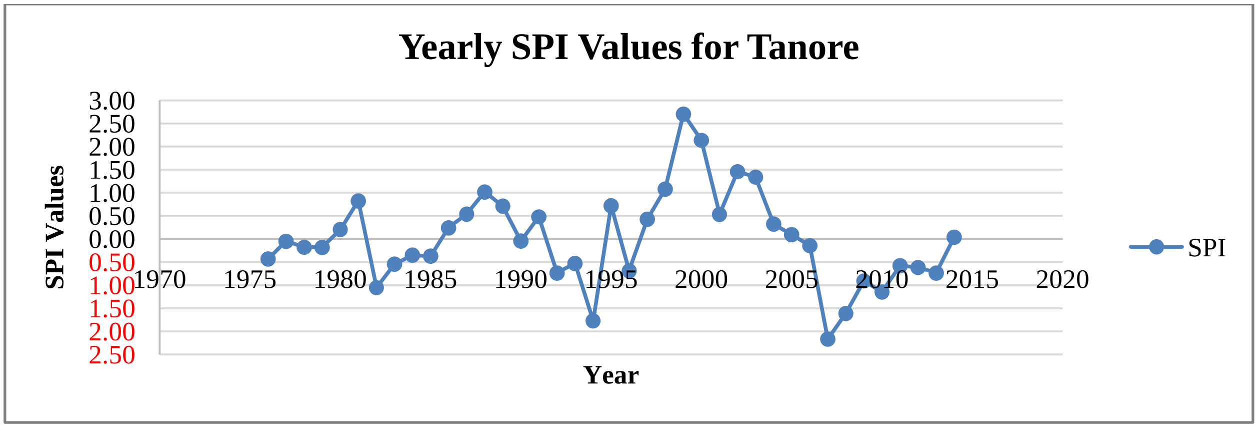


Figure 5.4: SPI values for Tanore using twelve months

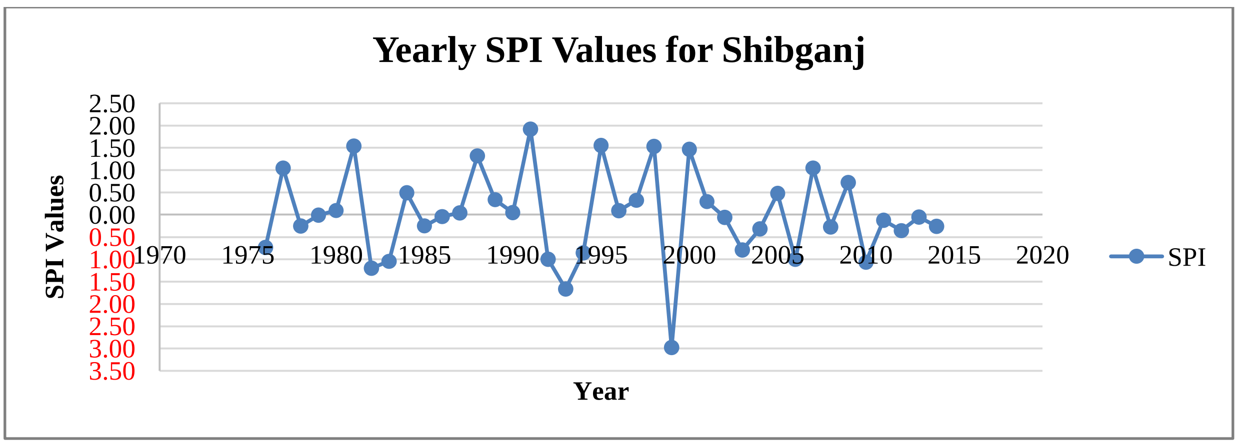


Figure 5.5: SPI values for Shibganj using twelve months

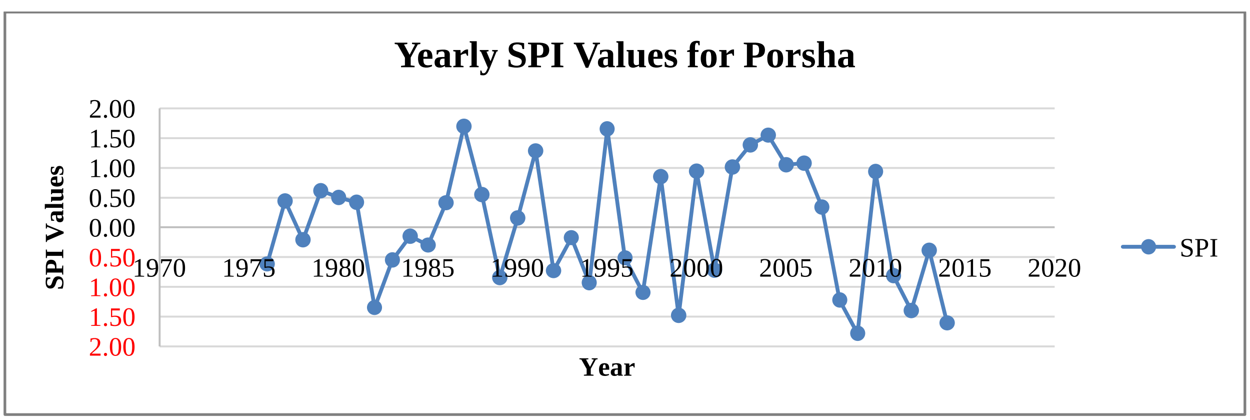


Figure 5.6: SPI values for Porsha using twelve months

5.3.2 Drought scale and frequency in the study area

5.3.2.1 Drought scale and frequencies using twelve months SPI

Analyzing long term rainfall data of 39 years for the period of 1976 to 2014, the results showed that 21 droughts occurred in Tanore and Shibganj, followed by Nachole and Porsha (20 times) and 19 times in Niamatpur and Godagari (Table 5.1) using 12 months SPI from January to December. Severe drought occurred in the year 2009 and 2014 in Porsha Upazila. Shibganj reported severe drought in the year 1993 and extreme drought in 1999. It was observed that severe drought occurred in Tanore in the year of 1994 and 2008. One extreme drought occurred in 2007 at Tanore during the period of 1976-2014. In Godagari Upazila, two severe droughts were recorded in the year of 2010 and 2012. Only one severe drought occurred in Nachole Upazila and Niamatpur Upazila in 1982. The mild dryness was the regular phenomenon in every location of the study areas. Tanore and Shibganj Upazila represented highest frequency of mild dryness followed by Nachole, Porsha, Godagari and Niamatpur Upazila. On the other hand, Niamatpur Upazila experienced 9 moderate dryness followed by Nachole, Godagari, Porsha, Shibganj and Tanore Upazila. Two severe droughts were reported in Porsha, Tanore and Godagari Upazila during the period of 1976 to 2014. Only one extreme drought has been identified in Tanore and Shibganj Upazila (Table 5. 1).

5.3.2.2 Drought scale and frequencies using nine months SPI

The nine months analyses showed local drought situation in this study. The rainfall data were used from January to December over the period of 1976 to 2014. The highest drought frequencies have been identified in Tanore Upazila (25 times) followed by Godagari, Porsha, Nachole, Niamatpur and Shibganj Upazila (Table 5.1). Only one severe drought has been identified in Tanore and Shibganj Upazila. In case of severe drought, Porsha and Godagari

Upazila affected 3 times during the period of 19976 to 2014. The lowest severe drought has been identified in Tanore and Shibganj Upazila. The highest number of moderate drought has been identified in Niamatpur Upazila and mild drought in Tanore Upazila.

5.3.2.3 Drought scale and frequencies using six months SPI

Two times six months SPI was used in this analysis, one with the time period from January to June and another from July to December. It has been identified 23 droughts in Niamatpur, Tanore and Porsha Upazila followed by Godagari, Nachole and Shibganj Upazila in the first half of the year (Table 5.1). Only one extreme drought and two severe droughts have been indentified in Shibganj Upazila. One severe drought in Tanore and Porsha Upazila has been identified. On the other hand, the highest drought frequencies have beenfound in Nachole, Shibganj and Porsha Upazila followed by Godagari, Niamatpur and Tanore Upazila in second half of the year (Table 5.1). Only one extreme drought occurred in Tanore and Shibganj Upazila. Three times severe drought has been identified in Godagari and Tanore Upazila.

Table 5.1: Drought scale and frequency using 6m, 9m and 12m SPI

Location	Drought type	Drought frequency using 6M, 6M, 9M & 12M months SPI			
		Jan-Jun	Jul-Dec	Jan-Sep	Jan-Dec
Niamatpur	Mild (0 to -0.99)	18	11	12	10
	Moderate(1 to-1.49)	5	7	5	9
	Severe(-1.5 to -1.99)	-	1	2	-
	Extreme(Less -2)	-	-	-	-
Nachole	Mild (0 to -0.99)	14	14	16	12
	Moderate(1 to-1.49)	7	6	3	7
	Severe(-1.5 to -1.99)	-	1	2	1
	Extreme(Less -2)	-	-	-	-
Godagari	Mild (0 to -0.99)	16	13	16	11
	Moderate(1 to-1.49)	6	4	3	6
	Severe(-1.5 to -1.99)	-	3	3	2
	Extreme(Less -2)	-	-	-	-
Tanore	Mild (0 to -0.99)	17	13	21	16
	Moderate(1 to-1.49)	5	2	2	2
	Severe(-1.5 to -1.99)	1	3	1	2
	Extreme(Less -2)	-	1	1	1
Shibganj	Mild (0 to -0.99)	14	14	13	14
	Moderate(1 to-1.49)	3	6	3	5
	Severe(-1.5 to -1.99)	2	-	1	1
	Extreme(Less -2)	1	1	1	1
Porsha	Mild (0 to -0.99)	18	14	15	13
	Moderate(1 to-1.49)	4	7	3	5
	Severe(-1.5 to -1.99)	1	-	3	2
	Extreme(Less -2)	-	-	-	-

Data source: BWDB, 2015

5.3.2.4 Drought scale and frequencies using three months SPI

Four times three months SPI was used to identify drought frequencies in the study area.

Table 5.2: Drought scale and frequency using 3m SPI

Study locations	Drought type and scale	Drought frequency using 3 months SPI			
		Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
Niamatpur	Mild (0 to -0.99)	22	18	15	18
	Moderate(1 to-1.49)	2	5	6	5
	Severe(-1.5 to -1.99)	-	-	-	-
	Extreme(Less -2)	-	-	-	-
Nachole	Mild (0 to -0.99)	27	15	15	23
	Moderate(1 to-1.49)	-	4	6	1
	Severe(-1.5 to -1.99)	1	-	-	-
	Extreme(Less -2)	-	-	-	-
Godagari	Mild (0 to -0.99)	24	19	14	16
	Moderate(1 to-1.49)	2	4	4	2
	Severe(-1.5 to -1.99)	-	-	3	3
	Extreme(Less -2)	-	-	-	-
Tanore	Mild (0 to -0.99)	25	13	17	22
	Moderate(1 to-1.49)	-	6	1	3
	Severe(-1.5 to -1.99)	-	2	4	-
	Extreme(Less -2)	-	-	-	-
Shibganj	Mild (0 to -0.99)	19	13	15	21
	Moderate(1 to-1.49)	4	5	5	3
	Severe(-1.5 to -1.99)	-	1	-	-
	Extreme(Less -2)	1	1	-	-
Porsha	Mild (0 to -0.99)	19	19	14	22
	Moderate(1 to-1.49)	5	4	6	4
	Severe(-1.5 to -1.99)	-	-	-	-
	Extreme(Less -2)	-	-	-	-

Data source: BWDB, 2015

The first quarter from January to March, second quarter from April to June, third quarter from July to September and forth quarter from October to December have been considered for this study. The highest drought frequencies (27 times) have been identified in the first quarter followed by fourth quarter (26 times), second quarter (23 times) and third quarter (22 times) respectively (Table 5.2). The highest frequencies of drought have been identified in Tanore (22 times) followed Niamatpur, Nachole, Godagari, Shibganj (21 times) and Porsha (20 times) in the third quarter.

5.4 Drought time scale percentage

Drought intensity in the study locations was calculated using SPI value for 3months time from July to September and from October to November, 6 months time from January to June and from July to December, 9 months time from January to Sepember and 12 months time from January to December for 39 years. Severe drought found at Niamatpur (Table 5.3) using 6 months SPI from July to December (2.56%) and 9months time SPI (5.13%). The highest mild drought intensity has been identified in 3 months time (46.15%) and 6 months time (46.15%). Table 5.4 showed that three times severe drought has been recorded at Nachole Upazila during 6months time (2.56%), 9months time (5.13%) and 12 months time (2.56%). On the other hand, severe droughts have been identified several timesin Godagari (Table 5.5) with the intensity of 3 months time in July to September (7.69%) and from October to December (7.69%) 6 months time from January to June (7.69%), 9 months time (7.69%) and 12 months time (5.13%). Analysis showed that maximum percentage of mild drought (53.85%) occurred at Tanore with extreme drought intensity (2.56%) during 6 months, 9 months and 12 months time (Table 5.6). In five time scales the extreme drought found at Shibganj with the percentage of 2.56 during 3 months time, 6 months time, 9months time and 12 months time scale (Table 5.7). The maximum mild drought occurrence intensity (56.41%) was recorded at Porsha Upazila without any extreme drought (Table 5.8).

Table: 5. 3: Drought intensity at Niamatpur Upazila

SPI VALUE	Drought category	Time (%) 3 Month- (Jul-Sep)	Time (5) 3 Month- (Oct-Dec)	Time (%) 6 Month- (Jan-Jun)	Time (%) 6 Month- (Jul-Dec)	Time (%) 9 Month- (Jan- Sep)	Time (%) 12 onth- (Jan- Dec)
0 to -0.99	Mild	38.46	46.15	46.15	28.21	30.77	25.64
-1.00 to -1.49	Moderate	15.38	12.82	12.82	17.95	12.82	23.08
-1.5 to -1.99	severe	-	-	-	2.56	5.13	-
less than -2	extreme	-	-	-	-	-	-

Source: BWDB 2015

Table: 5.4: Drought intensity at Nachole Upazila

SPI VALUE	Drought category	Time (%) 3 Month- (Jul-Sep)	Time (5) 3 Month- (Oct-Dec)	Time (%) 6 Month- (Jan-Jun)	Time (%) 6 Month- (Jul-Dec)	Time (%) 9 Month- (Jan- Sep)	Time (%) 12 onth- (Jan- Dec)
0 to -0.99	Mild	38.46	58.97	35.90	35.90	41.03	30.77
-1.00 to -1.49	Moderate	15.38	2.56	15.38	17.95	7.69	17.95
-1.5 to -1.99	severe	-	-	2.56	-	5.13	2.56
less than -2	extreme	-	-	-	-	-	-

Source: BWDB 2015

Table: 5. 5: Drought intensity at Godagari Upazila

SPI VALUE	Drought category	Time (%) 3 Month- (Jul-Sep)	Time (5) 3 Month- (Oct-Dec)	Time (%) 6 Month- (Jan-Jun)	Time (%) 6 Month- (Jul-Dec)	Time (%) 9 Month- (Jan- Sep)	Time (%) 12 onth- (Jan- Dec)
0 to -0.99	Mild	35.90	41.03	33.33	41.03	41.03	28.21
-1.00 to -1.49	Moderate	10.26	5.13	10.26	15.38	7.69	15.38
-1.5 to -1.99	severe	7.69	7.69	7.69	-	7.69	5.13
less than -2	extreme	-	-	-	-	-	-

Source: BWDB 2015

Table: 5. 6: Drought intensity at Tanore Upazila

SPI VALUE	Drought category	Time (%) 3 Month-(Jul-Sep)	Time (5) 3 Month-(Oct-Dec)	Time (%) 6 Month-(Jan-Jun)	Time (%) 6 Month-(Jul-Dec)	Time (%) 9 Month-(Jan- Sep)	Time (%) 12 onth-(Jan-Dec)
0 to -0.99	Mild	43.59	56.41	33.33	43.59	53.85	41.03
-1.00 to -1.49	Moderate	2.56	7.69	5.13	12.82	5.13	5.13
-1.5 to -1.99	severe	10.26	-	7.69	2.56	2.56	5.13
less than -2	extreme	-	-	2.56	-	2.56	2.56

Source: BWDB 2015

Table: 5. 7: Drought intensity at Shibganj Upazila

SPI VALUE	Drought category	Time (%) 3 Month-(Jul-Sep)	Time (5) 3 Month-(Oct-Dec)	Time (%) 6 Month-(Jan-Jun)	Time (%) 6 Month-(Jul-Dec)	Time (%) 9 Month-(Jan- Sep)	Time (%) 12 onth-(Jan-Dec)
0 to -0.99	Mild	38.46	53.85	35.90	35.90	33.33	35.90
-1.00 to -1.49	Moderate	12.82	7.69	15.38	7.69	7.69	12.82
-1.5 to -1.99	severe	-	-	-	5.13	2.56	2.56
less than -2	extreme	2.56	-	2.56	2.56	2.56	2.56

Source: BWDB 2015

Table: 5. 8: Drought intensity at Porsha Upazila

SPI VALUE	Drought category	Time (%) 3 Month-(Jul-Sep)	Time (5) 3 Month-(Oct-Dec)	Time (%) 6 Month-(Jan-Jun)	Time (%) 6 Month-(Jul-Dec)	Time (%) 9 Month-(Jan- Sep)	Time (%) 12 onth-(Jan-Dec)
0 to -0.99	Mild	35.90	56.41	35.90	46.15	38.46	33.33
-1.00 to -1.49	Moderate	15.38	10.26	17.95	10.26	7.69	12.82
-1.5 to -1.99	severe	-	-	-	2.56	7.69	5.13
less than -2	extreme	-	-	-	-	-	-

Source: BWDB 2015

5.5 Descriptive statistic of Rainfall in Barind Tract

Appendix 6 shows the year 1987 with the maximum annual rainfall at Niamatpur, which was recorded an annual rainfall 1977.7 mm with the highest mean value 164.8mm. The data depicted the standard deviation correlating the highest rainfall was 243.4mm and it was skewed right, meaning the rainfall is highly dispersed and there was inconsistency in the rainfall pattern in 1987, having the corresponding highest range value. The variation of CV values indicates the existence of strong variability. At Nachole, it was observed that the maximum annual rainfall 2615.4mm and the corresponding mean of 217.9 mm found in 1999 for the period of 19976 to 2014. The lowest annual rainfall found in 1982 (796.2mm) and the maximum standard deviation found in 1999. The highest standard deviation correlated with the high rainfall range and Coefficient of variation. The high range and standard deviation indicates variability of rainfall (Appendix 7). Godagari Upazila showed the lowest mean annual rainfall in 2012 with the mean value 69.5mm having correlated standard deviation of 84.3mm. On the other hand the highest mean annual rainfall was recorded in 1988 with the amount of 2180mm (mean 187.7 and SD 191) that indicates variability of rainfall among the years (Appendix 8). As per observation from Appendix 9, the maximum annual rainfall for the period of 1976 to 2014 observed in 1999 (2624.5mm) with corresponding maximum annual mean and standard deviation of 218.7mm and 304.8mm, respectively. The standard deviation is the measure of dispersion. A large assessment indicates that the figure is widely dispersed about the mean. The small value indicates less variation in the data set and the figure is tightly grouped about the mean. Shibganj demonstrated the highest annual rainfall in the year 1991 (2276mm) with corresponding mean 189.7mm and the standard deviation 212.9mm (Appendix 10). The standard deviation indicates the highest value during the period of 1976-2014. The high standard deviation indicates year to year variations are high while the low standard deviation indicates low differences or variation in data. Porsha Upazila from Naogaon district showed the highest annual rainfall in 1987 (2162.3mm) over the period of 39 years from 1976 to 2014. Corresponding data, the mean rainfall were 180.2 mm with the highest standard deviation 240.5mm (Appendix 11). The rainfall with high standard is measured more unstable than rainfall with low standard deviation.

5.6 Rainfall trend

The rainfal data variation over time was found in the study area. Several methods could be used for calculating trend but the common are least square regression techniques. The hypotheses have been tested using the least square regression method. Figures 5.7, 5.8, 5.9, 5.10, 5.11 and 5.12 present the line and least square composite graphs of the annual rainfall regimes for Niamatpur, Nachole, Godagari, Tanore, Shibganj and Porsha Upazila. The y-axes denote amount of annual rainfall in mm, the x-axes present time in years. The annual rainfall record values for Niamatpur above the mean values for 20 years and below the mean values for 19 years. The initial 20 years record after the starting years showed above mean values. The initial 20 years (1977-1996) demonstrated above average values at a wider. This fluctuating rainfall series for Niamatpur is statistically indicated by the function.

$Y = 3345 – 0.95x + e.$

It is not significant at (99%) confidence level with a coefficient of determination figure of 0.001 or 0.1% (Figure 5.7). The annual rainfall trend at Nachole is almost similar to Niamatpur. The record values for 39 years rainfall data showed that 20 years rainfall regimes is below the mean annual rainfall and 19 years for above the mean annual rainfall. This fluctuating rainfall data for Nachole is statistically defined by the function.

Y = 18361– 0.8.483x + e.

It is not significant at (99%) confidence level with a coefficient of determination figure of 0.058 or 5.8% (Fig 5.8).

The data for Godagari is very much close to Niamatpur. The record values showed that the rainfall regimes above the mean values for 20 years and for 19 years below the long term mean values. The equation can be drawn by the following function:

Y = 14818– 6.757x + e.

Result is not significant at (99%) confidence level with a coefficient of determination figure of 0.077 or 7.7% (Fig. 5.9).

Annual rainfall trend in Tanore Upazila is fluctuating. The data series reflected for 21 years above the mean value of the rainfall in that area. Again, 18 years for below the mean values. This can be defined by the following equation:

Y = 8955– 3.741x + e.

Result is insignificant at 99% confidence level with a coefficient of determination figure of 0.010 or 1% (Figure 5.10). Analyzing trend of rainfall for 39 years it was observed that the rainfall data of Shibganj Upazila indicates 21 years below the mean value and 18 years above the mean value only. The equation for the trend can be drawn in following manner:

Y = 7470– 3.022x + e.

It is not significant at (99%) confidence level with a coefficient of determination figure of 0.006 or 0.6%. (Figure 5.11). Rainfall data for 39 years were analyzed to know the rainfall trend in Porsha Upazila. It was observed that the annual rainfall regimes for 21 years below the mean value and 18 years above the mean value in the study Upazila. The following equation was drawn by using following function:

Y = 10118– 4.325x + e.

It also is insignificant at (99%) confidence level with a coefficient of determination figure of 0.015 or 1.5% (Fig.5.12).

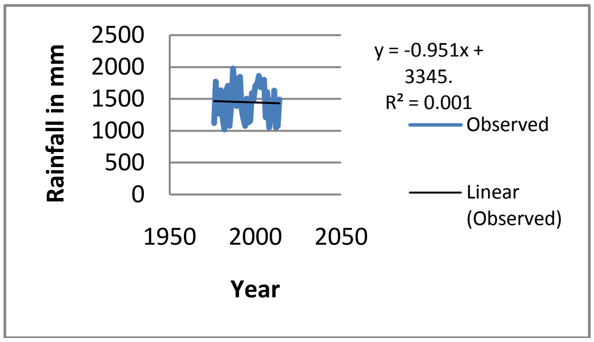


Figure 5.7: Rainfall trend in Niamatpur Upazila

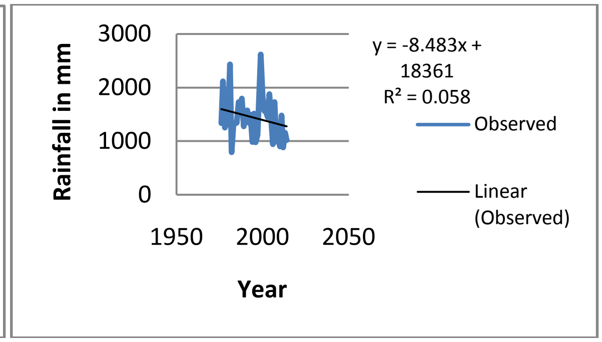


Figure 5. 8: Rainfall trend in Nachole Upazila

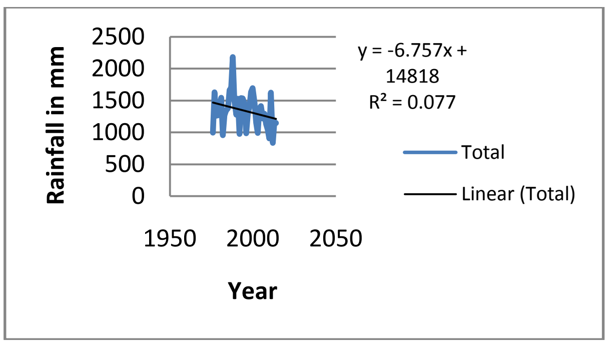


Figure 5.9: Rainfall trend in Godagari Upazila

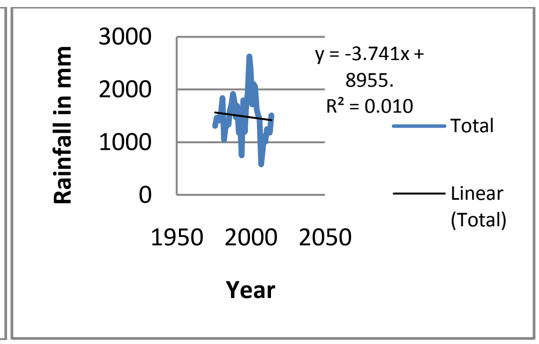


Figure 5.10: Rainfal trend in Tanore Upazila

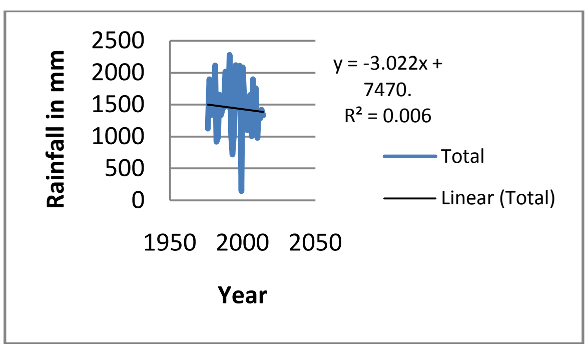


Figure 5.11: Rainfall trend in Shibganj Upazila

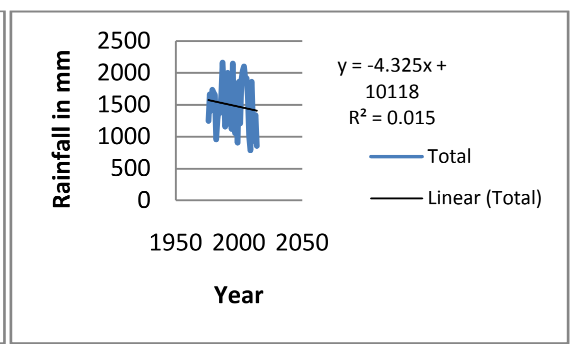


Figure 5.12: Rainfall trend in Porsha Upazila

5.7 Rainfall deviation

June to October is very much important in agricultural production. Our country mostly depends on rain fed agriculture during the season. Usually normal rainfall occurs in this season. The study areas are lacking from enough rainfalls due to geographical settings and climatic factors. In June, the maximum deviation of rainfall was recorded at Godagari (Appendix 12) in 19981 (84% deficit). 83 percent deficit were recorded in July, 100 percent in August (2008), 73 percent in Septemeber (1982) and 100 percent in October (1981 & 1996). The maximum rainfall deviation was recorded in October (100%) followed by September, July, June and August respectively at Tanore (Appendix 13). Three times severe rainfall deviations (100%) were recorded in the month of October and one time in the month of August at Niamatpur Upazila (Appendix 14). Two times severe rainfall deviation was recorded in the month of August and October at Nachole Upazila (Appendix 15). In the month of September 100 percent rainfall deviation were recorded at Shibganj in the year 2006 (Appendix 16). Two times rainfall deviation (100%) was recorded in September and October at Porsha (Appendix 17).

5.8 Predicted rainfall

Rainfall prediction has been done by using regression equation for the next ten years from 2015 to 2024. The prediction showed that there is a decreasing trend of rainfall in each and every year. The prediction indicates 77 mm rainfall will be reduced at Nachole followed by Godagari, Porsha, Tanore, Shibganj and Niamatpur respectively (Table 5.9).

Table 5.9: Predicted rainfall for all locations during the years 2015-2024

Year	Location wise predicted rainfall in mm					
	Niamatpur	Nachole	Godagari	Tanore	Shibganj	Porsha
2015	1429	1268	1203	1417	1421	1403
2016	1428	1259	1196	1413	1418	1399
2017	1427	1251	1189	1409	1415	1394
2018	1426	1242	1182	1406	1412	1390
2019	1425	1234	1176	1402	1409	1386
2020	1424	1225	1169	1398	1406	1382
2021	1423	1217	1162	1394	1403	1377
2022	1422	1208	1155	1391	1400	1373
2023	1421	1200	1149	1387	1397	1369
2024	1420	1191	1142	1383	1394	1364

5.9 Testing of hypothesis

Using the determinants of rainfall, hypothesis was tested. Regarding homogeneity and association of the statistics with a theoretical common base, the K-sample Chi-square test was used. It is noted that the data variances are not incorporated in this calculation. The determination of the expected frequencies for each entry is given in Table 5.10.

Table 5.10: Rainfall descriptive indices for six study locations in Barind Tract (1976-2014)

	Niamarpur	Nachole	Godagari	Tanore	Shibganj	Porsha
Mean	1447.4385	1437.341	1337.37	1491.5615	1441.9667	1489.5615
Max	1978	2615.4	2180	2624.5	2276	2162.3
Mini	1017	796.2	834.5	582.7	148.1	782.9
SD	288	401	276	419	434	396
cv	19.897	27.899	20.638	28.091	30.098	26.585

The test statistic is appended below:

$X^2 = (O-E)^2/E$ is utilized for rainfall data series

(1447.4-1415.6)2/1415.6+(1437.3-1572.8)2/1572.8+(1337.37-1385.29)2/1385.29+(1491-56-1533.50)2/1533.50+(1441.96-1290.42)2/1290.42+(1489.56-1606.79)2/1606.79+(1978-2265.64)2/2265.64+(2615.4-2517.23)2/2517.23+(2180-2217.08)2/2217.089+(2624.5-2454.28)2/2454.28+(2276-2065.25)2/2065.25+(2162.3-2316.68)2+(1017-681.42)2/681.42+(796.2-757.08)2/757.08+(834.5-666.81)2/666.81+(582.7-738.15)2/738.15+(148.1-621.14)2/621.14+(782.9-696.77)2/696.77+(288-362.53)2/362.53+(401-402.79)2/402.79+(276-354.766)2/354.76+(419-392.72)2/392.72+(434-330.47)2/330.47+(396-411.49)2/411.49+(19.89-25.08)2/25.08+(277.89-27.87)2/27.87+(20.63-24.55)2/24.55+(28.0927.17)2/21.17+(30.09-22.86)2/22.86+(26.58-28.47)2/28.47
= (218.89+17.52+62.55+47.48+434.28+4857.34)
=5638.09 df 20 tvalue is 37.5662

At 99% confidence level and (number of rows-1) (number of columns-1) = (5-1) (6-1) = 20 degrees of freedom, the calculated chi-square value i.e. calculated value is greater than critical value (5638.09 › 37.5662). According to assumed hypothesis the null hypothesis is rejected and alternative hypothesis is accepted. Rainfall is significantly varied among the locations over time.

5.10 Descriptive statistics on temperature in the study area

The Table 5.11 showed that the highest mean annual temperature in 2010, which is recorded the mean temperature of 25.78^0C with a corresponding maximum of 31.3^0c.

Table 5.11: Descriptive statistics on temperature during the period 1976-2014

Year	Average	Maximum	Minimum	StDev	Variance	Median	Range	Skewness	Kurtosis
1976	25.95	29.8	18.4	4.07	16.56	27.85	11.4	-1.18	-0.08
1977	25.48	29.4	17.2	4.12	16.99	27.35	12.2	-1.11	-0.15
1978	24.94	28.3	17.4	4.15	17.19	27.65	10.9	-0.92	-0.8
1979	26.00	32.4	18.4	4.77	22.74	27.85	14	-0.95	-0.9
1980	25.40	31.7	17.1	4.63	21.47	27.25	14.6	-0.64	-0.84
1981	24.75	29.1	17.4	4.34	18.84	26.65	11.7	-0.81	-0.87
1982	25.02	30.5	17.6	4.81	23.09	27.2	12.9	-0.56	-1.43
1983	24.90	30.1	16.3	4.94	24.42	27.15	13.8	-0.86	-0.86
1984	24.96	30.2	16.4	4.86	23.67	27.6	13.8	-0.84	-0.98
1985	25.16	30.1	17.7	4.48	20.08	27.15	12.4	-0.78	-1.15
1986	25.08	29.5	17.5	4.23	17.93	26.55	12	-0.8	-0.89
1987	25.51	30.2	17.4	4.41	19.46	27.55	12.8	-0.83	-0.77
1988	25.43	29.3	17.7	4.19	17.56	27.6	11.6	-0.81	-0.93
1989	25.02	30.3	15.6	5.2	27	27.65	14.7	-0.81	-0.89
1990	24.80	29.2	17	4.45	19.76	26.5	12.2	-0.73	-0.94
1991	24.99	29.1	16.2	4.83	23.32	27.1	12.9	-0.9	-0.77
1992	25.07	30.5	16.4	5.22	27.26	27.3	14.1	-0.79	-1.1
1993	24.98	28.8	15.8	4.4	19.39	27.35	13	-1.03	-0.08
1994	25.05	29.9	17.5	4.73	22.39	27.15	12.4	-0.78	-1.14
1995	25.28	31.3	15.7	5.2	27.01	27.7	15.6	-0.76	-0.82
1996	25.33	30.4	16.9	4.79	22.99	27.45	13.5	-0.83	-0.94
1997	24.68	29.6	16	4.82	23.24	25.95	13.6	-0.85	-0.74
1998	25.29	30.9	15.1	5.02	25.18	27.7	15.8	-0.91	-0.31
1999	25.65	30.9	17	4.45	19.84	27.45	13.9	-0.87	-0.47
2000	24.94	29.3	16.4	4.77	22.77	27.4	12.9	-0.88	-0.88
2001	25.15	29.5	15.9	4.82	23.27	27.45	13.6	-1	-0.45
2002	25.12	29.2	17.8	4.31	18.55	27	11.4	-0.84	-0.93
2003	25.11	29.7	14.3	5.22	27.26	27.65	15.4	-0.96	-0.22
2004	25.24	30.6	15.7	4.78	22.85	27.2	14.9	-0.91	-0.44
2005	25.51	30.4	16.9	4.68	21.94	27.35	13.5	-0.79	-0.87
2006	25.56	29.5	16.7	4.47	19.95	27.75	12.8	-1.06	-0.16
2007	25.04	29.6	16	4.95	24.54	27.7	13.6	-0.86	-0.8
2008	25.10	29.2	16.7	4.71	22.14	27.35	12.5	-0.87	-0.99
2009	25.52	31	17.3	4.92	24.19	27.6	13.7	-0.74	-0.97
2010	25.78	31.3	15.1	5.46	29.86	27.9	16.2	-1.02	-0.32
2011	24.90	29.3	14.7	5.13	26.3	27.4	14.6	-1.05	-0.33
2012	25.35	31.2	16.6	5.38	28.9	27.5	14.8	-0.68	-1.1
2013	25.26	29.9	15.5	5.07	25.68	27.6	14.4	-0.9	-0.65
2014	25.26	30.6	16.2	5.46	29.79	27.85	14.4	-0.7	-1.25

The record indicates the standard deviation correlating the highest mean annual temperature 5.46 and the left data. It meant that the temperature distribution was highly dispersed in 2010. There was inconsistency in temperature pattern in 2010, with the corresponding highest range value.

5.11 Testing hypothesis using temperature data

Mean annual monthly temperature was used for the analysis using 39 years data of Rajshahi meteorological station from 1976 to 2014. Only one station data was considered for this study due to lack of long data and station from Barind Tract. Temperature data were used to draw descriptive statistics of mean, standard deviation, coefficient of variation with maximum and minimum value for long term periods of 1976 2014 (Table 5.12).

Table 5.12: Temperature descriptive indices for twelve months in Barind (1976-2014)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	16.62	19.97	25.17	28.88	29.20	29.24	28.74	28.86	28.47	26.68	22.63	18.17
MAX	18.60	23.00	28.10	31.70	32.40	31.00	28.80	29.60	29.40	27.80	24.80	19.60
Min	14.30	18.30	22.80	26.00	27.50	27.20	27.60	28.10	27.40	25.10	21.10	16.60
SD	1.00	1.03	1.18	1.26	1.15	0.81	0.51	0.39	0.49	0.58	0.87	0.81
CV	5.99	5.14	4.67	4.38	3.95	2.75	1.77	1.34	1.72	2.16	3.86	4.46

Using the determination of the expected frequencies for each entry in Table 24, the test statistic is appended below:

$X^2 = (O-E)^2/E$ is utilized for static ground water level

(16.62 -15)2/15+ ------------(18.17-15.84)2/15.84 +(12.72-23)2/23+-------------+(19.60-13.42)2/13.42+(14.30-10.25)2/10.25+-----------------+(16.60-10.82)2/10.82+(1-8.16)2/8.16+-------------------+(.81-8.62)2/8.62+(5.99-10.36)2/10.36+------------------+(4.46-10.94)2/10.94

=356.40

At 99% confidence level and (number of rows-1) (number of columns-1) = (5-1) (12-1) = 44 degrees of freedom, the calculated chi-square value i.e. calculated value is greater than critical value (356.40 › 37.5662). According to assumed hypothesis the null hypothesis is rejected and alternative hypothesis is accepted. So temperature is significantly varied among the locations over time.

5.12 Humidity and Its trend

The state of humidity was analyzed using long term data from 1976 to 2014. The trend of humidity is very much visible. The percentage of humidity is increasing over the times (Fig 5.13).

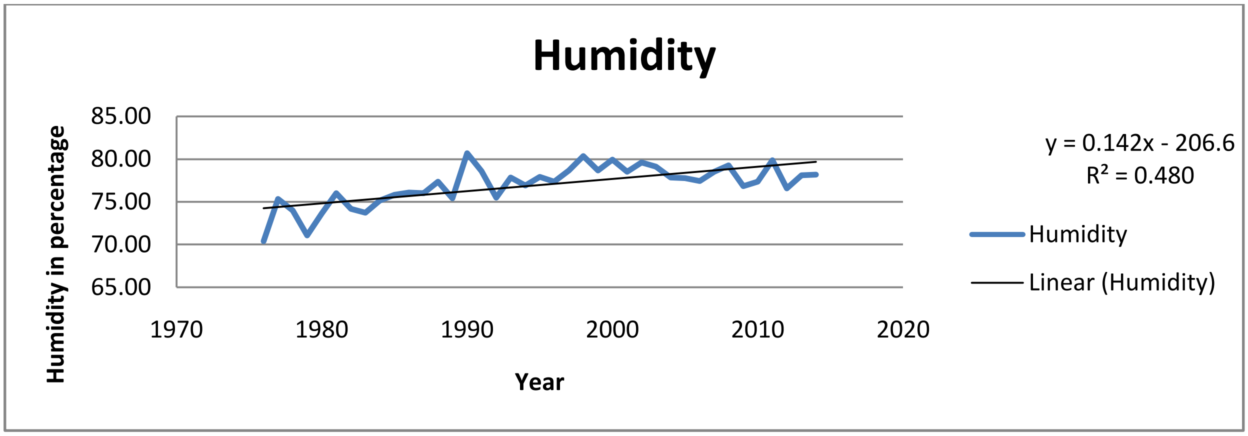


Figure 5.13: Linear regression of humidty

Drought and climate scenario contributes in Chapter Six where how farmers perceived drought and its impacts in the study area. Eventually this can helps in understanding the consequences of drought including causes of drought and symptom of drought.

Summary and conclusion

Drought is increasing frequently in the study locations. Mild and moderate droughts were observed more frequent in the study locations during rainy seasons and other period. Severe and extreme droughts were observed in Niamatpur, Nachole, Porsha and Tanore Upazila compared to Shibganj and Godagari Upazila. Temperature is increasing significantly over times. On the other hand, rainfall is decreasing significantly in the study locations. Predicted rainfall indicated that decreasing trend of rainfall in future in the study locations. It is crucial to take care about drought and climate change issues.

Chapter 6: Peoples' perception on drought and its consequences

6.1 Perception of drought

This chapter has been made a link with the drought scenario and peoples' perception on drought and its consequences in the study locations. Several factors including precipitation, temperature, humidity, soil moisture and groundwater are associated with droughts. The respondents of the study locations do not know the exact definition of drought. They understand drought as a natural disaster with extreme temperature and lack of rainfall. Most of the people think drought as a period of unusually dry weather that persists long time to cause problems such as crop damage and water shortage. There is no exact definition and clear understanding of drought as perceived by the respondents. They meant that drought is the lack of soil moisture for the spell of periods, dryness of weather and no rainfall over the periods. As perceived by the local people watertable goes down and high temperature prevails during drought and no water for irrigation. If there is no rainfall for consecutive fifteen days during summer and rainy season is considered as drought. Few indications were made by the local people to perceive drought. If there is no rainfall for consecutive twenty one days during *Aman* season, nine consecutive days during *Boro* season and fifteen consecutive days during *Aus* season is termed as drought. Most people in the study areas are well understood of drought through the absence of rainfall for long time. A reduction of water availability might qualify as a drought. Thus drought is the period of anomalous dryness, are therefore a natural climatic occurrence. It is defined as transitory reduction of soil moisture availability drastically goes below the normal for a specified period. Basically drought is transitory both long and temporary drought may transpire in an area that normally experiences blinking wet and dry periods. Essentially temporary cutback of water/ soil moisture accessibility as a drought is extremely complex and depends upon the time period being considered.

6.2 Causes of drought

Erratic and less rainfall in any season, non availability of groundwater and extreme temperature causes drought in the Barind Tract. The respondents do not know the causes of drought clearly. Most of them think that drought is a natural disaster given by the almighty Allah. Few respondents mentioned that global warming and desertification occurs due to deforestation. They told that drought occurs in the hot summer season due to the extreme temperature, lack of rainfall and absence of available soil moisture. Lack of soil moisture associated with agricultural drought. Meteorological drought is associated with the reduction of monsoon rainfall. Hydrological drought is associated with the reduction of groundwater level, stream flow and surface water in canal, rivers and ponds. Drought conditions are becoming severe due to lack of moisture retention into the soil, unavailability of groundwater, erratic and low rainfall and low adaptive capacity of the farmers. Drought in Bangladesh is interlinked with climate extremes, lack of soil moisture and non availability of groundwater and surface water resources. Erratic rainfall or low rainfall is also one of the causes of drought in the study locations. Inefficient use of surface water and over extraction of groundwater is also important causes of drought. Excess evaporation and transpiration is also making the situation more critical. Decreasing numbers of pond, canal and *kahri* is also limiting the surface water availability. Siltation of ponds, canals and rivers are restricted water flow through the channel. The direct cause of a rainfall deficiency may be due to several factors including moisture deficiencies in the atmosphere or large scale downward movement of air within the atmosphere which restrains rainfall. Alterations in such factors lead changes non local, regional and global weather and climate. Increased carbon dioxide and other greenhouse gasses have been suggested as causes of erratic and low rainfall, which are, in turn, attributed as climate change. There is strong evidence that climate change will affect the rainfall pattern and as a result, droughts that are more frequent are expected. The local level factors are human induced activities resulting from vegetation loss due to over exploitation of resources and deforestation. More than 97 percent respondents (n=335) mentioned that drought occurrs due to high temperature followed by lack of ground water (97. 38%), lack of soil moisture (98.79%), less rainfall (93.29%), erratic rainfall (86.595%) and environmental hazards (86.59%) respectively (Table 6.1). The people of the study locations believed that drought occurs due to number of causes. In Chapai Nawabganj 100 percent respondents (n=126) reported that drought occurs due to lack of soil moisture, erratic rainfall, high temperature, less rainfall, lack of groundwater and environmental hazards respectively (Table 6.1). In Rajshahi, all the respondents (n=52) from Parisho village agreed same reasons but in Aye-Hi village 100 percent (n=62) respondents mentioned that high temperature is the main cause of drought. 96.8 percent (n=60) respondents told about less rainfall followed by lack of groundwater (90.3%), lack of soil moisture (88.7%), erratic rainfall (67.7%) and environmental hazards (66.1%). In Naogoan, all the respondents (63) from Bhabicha mentioned that lack of soil moisture and lack of groundwater is responsible for the drought. 98.4 percent (62) respondents reported that high temperature is responsible for drought. 81 percent (51) respondents mentioned that erratic rainfall, less rainfall and environmental hazards are responsible for the occurrence of drought. On the other hand,92.5 percent (n=37) respondents of Mollapara reported that lack of groundwater is the main causes followed by lack of soil moisture (90%), high temperature (82%), less rainfall (77.5%), environmental hazards (67.5%) and erratic rainfall (65%) respectively.

Table 6.1: Causes of drought

Causes	Study location with respondents (%)						
	Rajshahi		Chapainawabganj		Naogaon		All (%)
	Parisho n=52	Aye-Hi n=62	Nizampur n=75	Chokghorpakhia n=51	Bhabicha n=63	Mollapara n=40	
Lack of soil moisture	(100)	(88.7)	(100)	(100)	(100)	(90)	(96.79)
Erratic rainfall	(100)	(67.7)	(100)	(100)	(81)	(65)	(86.59)
High temperature	(100)	(100)	(100)	(100)	(98.4)	(82)	(97.67)
Less rainfall	(100)	(96.8)	(100)	(100)	(81)	(77.5)	(93.29)
Lack of ground water	(100)	(90.3)	(100)	(100)	(100)	(92.5)	(97.38)
Environmental hazards	(100)	(66.1)	(100)	(100)	(81)	(67.5)	(86.59)

Source: Field survey2015, multiple responses, Figure in parenthesis indicates percent value

The common attributed causes of drought and the sources of information (knowledge) that mentioned by respondents and participants of Focus Group Discussions. The general causes for drought include punishment, sins, lack of sacrifices, reckless behaviour & immorality, natural occurrence, deforestation, industrialization, brick fields and burning of fuel (wood , firewood , crop residues, charcoal, dry cow dung and fossil fuels). The sources of information (knowledge) included generational knowledge transfer, religious leaders, teachers, Mass media (radio, television and news paper), NGOs and government sources (Table 6.1a). Eventually this information was collected from informal discussion at the tea stall during field works. Generally the above mentioned causes had a strong logic on social realms, especially sacred reasons and religious disobedience.

Table 6.1a: Perceived general cause of drought

#	Perceived causes of drought	Sources of information
1	Punishment of God (Allah)	Aged persons, religious leaders like Imam, Priest
2	Reckless and immoral behaviour	Aged person, teacher and religious leaders
3	Failure to offer sacrifices to divine beings	Religious leader
4	As a test of faith to God (Allah)	Religious leaders and aged person
5	Natural occurrence	General people (Farmers, housewives etc)
6	Human activities (cutting of trees, use of chemicals, irrigation, pond filling etc)	Farmers, housewives, teachers etc
7	Deforestation (reduces rainfall)	General people, religious leaders, teachers and mass media
8	Brick field and burning of fire wood for cooking (This create and escape plenty of smoke in the atmosphere that finds its way here to distort the rainfall pattern)	Mass media, NGOs and Government
9	Sign of *Akherat* (Day of judgement)	Religious leader and aged person
10	Commercialization and industrialization	Mass media, NGOs and general people
11	Switch for even more hazardous events	Religious leader

Source: Field work (discussion, interviews and Focus Group Discussion)

Allah (God) may bring drought in the area for several reasons, including immoral conduct, failure to perform religious customs, cutting of trees that belong to the deities and unwillingness to give *Zakat*. *Zakat* is a Muslim customs to pay the needy at least once a year. Peoples believed that the generation is not practicing religious customs and culture as religious bylaws.

6.3 Types of drought

Respondents are not clear about drought types. They mentioned that soil moisture, riverflow and rainfall are associated with drought. They identified agricultural drought if the soil is lacking from moisture; hydrological drought if there is no water flow in the river; meteorological drought if there is no rainfall for long time. Several literatures have been recognized five types of drought including agricultural drought, meteorological drought, hydrological drought, socio-economic drought and seasonal drought. Meteorological drought notices when the reduction in rainfall for a specified period of time. Hydrological drought occurs when deficiencies in surface and subsurface water supplies based on measurements of stream flow and lake, reservoir and groundwater levels. Agricultural drought happens when there is no enough soil moisture to meet the needs of agricultural production at a particular time. Socio-economic drought occurs when physical water shortage starts to affect people. Seasonal droughts are related to deficit soil moisture during certain time within a season. According to the Key Informants' there are three types of seasonal droughts in Bangladesh during monsoon season likely early season drought, mid season drought and terminal season drought. Early season drought is due to delayed start or early break in monsoon rainfall. Mid-season droughts are originated by sporadic or extended dry spells. Terminal season droughts are rooted by early withdrawal of monsoon rainfall. In the study areas, terminal droughts are more dominant and coincide with the most important growth phases of the rice crop.

6.4 Drought symptoms

Extreme temperature is one of the symptoms of drought as mentioned by the respondents. The respondents reported that, they have to face temperature above $40^{\circ C}$ during drought season. Lack of rainfall is another indication of drought. They experienced over a month without any rainfall for several droughts. It is also depend on drought severity and spatial arrangement. Water dried out from the sources including ponds, rivers and canals. Water table is going down than the normal level and the respondents are not able to collect groundwater from tubewell. Sometimes they have to collect drinking water from pond and make sure water purification by boiling water or using *fitkary* before drink. The agricultural lands dried along with the crops growing in the fields and the soil has been cracked due to over evaporation. Even the grasses, herbs, shrubs are dried in the drought season. Wilting of the crops usually starts during drought. Increase of dust particles in the air is another symptom of drought. Three important drought damage symptoms were recognized by the respondents in the study area. 97.67 percent respondents (n=335) mentioned that cracking of soil as the top drought symptoms followed by burnings of crops and drying of pond/canals or rivers respectively (Table 6.2). In Bhabicha, 95.2 percent respondents (n=59) were mentioned burning of crops as the top drought damage symptom.

Table 6.2: Drought damage symptoms

Drought damage symptoms	Study locations with drought damage symptoms						All (%)
	Rajshahi		Chapainawabganj		Naogaon		
	Parisho n=52	Aye-Hi n=62	Nizampur n=75	Chokghorpakhia n=51	Bhabicha n=63	Mollapara n=40	
Burning of crops	(100)	(100)	(96)	(100)	(95.2)	(75)	(95.04)
Cracking of soil	(100)	(100)	(100)	(100)	(93.5)	(92.5)	(97.67)
Drying of pond/canal/river	(100)	(95.2)	(96)	(100)	(59.7)	(95)	(90.09)

Source: Field survey2015, multiple responses, Figure in parenthesis indicates percent value

6.5 Drought frequency

The respondents were asked to know the frequency of drought in the study area. Data in Table 6.3 indicate that all the respondent of Rajshahi and Chapai Nawabganj Districts agreed about the drought frequency in each and every year but the respondents from Naogoan argued with the statement. In Naogaon, 44.4 percent (n=28) and 90 percent (n=36) respondents of Bhabicha and Mollapara Village believes that drought occurs in every year but 54 percent (n=34) respondent of Bhabicha and 10 percent (n=4) respondents of Mollapara said that drought occurs after 2-4 years interval. Only 1.6 percent respondents from Bhabicha said that drought occurs after 5-9 years interval. Table 6.3 represents 88.63 percent respondents (n=304) reported that the drought is frequently occur in each and every year but 11.08 percent respondents (n=38) disagreed with the statement. They said that drought occurs after 2-4 years interval and only 0.29 percent respondent in favour of 5-9 years. Drought occurs almost every year in the study area but the drought severity varies from locations to locations and year to year. The respondents mentioned that, the last drought occurring year was 2014. Drought severity is higher in the Bengali months *Choitro* and *Boisakh*. The severe drought occurring years in the study areas was 1981, 1983, 1994, 2000 and 2006.

Table 6.3: Drought frequency

Drought frequency	Study location with Drought Frequency						All (%)
	Rajshahi		Chapainawabganj		Naogaon		
	Parisho n=52	Aye-Hi n=62	Nizampur n=75	Chokghorpakhia n=51	Bhabicha n=63	Mollapara n=40	
Every year	(100)	(100)	(100)	(100)	(44.4)	(90)	(88.63)
After 2-4 years					(54.0)	(10)	(11.08)
After 5-9 years					(1.6)		(0.29)

Source: Field survey2015, Figure in parenthesis indicates percent value, n=number

6.6 Last drought year

On an average 99.42 percent respondents (n=341) agreed about the occurrence of drought in several years. Around 71.72 percent respondents (n=246) have been identified that 2014 was the last drought year and 18.95 percent respondents (n=65) pointed out the last drought year was 2013. Besides, some respondents have been identified several drought years from 1998 to 2015.

Only 2.04 percent respondents reported that the year 2015 was the last drought year and 0.58 percent respondents pointed the last drought year was in 1998 (Table 6.4). In Rajshahi District, all the respondents (n=52) from Parisho Village have been identified that the last drought year was 2014, while 69.4 percent respondents (n=43) from Aye-Hi Village. 1.3 percent respondents from Aye-Hi village mentioned that the year 2015 followed by 2012 (8.1%), 2010 (4.8%) and 2000 (1.6%). In Chapai Nawabganj, 93.3 percent (70) respondents of Nizampur Village reported that 2014 was the last drought year while 98 percent (50) respondents of Chokghorpakhia

Table 6.4: Last Drought year

Last drought	Study locations and drought year (%)						All (%)
	Rajshahi		Chapainawabganj		Naogaon		
	Parisho n=52	Aye-Hi n=62	Nizampur n=75	Chokghorpakhia n=51	Bhabicha n=63	Mollapara n=40	
1998					(1.6)	(2.5)	(0.58)
2000		(1.6)					(0.29)
2006			(5.3)			(2.5)	(1.46)
2008						(2.5)	(0.29)
2010		(4.8)					(0.87)
2011		(3.2)				(7.5)	(1.46)
2012		(8.1)			(1.6)		(1.75)
2013				(2.0)	(95.2)	(10.0)	(18.95)
2014	(100)	(69.4)	(93.3)	(98.0)	(1.6)	(75.0)	(71.72)
2015		(11.3)					(2.04)

Source: Field survey 2015, Figure in parenthesis indicates percent value, n=number

.On the other hand 5.3 percent (4) respondents of Nizampur opined that 2006 was the last drought year but the remaining 2 percent (1) respondents from Chokghorpakhia mentioned the year 2013 was the last drought year. In Naogoan, 95.2 percent respondents (n=60) from Bhabicha Village said that 2013 was the last drought year while only 10 percent respondents from Mollapara. Although 75 percent (30) respondents (n=30) of Mollapara mentioned that 2014 was the last drought year followed by 7.5 percent in 2011, 2.5 percent in 2006 and 1998 respectively.

6.7 Drought impacts

Several impacts were mentioned by the respondents. Drought impacted on agriculture, livelihoods, health and society. The dilemma of drought impacts is critical. The situation is not come to observation within single day or couples of days. They can notice it gradually for over the period. Local level drought occurs in each and every year and affects crop production.

6.7.1 Impacts on livelihood

Loss of employment occurs in each and every drought year due to crop failure in the drought season because the respondents are directly or indirectly involved with agriculture for their livelihood. Respondents look for an alternative livelihood option to feed their family. The alternative livelihood options are wage labour, rickshaw or van-pulling, auto-bike or *nosimon* driving, and small business. Some of them or family member migrated to the nearby city or Dhaka city for alternatives livelihood options.

6.7.2 Impacts on food production and security

Drought causes huge damage to the crops depending season, scale and crops. It reduced crop production and impacted on food security issues. Few farmers were claimed that they had no food to eat, even the price is so high during drought period and they had no money to buy it from market with high price. The ultimate results of drought lead them towards food insecurity.

6.7.3 Impacts on fish production

The respondents involved with fish farming reported that, it is highly quite impossible to cultivate fish in drought season. Lack of rainfall and high temperature has resulted in reduced fish production. Fish farming hampered for the shortage of water in the ponds due to over evaporation rate during drought. People irrigate their pond by water pump or deep tubewell. Methane and ammonia gas formed in the pond water due to excessive temperature which is very harmful for fish cultivation. Gas bubbles come out from the bottom of the pond. Oxygen shortage appeared in the pond water in drought season. Gradually all of the fishes die and float on the water surface of the pond. The respondents involved with fish firming reported that, fish production decreased up to 80 percent when drought occurred. They apply *fitkari*, lime and chemicals (ammoline, zeolite etc.) to purify pond water from the impact of methane and ammonia in drought season. Sometimes, drought occurs so harshly that fish farming is not possible and the fishermen (the people involved with only fish firming) became unemployed or switched to other jobs.

6.7.4 Impacts on Health

Several diseases break out in the drought seasons. They mentioned few diseases such as fever, dizziness, heat stroke, skin diseases (due to sun burn) diarrhea, dysentery, blood pressure, heart stroke and respiratory problems (related to dust). Sometimes severe drought cause human death (Old people and baby). 99.71 percent respondents (n=342) of the study areas were agreed with health problems due to drought (Table 6.5). Only 0.29 percent respondents mentioned that there is no health ailment due to drought. 100 percent respondents from four study locations were mentioned that drought cause health impacts to the human. The respondents reported that, different types of health hazards erupt in the drought season. Almost all of the people became attacked by water borne diseases like diarrhea, dysentery in drought season. These diseases are caused by drinking unpurified water. Safe drinking water from tube-wells became unavailable because water table goes down in the drought season. The excessive temperature also increases blood pressure and heart attack especially to the old people. Depression due to drought is an important cause of health hazard in the study locations. Respondents were mentioned that there are number of diseases occured due to drought. Around 91 percent respondents (n=313) agreed that drought is liable for diarrhea followed by heat stroke (90%), skin diseases (83%) and 79 percent dysentery (Table 6.5). In Parisha all the respondents were reported that diarrhea is the primary disease which occured due to drought followed by skin diseases 98 percent, heat stroke 96.15 percent and dysentery 92 percent.While it was reported at Aye-Hi village 96.77percent, 88.71percent, 83.87percent and 62.90 percent respectively.

Table 6.5: Diseases occurred by drought

Health problems	Study location with health problems (%)						All (%)
	Rajshahi		Chapainawabganj		Naogaon		
	Parisho n=52	Aye-Hi n=62	Nizampur n=75	Chokghorpakhia n=51	Bhabicha n=63	Mollapara n=40	
Yes	(100)	(100)	(98.7)	(100)	(100)	(100)	(99.71)
Skin diseases	(98.08)	(88.71)	(96.00)	(100)	(53.97)	(55)	(83.09)
Dysentery	(92.31)	(62.90)	(93.33)	(100)	(73.01)	(42.5)	(79.01)
Diarrhea	(100)	(96.77)	(93.33)	(98.03)	(85.71)	(67.5)	(91.25)
Heat stroke	(96.15)	(83.87)	(96.00)	(88.24)	(87.30)	(87.5)	(90.09)

Source: Field survey 2015, Figure in parenthesis indicates percent value, n=number

Skin diseases and dysentery are the primary diseases which have been identified by the all respondents of Chokghorpakhia village of Chapai Nawabganj and 98 percent respondents noticed diarrhea due to drought followed by heat stroke (88%). 96 percent respondents of Nizampur village were mentioned that heat stroke and skin diseases are the primary health hazard followed by dysentery and diarrhea. In Naogoan, 87.30 percent respondents from Bhabicha were noticed that heat stroke is the primary health hazard followed by diarrhea 85.71 percent and dysentery 73 percent while the respondents of Mollapara were reported 87.5 percent, 67.5 percent and 42.5 percent respectively.

6.7.5 Impacts on agriculture

6.7.5.1 Impacts on crops

Agriculture and production is affected by drought. This part depicts the information related to the damage of crops due to drought.

Table 6.6: Crop damage percentage

Crops damage (%)	Study locations with crop loss in percentage						All (%)
	Rajshahi		Chapainawabganj		Naogaon		
	Parisho n=52	Aye-Hi n=62	Nizampur n=75	Chokghorpakhia n=51	Bhabicha n=63	Mollapara n=40	
Yes	(53.8)	(77.4)	(96.0)	(98.0)	(88.9)	(77.5)	(83.09)
5 and less	(53.8)	(79.0)		(98.0)	(41.3)	(40.0)	(49.27)
6-15			(36.0)		(34.9)	(35.0)	(18.37)
16-25			(26.7)		(6.3)	(7.5)	(7.87)
26=35			(17.3)		(4.8)		(4.66)
36-45			(9.3)		(3.2)		(2.62)
46-55			(2.7)				(0.58)

Source: Field survey 2015, Figure in parenthesis indicates percent value, n=number

Among all, 83.09 percent respondents (n=285) believed that crop damage occurs due to drought and another 16.04 percent respondents (n=55) disagreed with the statement. They didn't believe the interference of drought in crop damage (Table 6.6). It was found that the higher damage occurred in ChapaiNawabganj district. 98 percent respondents (n=50) of Chokghorpakhia village were agreed that less than 5 percent crops were damaged due to drought while 96 percent respondents (n=72) reported from Nizampur (Table 6.6). The percentage of crop damage due to drought in Rajshahi district found lower compare to other two districts. In this district 77.4 percent respondents from Aye-Hi village were reported that the crops damaged due to drought while 53.8 percent respondents from Parisho village. Additionally, Farmers lost money as because droughts destroy their crops. The agricultural lands become cracked due to high evaporation & lack of water; land becomes harder to cultivate. Shortage of water for irrigation is the common problem in the drought prone area. Lack of hardware (irrigation pump and water source) is crucial in the study area especially in Nizampur and Mollapara. If hardware is available farmers need to spend more money for irrigation during drought. The respondents reported that, raid of rats become intolerable in the drought season. The respondents added that, about 20-25 percent crops are being damaged by the rats in the drought prone area. They also added that, every year about two lacs metric ton crops are being damaged by the raid of rats in the whole Barind when drought occurred. Among the three cropping seasons, the *Boro* (IRRI) seasons become most affected by drought. People have to face less rice production with maximum cost and effort due to drought. Sometimes drought occurs so cruelly that the crop start dying just before the harvesting period. The respondents told that, average 20 percent of their crops damaged every year due to drought. The production loss was about BDT4000 per *bigha*. They got at least 200kgs less production per *bigha* when drought occured in the IRRI season.

6.7.5.2 Impacts on livestock

Low rainfall caused shortage of fodder supplies; it leads to the poor pasture growth. In the drought season, cattle are attacked by different diseases and food poisoning. Among them, footrot is very common to the cows in the drought season. The respondents reported that, about 5 percent cattle died when drought occurred. The respondents kept their cattle under shade in day time and gave them more drinking water to reduce drought impacts on cattle. Some people sold their cattle in drought seasons due to the lack of available fodder. To maintain their livelihood is another reason for selling cattle as they remain unemployed in the drought season. The respondents reported that, they need to spend BDT 1000-2000 for the treatment of cattle disease in drought season.

6.7.5.3 Impacts on poultry

Loss of poultry during drought is common in the study locations. The respondents reported that, they lost 25 percent of their chicken and duck due to drought. The respondents having poultry farm, faced a huge economic loss due to the death of chicken. They have no options to save their poultry birds from drought impacts.

6.7.6 Other impacts

The respondents were asked to know other damages due to droughtsrather than crops damage and health hazards. 76.09 percent respondents (n=261) of the study locations claimed that livestock loss was the prime to them. Among therespondents, the higher percentage was found in Parisho village (86.54%) followed by Nizampur (82.67%), Mollapara (80%), and Aye-Hi (70.97%) respectively (Table 6.7). 48.40 percent respondents (n=166) have been identified economic loss as the second tier damage in the study locations. It was found that 100 percent respondents from Chokghorpakhia followed by Bhabicha (57.14%), Aye-Hi (46.77%), Mollapara (45%), Nizampur (29.33%) and Parisho (19.23%) mentioned about economic loss. In addition, 13.12 percent respondents (n=45) mentioned about loss of employment and 18.95 percent respondents (n=65) mentioned about assets loss due to drought.

Table 6.7: Other damage due to drought

Damage/loss	Rajshahi (%)		Chapainawabganj (%)		Naogaon (%)		Total
	Parisho n=52	Aye-Hi n=62	Nizampur n=75	Chokghorpakhia n=51	Bhabicha n=63	Mollapara n=40	(%)
Economic loss	(19.23)	(46.77)	(29.33)	(100)	(57.14)	(45)	(48.40)
Asset loss	(9.62)	(4.84)	(2.67)	(35.29)	(53.97)	(7.5)	(18.95)
Livestock loss	(86.54)	(70.97)	(82.67)	(66.67)	(69.84)	(80)	(76.09
Lossof employment	(5.78)	(3.23)	(2.67)	(13.73)	(47.62)	(2.5)	(13.12)

Source: Field Survey 2015, Figure in parenthesis indicates percent value, n=number

6.7.6.1 Impact on society

Respondents mentioned that drought caused huge impacts to the society. Society people become helpless and hopeless due to anxiety or depression about economic losses caused by drought. Loss of human life occurred especially older people and new born children died during drought. Seasonal migrations have been taken place due to drought. Conflicts rose among water users. Drought also affects the quality of life and increase hunger and famine.

6.7.6.2 Environmental impact

It was observed that most of the canals, *khari*, ponds and wetlands became dry due to lack of surface water and adequate rainfall. On the other hand, rivers are becoming dry during drought period which lead towards water scarcity during drought period. Riverbank erosion and agricultural practices are responsible for the siltation. Remarkable environmental drawbacks were mentioned by the respondents during key informants interview and focus group discussion. Drought reduces biodiversity and causes damage to plant and animal species, damage to wildlife habitat and deteriorating water and air quality. It also degrades landscape quality through loss of biodiversity and soil erosion.

6.7.7 Drought prediction

The respondents predict drought by feeling extreme temperature, lack of rainfall, settled water table and crack of soil for the absence of soil moisture. Some respondents added that, they predict drought by observing the dust in the air, excess evaporation from the water body, color of the sky in the horizon at evening, poor condition of cattle, flapping of birds, aviate of insects especially termites and grasshopper, and lack of water supply by their tube-well due to the reduction of groundwater table. The perception of drought can contribute in chapter seven, how groundwater table is declining due to drought.

Summary and conclusion

Drought perception by its definition was varied from country to country, region to region and site to site. It also varied from person to person and season to season. There is no firm definition of drought. Lack of soil moisture, lack of water, no or less rainfall and high temperature is the indication of drought. People recognized drought sufferings, causes and symptoms in their own words. Agriculture and crops production were affected severely by drought and causing huge economic losses.

Chapter 7: Trend of declined Groundwater table in Barind Tract: Its state and consequences

7.1 Irrigated agriculture and drought

In the chapter six it was discussed how people perceive drought and its impacts on different sectors including groundwater table depletion. They mentioned that groundwater table is decreasing day to day. All most all the deep tube well and tube well do not work during drought especially in summer due to declined groundwater table in the study area. This chapter explores how rain fed agriculture shifted by irrigated agriculture and groundwater is depleting over the times in the study areas. The analysis of static ground water level also indicates present status of groundwater with the future predicted trend. Rice farming in Bangladesh differs with the change of season and water supply. There are distinct three rice growing season in Bangladesh, likely Boro (January to June), *Aus* (April to August), and *Aman* (August to December) wrapping huge land areas in Bangladesh. The contribution of Boro rice was 56.47 percent and 55.77 percent of total rice production in Bangladesh during the period of 2009-10 and 2010-11 respectively[2]. Eventually dry season *Boro* rice production mostly relies on additional irrigation. Drought is risky to crops as they grow depending on rainfallduring the monsoon. Due to lack of surface water in dry season, groundwater substitutes the irrigation water causing relentless groundwater duction and may be an immense warning for future groundwater availability for *Boro* rice production especially in Barind Tract of Bangladesh. The Northern Barind Tract of Bangladesh is currently experiencing water paucity troubles in agriculture and safe livelihood. Monsoon rainfalls and flooding contributes in groundwater recharging in Bangladesh. Barind Tract is situated in the highly elevated and floods free zone. Rainfall is recharging groundwater in this Barind, erratic and low rainfall happens in northwestern part of Bangladesh and the area has turn

[2] Details in the report of BBS, 2011

into extremely drought prone area. Furthermore, the soil types (thick sticky clay) of Barind Tract obstruct groundwater recharging and enhance surface runoff.

7.2 How groundwater decline by drought and irrigated agriculture

The groundwater recharge is also affected if drought occurs in the monsoon. It affects both surface and groundwater situation vis-à-vis the irrigation in the following dry season. The river flow of the Mohananda and the Punarbhava leans to decline during dry season. Groundwater decreasing rate has been increased after crop intensification through Deep tubewell irrigation began in the early 1980s. The Groundwater table in High Barind is depleting continuously over the time especially in dry season due to over exploitation of groundwater by tubewell. Respondents mentioned that groundwater level in this area is declining consecutively over times with escalating extraction of water for irrigation. Careful monitoring on groundwater level for agriculture is essential; there is an immediate need of study on better crop yield and groundwater table suction limit available in the study areas. Bangladesh Agriculture was irrigated by traditional means up to 1950s. The excessive abstraction of groundwater has depleted groundwater table to fall to the degree of not getting fully refilled through natural recharging. This groundwater based irrigation system including deep and shallow tubewells has dropped below the depth in many places of the study areas. BMDA authority is also concerned on these crucial aspects.

7.3 Barind Multipurpose Development Authority (BMDA) and irrigated agriculture

The Barind Tract is situated in the northwestern part of Bangladesh with total area of 7727 square kilometer. Physically this Barind Tract stands between 24°20’N and 25°35’N latitudes and 88°20’E and 89°30’E longitudes. Barind Tract was debarred all through 3000 Deep Tubewell

(DTW) installation programs of BADC in Northwest Irrigation Project allowing for as low impending area for groundwater development[3]. Groundwater development takes place in Barind by creation of Barind Integrated Area Development Project (BIADP) in 1985 under BADC and afterward through creation of Barind Multipurpose Development Authority (BMDA) in 1992. Groundwater reduction rate in dry and wet season is diverse. Groundwater reduction rate in wet season is higher than the rate in dry season. Corresponding Table 7.1, the maximum (100.78%) irrigated lands have been increased at Nachole Upazila over times with maximum depletion of ground water (3.39 feet/yr) and increased numbers (180) of Deep tubewell.

Table 7.1: Irrigated area, number of Deep Tubewell and fluctuation rate of SGL

Description	Locations					
	Niamatpur	Nachole	Godagari	Tanore	Shibganj	Porsha
Irrigated land in 2014 (Hectares)	36915	42213	64949	38717	8655	14010
Irrigated land in 2005 (Hectares)	26415	21025	37176	33299	7280	7390
Difference in Hectares	10500	21188	27773	5418	1375	6620
Percentage increased (Irrigated land)	**39.75**	**100.78**	**74.71**	**16.27**	**18.89**	**89.58**
Groundwater depletion in Feet/Yr	**2.75**	**3.39**	**2.06**	**1.76**	**0.2**	**1.69**
No. of deep tube well in 2014	660	544	714	552	238	283
No. of deep tube well in 2005	522	364	558	489	245	192
Increased/decreased number of deep tube well	**108**	**180**	**156**	**63**	**-7**	**91**

Source, BMDA data (2015)

The maximum numbers of deep tubewell were increased in Nachole followed by Godagari, Niamatpur, Porsha and Tanore respectively. It was observed that the numbers of deep tubewell decreased at Shibganj Upazila.

[3] See report of BMDA,2006

7.4 The state of groundwater as perceived by the local people

During the discussion with the Focus Group participants, they mentioned that groundwater table is decreasing over the times. The pump and shallow tubewell does not work due to low groundwater table. Lot of tubewells and pumps are now out of work. Eventually they reported that they use huge groundwater after intervention of BMDA irrigation project. It needs to find out suitable and vulnerable area of irrigation scheme. So, evaluation is needed to measure the geological condition in this region. Most of the canals, *beels*, *kharies* and ponds of the study areas dry up in the drought period. The people in the study areas are reliant on groundwater for irrigation and other uses. It was reported by the respondents that 90 percent irrigation water comes from under groundwater.

7.5 Sign of groundwater table depletion

Several signs have been mentioned by the respondents during interview and Focus Group Discussions in relation to groundwater depletion. The sign including lack of water availability in the tubewell, water crisis, high temperature, less or no rainfall, dying of ponds, canals and rivers. Most of the respondents (n=285) mentioned that tubewells don't work at that time and it goes out of works (Table 7.2). They mentioned that the numbers of Deep Tubewell and Shallow Tube well are plenty in the study locations. These huge numbers water infrastructures abstracted water from the aquifer as a result groundwater table is going down. They also mentioned that groundwater recharging rate is insufficient compare to amount withdrawal. Hence it makes water deficiency at the aquifer.

Table 7.2: Sign of of groundwater table depletion

Causes	Study location with respondents (%)						
	Rajshahi		Chapainawabganj		Naogaon		All (%)
	Parisho n=52	Aye-Hi n=62	Nizampur n=75	Chokghorpakhia n=51	Bhabicha n=63	Mollapara n=40	
No water from tube well	(100)	(100)	(98.66)	(86.24)	(52.38)	(50)	(83.09)
Lack of water					(14.29)	(5)	(3.21)
High temperature		(1.61)			(14.29)	(5)	(3.50)
Less rainfall		(3.23)				(7.5)	(1.46)
Drying of pond	(1.92)	(17.7)			(20.63)		(7.29)
Drying of river					(1.59)		(0.29)

Source, Field Survey (2015), Figure in parenthesis indicates percent value, n=number

7.6 Analysis of water level hydrographs

By using ten years data, groundwater level hydrographs have been prepared based on fortnightly collected data. The data were collected from monitoring wells of BMDA from 2005 to 2014. Only one monitoring well was considered for each Upazila. The fluctuation of groundwater depth has been shown by the hydrographs. Individual hydrograph has been prepared for each study location showing the fluctuation trend of groundwater table. Respondents mentioned that groundwater table is going down drastically.

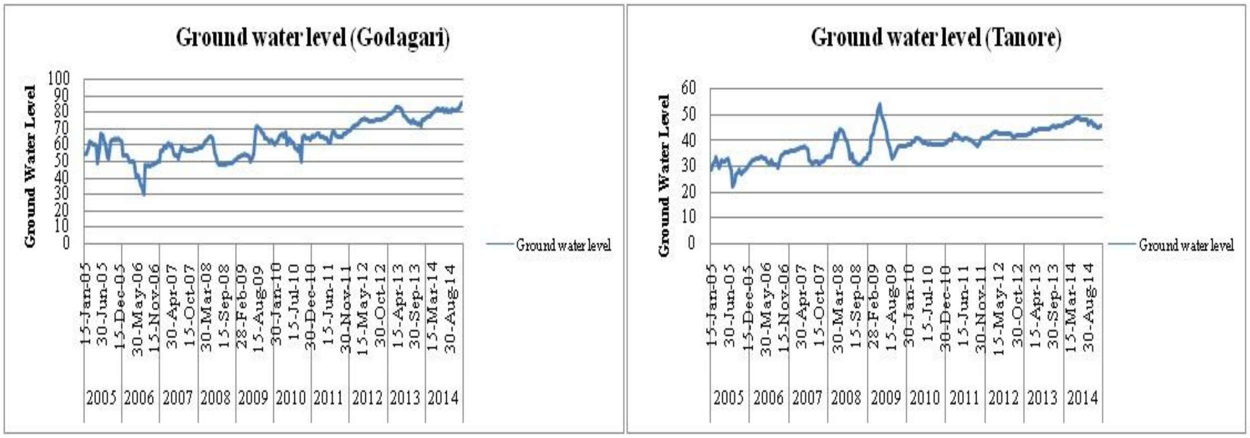


Figure 7.1 Hydrographs for Godagari and Tanore

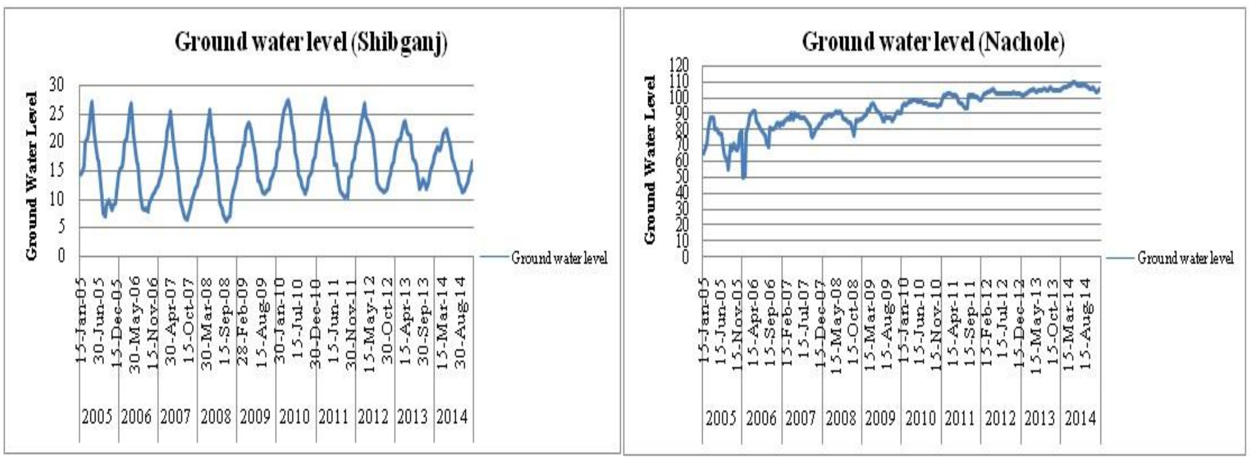


Figure 7.2 Hydrographs for Nachole and Shibganj

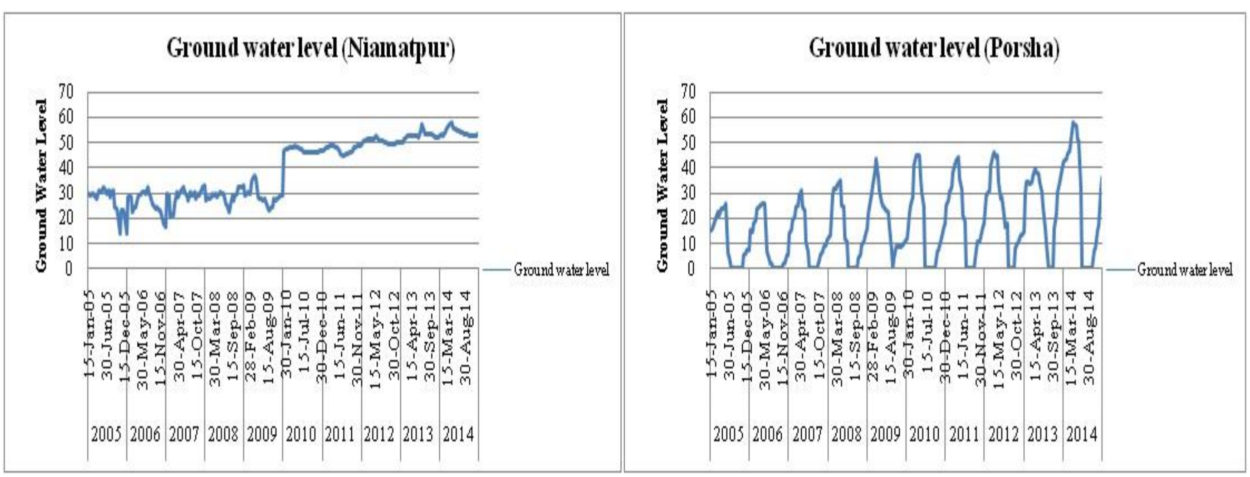


Figure 7.3 Hydrogaphs for Niamatpur and Porsha

Usually it fluctuates each and every year and there is a close relationship with the rainfall and temperature. Increased temperature and less rainfall lead towards low groundwater table. It was observed that the mean groundwater table in Godagari Upazila was 63.9 feet with the maximum 85.8 feet (December 2014) and minimum 30.2 feet (July 2006). Corresponding figure for Tanore Upazila the maximum groundwater table was 53.7 feet (April 2009) and minimum level was 21.8 feet (July 2005) with the average 38.3 feet (Figure 7.1). Shibganj Upazila showed less fluctuation compare to other locations. The hydrograph in Shibganj is more or less very gentle in nature. The average water table was 16.2 feet with the minimum groundwater table 6.2 feet in the month of September, 2008 and maximum 27.7 feet in the month of March, 2011 (Figure 7.2). In Nachole, the lowest groundwater table was 49.7 feet in the month of January, 2006 and maximum groundwater table was in the month April, 2014 (109.4 feet) with average 92.2 feet (Figure 7.2). Niamatpur showed the lowest groundwater table in the month of December 2005 (14 feet) with the highest groundwater table in the month of April, 20014 (58.3 feet) with the average level 39.3 feet. On the other hand, the average groundwater table in Porsha was 17.9 feet. The maximum groundwater table was 58.3 feet (March, 2014) and minimum was 1.8 feet in the month of January, 2006 (Figure 7. 3). The hydrographs of all Upazilas except Shibganj, showed that groundwater table is decreasing day by day but the significantly started from 2010 in most of the Upazilas.

7.7 Ground water restrains

Secondary data were collected from Barind Multipurpose Development Authority (BMDA). Paramanadapur mouza from Godagari, Haripur mouza from Tanore, Chandpur mouza from Shibganj, Somaspur mouza from Nachole, Darajpur mouza from Niamatpur and Balashohid mouza from Porsha were selected for data. Ten years data on static water table (SWL) from six different locations (six wells) were collected for the period of 2005 to 2014. All six locations were considered for the calculation of average SWL for 2014 and 2005 and eventually dry and wet season. Analyzing six wells data, it was observed that groundwater is depleting over the times. The maximum annual depletion rate was found in Nachole followed by Niamatpur, Godagari, Tanore, Porsha and Shibganj respectively (Table 7.3). The maximum depletion rate was 3.39 feet in a year with the minimum depletion rate was 0.2 feet (Shibganj). The rate of groundwater recharge was too low considering withdrawal amount of groundwater in the study area. The water table continued at the maximum depth during dry season and minimum during wet season. The groundwater table is diminishing in alarming rate in the study area of Barind Tract with the expansion of irrigation scheme.

Table 7.3: Average Static Groundwater Level in Feet

Description	Locations					
	Niamatpur	Nachole	Godagari	Tanore	Shibganj	Porsha
Static Groundwater level in 2014 (Feet)	54.4	106.8	80.85	46.7	16.7	27.2
Static Groundwater level in 2005 (Feet)	27	72.8	60.23	29.1	14.7	10.3
Difference in Feet	27.5	33.9	20.62	17.6	2	16.9
Time period (2014-2005) 10yr	10	10	10	10	10	10
Fluctuation in Feet/Yr	2.75	3.39	2.06	1.76	0.2	1.69

Source, BMDA data (2015)

7.7.1 Ground water restrain in dry season

January to May was considered as the dry season due to no or less rainfall pattern. The groundwater depletion rate was calculated based average value of the data for five months from

January to May then put it in the table. Corresponding table 7.4, only shibganj showed no depletion of groundwater during dry season. The maximum groundwater depletion was found in Porsha (2.95 fee per year) followed by Nachole (2.93 feet/yr), Niamatpur (2.53 feet/yr), Godagari (2.16 feet/yr) and Tanore (1.63 feet/yr) respectively. Water table drop and attain at the maximum depth from surface and the height continued minimum from the sea level during dry season. The minimum depletion rate of groundwater in dry season was found in the Shibganj (Chandpur) may perhaps due to close location from the river and soil types which give maximum recharge and higher water retention capacity.

Table 7.4: Average Static Groundwater Level in Feet during dry season (January to May)

Description	Locations					
	Niamatpur	Nachole	Godagari	Tanore	Shibganj	Porsha
Static Groundwater level in 2014 (Feet)	55.3	107.4	79.44	47.3	19.96	50.6
Static Groundwater level in 2005 (Feet)	30	78.1	57.89	30.9	20.23	21.1
Difference in Feet	25.3	29.3	21.55	16.3	-0.27	29.5
Time period (2014-2005) 10yr	10	10	10	10	10	10
Fluctuation in Feet/Yr	2.53	2.93	2.16	1.63	-0.027	2.95

Source, BMDA data (2015)

7.7.2 Groundwater restrain in wet season

The wet season was considered from June to September. Normally rain occurs during wet season in Bangladesh. The maximum 3.96 feet/yr groundwater depletion was recorded at Nachole during wet season followed by Niamatpur (2.75feet/yr), Godagari (1.973feet/yr), Tanore

(1.97feet/yr), Porsha (0.36feet/yr) and Shibganj (0.342 feet/yr) respectively (Table7.5). The depletion rate of groundwater between wet and dry season differ from locations to locations. The lowest depletion rate of groundwater was found in wet season due to availability of precipitation. Groundwater recharging occurs in rainy season in connecting the month of June to October. It was found that around eighty percent rainfall occurs in monsoon period in Bangladesh. The deficit was created by excess extraction of groundwater over recharge. Annual maximum rate of depletion and minimum rate of depletion in Tanore Upazila from five monitoring wells (two different organizations BWDB and BMDA) extend over diverse parts of the study area is 1.04feet/year.

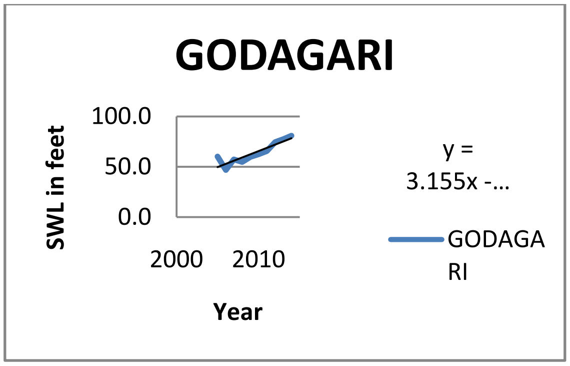
Table 7.5: Average Static Groundwater Level in Feet during wet season (June to September)

Description	Locations					
	Niamatpur	Nachole	Godagari	Tanore	Shibganj	Porsha
Static Groundwater level in 2014 (Feet)	54.1	107	81.11	46.9	14.12	4.7
Static Groundwater level in 2005 (Feet)	26.6	67.4	61.38	27.3	10.70	1.1
Difference in Feet	27.5	39.6	19.73	19.7	3.42	3.6
Time period (2014-2005) 10yr	10	10	10	10	10	10
Fluctuation in Feet/Yr	2.75	3.96	1.973	1.97	0.342	0.36

Source, BMDA data (2015)

7.8 Analysis of Groundwater trend

Groundwater trend have been analysed by using regression equation for different locations from the study areas. Six well data from six different locations were considered for this study. Ten years long term trends of groundwater level of Niamatpur, Nachole, Godagari, Tanore, Shibganj and Porsha. It was observed that in all locations groundwater table is gowing down (figures 7.4, 7.5, 7.6, 7.7, 7.8 & 7.9).



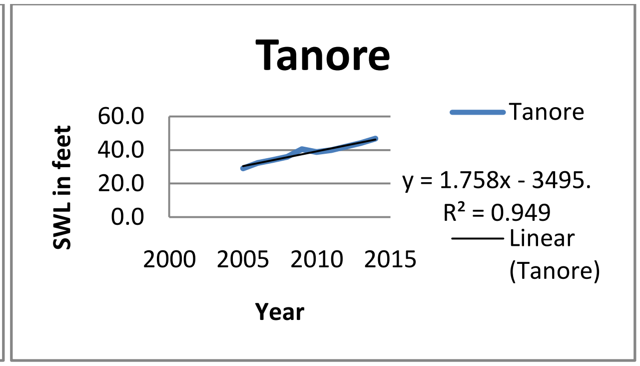
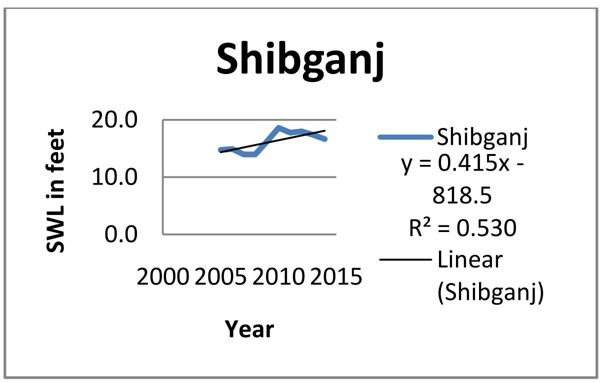


Figure 7.4: Groundwater table regressin in Godgari **Figure 7.5: Groundwater table regressin in Tanore**



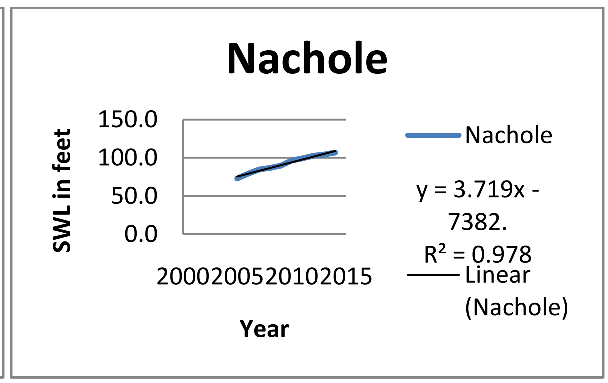
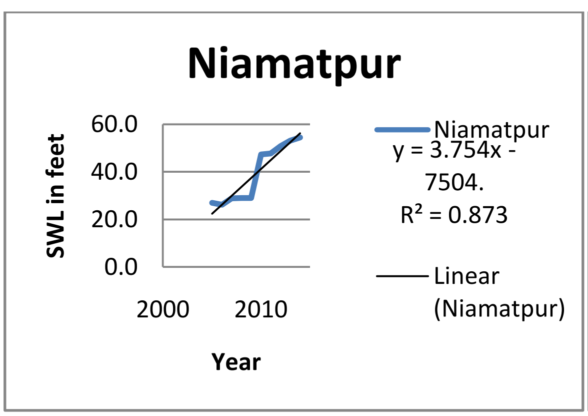


Figure 7.6: Groundwater table regressing in Shibganj **Figure 7.7: Groundwater table regressing in Nacole**



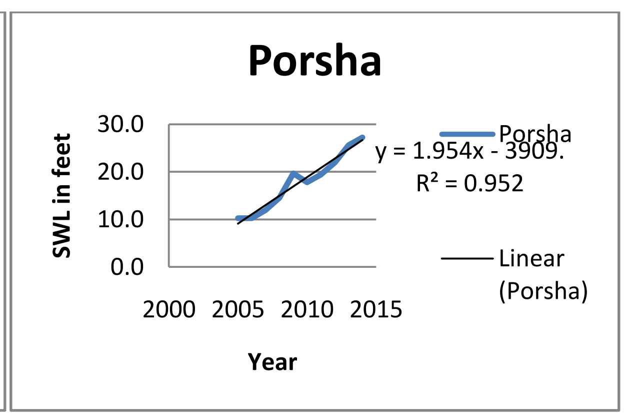


Figure 7.8: Groundwater table regressing in Niamatpur **Figure7.9: Groundwater table regressing in Porsha**

7.9 Predicted Static Groundwater Level using regression equation (2016-2025)

Using regression equation for six study locations, the predicted groundwater table was calculated and it was found that the maximum groundwater depletion will be found in Niamatpur followed by Nachole, Godagari, Porsha, Tanore and Shibganj respectly over following next 10 years (Table 7.6).

Table 7.6: Predicted groundwater table

Year	Location					
	Niamatpur	Nachole	Godagari	Tanore	Shibganj	Porsha
2016	64.1	115.5	84.5	49.1	18.1	30.3
2017	67.8	119.2	87.6	50.9	18.6	32.2
2018	71.6	122.9	90.8	52.6	19.0	34.2
2019	75.3	126.7	93.9	54.4	19.4	36.1
2020	79.1	130.4	97.1	56.2	19.8	38.1
2021	82.8	134.1	100.3	57.9	20.2	40.0
2022	86.6	137.8	103.4	59.7	20.6	42.0
2023	90.3	141.5	106.6	61.4	21.0	43.9
2024	94.1	145.3	109.7	63.2	21.5	45.9
2025	97.9	149.0	112.9	64.9	21.9	47.8

7.10 Testing of hypothesis

Table 7.7: Static Ground water level descriptive indices for six study locations in Barind Tracts (2005-2014)

Determinants	Godagari	Tanore	Shibganj	Nachole	Niamatpur	Porsha
Mean	63.9	38.3	16.2	92.2	39.3	17.9
Maximum	80.9	46.7	18.6	106.8	54.4	27.2
Minimum	46.8	29.1	14.7	72.8	26.2	12.0
SD	10.7	5.5	1.7	11.4	12.2	6.1
CV	107.2	54.6	17.3	113.8	121.6	60.6

The static ground water level data was used to derive descriptive statistics of mean, standard deviation, coefficient of variation with maximum and minimum value for the periods of 2005 to 2014 (Table 7.7). The expected frequencies (Fe) were calculated using the determination for each entry in Table 23, the test statistic is appended below:

$X^{2}{}_{2}= (O-E)^{2}/E$is utilized forstatic ground water level

$$\frac{(63.93-72.5)^2}{72.5}+\ldots\ldots+\frac{(17.9-62.2)^2}{62.2}+\frac{(80.9-77.2)^2}{77.2}+\text{---------}\frac{(27.2-66.23)^2}{66.23}+\frac{(46.8-25.1)^2}{25.1}+\text{----------}$$
$$+\frac{+(12-21.51)^2}{21.51}+\frac{(10.7-12.4)^2}{12.4}+\text{----------------}+\frac{(6.1-10.68)^2}{10.68}+\frac{(107.2-39.4)^2}{39.4}+\text{------------}+\frac{(60.6-33.82)^2}{33.82}$$

=190.7

The level of confidence (99%) and (number of rows-1) (number of columns-1) = (5-1) (6-1) = 20 degrees of freedom, the calculated chi-square value i.e. calculated value is greater than critical value (190.7 › 37.5662). The null hypothesis was denied and hence static ground water level decrease significantly among the locations over times. It was found that groundwater is depleting due to drought and huge withdrawal of groundwater for irrigation in the study area. All of the locations except shibganj are very much critical. The area are usually recharging by rainfalls which is also declining over the periods. Groundwater table is depleting in the study area due to huge withdrawal of groundwater and surface water over times. River flows and rainfalls are the main sources of recharging groundwater. Another hindrance of groundwater recharge is poor infiltration capacity of the soil in the Barind Tract. As a result quick run off is occurred and discharge huge rain water during monsoon. Average depletion rates in the dry season is 2.028 feet/year and depletion rates in wet season is 1.892 feet/year respectively. Rate of declination of groundwater table in dry season is higher than wet season which mean groundwater recharge coming down due to withdrawal of excessive groundwater for irrigated crops. In conclusion, it can be said Upazilas of Nachole, Niamatpur, Porsha, Tanore and

Godagari are very much vulnerable for irrigation. Filling of ponds, siltation of water body and rivers are leading low water reserve for surface irrigation with the ultimate result of groundwater depletion. There is direct relation between groundwater and irrigated crops especially Boro i.e. irrigated rice production and groundwater depletion. Respondents believed that they need to change the cropping pattern instead of irrigated crops. Hence few environmental negative effects may arise like excessive temperature, reduce surface water supplies, erratic or less rainfalls. Diversification of crops from more water consuming crop (paddy) to less water consuming crops (vegetables, fruits etc.), excavation and re-excavation of ponds, canal, khal, beel, cultivation of dought resistant crops (Seasam, mung), Agroforestry, organic agriculture, increasing dependency on surface water, irrigation efficiency application of Alternate Wetting and Drying (AWD) method, rainwater harvesting etc, can be option for the study area.

Summary and conclusion

People are heavily reliant on rain fed agriculture in the Barind Tract. They shifted their agricultural production to irrigated agriculture from rain fed agriculture due to Irrigation facility developed by BADC and BMDA to cope with drought. Huge area has been brought under irrigated agriculture during the period of 1985 to 2014. Huge number of deep tubewell and shallow tubewell established and operated in this period. It was evident from this study that groundwater table is depleting with the passage of time. On an average 3.96 feet is depleting every year during rainy season, eventually the water related infrastructures are not getting water from the sources. It is happening due to huge withdrawal of groundwater.

Chapter 8: Factors influencing crop loss due to drought: Prospects and Challenges

This chapter discussed about the factors that are related with crop loss due to drought. Detail discussions on groundwater table were made in the earlier section mentioning expansion of irrigated agriculture and depletion of groundwater table. Few discussions were made in the chapter five related to status of drought (frequency, scale, magnitude, seasonality etc).

This chapter discussed other factors (low precipitation, drought frequency and non availability of groundwater) that are influencing crop loss during drought. Drought stressors, Impact sectors and different variables (dependent variables and independent variable) were discussed in this chapter.

8.1 Crop loss factors

Mostly drought affects rice crop in three different seasons. In March and April, it creates problem in land preparation and delay planting during monsoon. Secondly, inadequate rains in July and August delayed transplantation in highland areas, while droughts in September and October reduce yields of delay sowing of pulses and potatoes. Several crop loss factors are associated in relation to socio-economic and environmental contexts among study locations in Barind Tract, the information gathered in following heads:

1. Drought stressor: Factors that lead towards drought including erratic and low rainfall, high temperature (extreme heat), depleted groundwater, low soil moisture and inadequate stream flow and water. This includes weather extreme related parameters and frequent and gradual changes over time.

2. Drought frequency: Focus on frequency of drought occurrences over space, time and scales. This may twice in a year, every year or concurrently after one or few years.
3. Households' income: This refers total family income (socio-economic determinant from chapter four) and its contribution to family economy. More income households can tackle drought than having low income households
4. Agricultural land: The land used for the cultivation of agricultural crops. The household having more land, there is a chance of more crop loss but they can manage drought by adopting wide range of options like changing cropping pattern or through crop diversification.
5. Mitigation measures: Short term measures including migration, taking supports (food, cash and others) from relatives and friends, re sowing & early sowing and migration are the few options to cope with crop loss due to drought (see details in chapter ten).
6. Adaptation measures: refers to long term measures (supports from individuals, BMDA, DAE and NGOs) in addressing drought, farmers adopts irrigation agriculture to reduce crop loss instead of rain fed agriculture (see details in chapter eleven)
7. Livelihood diversification: Occupation and livelihood options. The households having diverse options can manage crop loss risks better than those having limited livelihood options due to drought. The alternative livelihood options may include nursery business, day laborer, small business, van pulling etc.
8. Loss of assets: This effort is treated as the last effort to manage crop loss related to drought. This may include dismal of housing structure, selling of land or other accumulated assets

Boro rice, wheat and other crops are also periodically affected by drought during dry season. Drought causes eighty percent *T.aman* crop loss in High Barind Tract in September-October due to delayed planting. Drought reduces food production, frequently rise prices of food grains. These lead to non availability of employment and food entitlement of rural people, particularly the small farmers, lease farmers and landless laborers. The drought victims often are get support from relatives, neighboring rich people. The loss comprises the incapability to respond satisfactorily to drought and the costs and bad effects linked with the adaptation and coping measures themselves. The negative effects and costs may be both economic and noneconomic.

8.2 Crop loss, drought stressors and impact sectors perceived by the respondents

Several climatic stress factors including erratic and less rainfall, high temperature and lack of ground water were reported by the respondents that affect crops due to drought. On the other hand, maximum respondents adopted measures to reduce crop loss from chokghorpakhia followed by Parisho, Aye –Hi, Babicha, Nizampur and Mollapara respectively. Similarly it was reported that maximum number of respondents from Chokghorpakhia lost crops followed by Nizampur, Babicha, Mollapara, Aye-Hi and Parisho respectively.

Table 8.1: Drought Stressors, impact stressors, responses and loss and damage (% of households)

Locations	Drought related climatic stressors	Experienced climatic stressors (%)	Adopted measures (%)	Crop loss (%)
Parisho	Erratic rainfall	100	98	59
Aye-Hi	High temperature	100	98	79
Nizampur	Less rainfall	100	95	92
Chokghorpakhia	Less rainfall	100	100	98
Bhabicha	Lack of groundwater	100	98	90
Mollapara	Lack of groundwater	92	77	82

Source: Field survey 2015

100 percent respondents from Parisho mentioned that they experienced erratic rainfall as the climatic stressors and 59 percent respondents lost their crops though 98 percent adopted measures for drought (Table 8.1). Several impact sectors were mentioned by the respondents. Crops, economics, livestock, housing and physical assets are mostly impacted by drought. The maximum percentage of the respondents from chokghorpakhia opined that crop loss as the impact sector 1 followed by Nizampur, Babicha, Aye-Hi, Mollapara and Parisho respectively (Table 8.2).

Table 8.2 Impact sectors (% of households)

Locations	Drought related climatic stressors	***Impact sector 1 (%)***	***Impact sector 2 (%)***	***Impact sector 3 (%)***
Parisho	Erratic rainfall	Crops (54)	Economic loss (19)	Livestock (87)
Aye-Hi	High temperature	Crops (77)	Economic loss (47)	Livestock (71)
Nizampur	Less rainfall	Crops (96)	Economic loss (29)	Livestock (83)
Chokghorpakhia	Less rainfall	Crops (98)	Economic loss (100)	House (67)
Bhabicha	Lack of groundwater	Crops (89)	Economic loss (57)	Livestock (70)
Mollapara	Lack of groundwater	Crops (77)	Economic loss (45)	Phys. assets (80)

Source: Field survey 2015, Figure in parenthesis indicates percent value

Economic loss as the impact sector 2 has been mentioned by the respondents from chokghorpakhia followed by Babicha, Mollapara, Aye-Hi, Nizampur and Parisho. Live stock, housing and physical assets were reported as the impact sector 3. The maximum number of respondents was reported live stock as the impact sector 3 from Nizampur and only 67 percent respondents from chokghorpakhia reported housing as the impact sector 3. A first order impact of drought is observed in the form of less food production (decrease in area and yield). The second order impact is lead to less employment and low income. Sometimes they are bound to buy food by selling their lands, household goods, and livestock at distressed prices. Eventually few people dismal their housing structure often start short term migration. People manage and consume wild plants, tubers, and leaves not normally eaten during the usual time. The shock of drought extends inexplicably in the northwestern Barind Tracts.

8.3 Factors influencing crop loss due to drought

Numerous variables, likely (1) family income, (2) drought frequency for both time scale and intensity, (3) locations of the respondent (high to low drought prone area), (4) sex of the respondents (male and female), (5) migration (short term and long term either short distance or long distance), (6) age of the respondents, (7) support during and after drought (cash, kinds and incentives), (8) Occupation (agriculture and others) and (9) agricultural land owned by the respondents were considered as the independent variables. Crop loss was considered as the dependent variable for this Least Square Model. The results showed that apart from income, gender, migration and age of the respondents, all other variables had significance influence on crop loss due to drought. Drought frequency, locations, support, occupations and agricultural land were taken as the significant variables for this model. Recurrent and frequent drought cause huge loss to the crops in the study area. As mentioned by the respondents that drought frequency is increased due to several factors including climate change, huge ground water abstraction and erratic & less rainfall in the study area. There is a significant relation with the crop loss and drought frequency (Table 8.3). Drought frequency in the study area is increased over the period as mentioned by the respondents. It depends on time scale and duration of the particular period of the year. Drought effected at the end of late *rabi* and beginning of *kharif-1* most severely. Study locations were varied by the geographical settings. At the same time the locations were affected in different scale by drought. The locations were categorized based on drought severity ranking. The findings also showed that there is significant different of crop loss with study locations. The degree of crop loss varied with locations according to low to high drought locations. The higher crop loss percentage was observed in the high drought prone locations. Eventually support is very much important in the drought area. The respondents those received support (cash, kinds, irrigation, technology, resistant variety) could manage crop loss effectively. Usually support come from relatives, friends, neighboring people, concerned nation building department (DAE), NGOs, and BMDA. The farmers who received more support can manage crop loss better than other farmers. Occupation is another factor and the key determinants of crop loss. The respondents belongs to agriculture are very much susceptible to crop loss. They have no options to cope and manage with drought impact. The respondents rather than agriculture can manage their loss with varied earnings. Again agricultural land is also responsible for key significance of crop loss. Those farmers who have more agricultural land are subject to more crop loss due to drought. It was observed that who are actively involved with agriculture affected more than who are not involved with agriculture. As discussed in the earlier, the majority farmers are poor, actively involved with agriculture and severely affected by drought. Those respondents having more assets (cash, livestocks, poultry and diversified livelihood options) are in better position compared with those having only few assets. The household having more support including access to credit/loan, borrowing, diversified livelihood options, more working people in the family, varied occupational skills are able to manage better of drought loss (crop loss) due to drought than others. This study showed that any kind of support is very much important to manage drought loss. Barind Multipurpose Development Authority is supporting enormous support to combat drought and its loss. The study demonstrates that any kind of support either from individual or from government or from NGOs is very much significantly related to the dependent variable drought loss (crop loss). It directs that crop loss would increase as the supports withdraw. In the context of Barind Tract, the active adult number in the family is very much crucial for earnings. The households those have more active adult members can manage better loss than who have less active adult members in the family. In adventto this study it was expected that family size would have a positive sign, the logic being that large family size makes available more labor which can actively engage in work, better facilitating the adoption of adaptive measures against drought effects.

Table 8.3 Ordinary Least Square

Variable	Coefficient	t-value	Significance
Income in (BDT)	.0505201	1.77	0.078
Drought frequency (dummy)	.9467631	-6.67	0.000
Locations (dummy)	-.0896118	-7.62	0.000
Gender (Male and Female)	-.1078469	-1.21	0.226
Migration (dummy)	.0751319	0.32	0.753
Age (years)	-.4551044	-1.96	0.051
Support (dummy)	-.185442	-3.46	0.001
Occupation(dummy)	.466802	2.79	0.006
Agricultural land (decimal)	.3468439	20.18	0.000
Constant	2.541278	5.79	0.000
R-square: 0.6095			

Source: Field survey 205

The rural economy of Bangladesh is mostly depending on agriculture. The agriculture of Bangladesh is relies on manual labour that indicates family labour. Thus the household having more active members involved in economic activities would be an asset in income generation deploying themselves in diversified livelihood activities ultimately which led to better drought loss management. Therefore, it can also be argued that those households having more diversified livelihood occupations, extended more support can manage drought loss better than those household having less support and single occupation like agriculture. The regression model (Table 8.3) indicates that age is negative and significantly (at 10% level) related to crop loss factors due to drought effects. It indicates that the probability of adaptation significantly decreases the older respondent. It can be assumed that older farmers have less interest in taking drought adaptation measures. Perhaps older farmers do not see the necessity to adapt to drought effects. Moreover, they are interested in following traditional methods rather than adopting modern farming techniques.

8.4 Ways for minimizing crop loss

Drought frequency is increasing due to climate change in globally. We can't deny it but we can adapt few measures for the better management of drought loss in sustainable manner. Small and poor vulnerable farmers can not able to cope up with the drought impacts due to poverty and incapability. It is almost impossible to adopt mitigation and adaptation measures. Over the time, the farmers were habituated with the drought situation and they can tackle it by intermingled of adoption technology, social resilience and livelihood options. Drought damage also can be managed by better management options. Crop production is severely affected by drought, if it beyond the management capacity. In severe situation drought caused huge crop loss to the farmers. Better management options prevail with the social resilience. If the society can hunt available livelihood options, they can tackle drought situation better. Several factors are responsible for crop loss. Drought frequency is one of them. Though the study locations are experiencing drought frequently, the farmers were able to minimize crop loss through better management options. It means that they were used enhance management tactic to reduce crop loss. Several options were adopted by the farmers including better irrigation, enhanced irrigation efficiency, crop diversification. Farmers who have increased income they can manage more irrigation than poor. On the other hand, farmers who have more land they can grow diverse crops in planned way than poor farmers. Irrigation at night increased water use efficiency of the soil and crops by minimizing transpiration loss and evapo-transpiration loss. In some extent the farmers are using AWD method of irrigation through which irrigation efficiency has increased 40-50 percent. Social resilience is very much important in reducing crop loss, the farmers get support from neighboring large farmers (cash and inputs), relatives and friends, NGOs and government support for better management of the crops during drought. People have increased access in the diverse employment opportunity to reduce the impacts of crop loss due to drought.

Re-sowing, early sowing, late planting are the few adaptation measures through which farmers can reduce crop loss. Migration also help them in managing crop loss due to drought, usually they do short term migration to the nearby city from rural areas. Even they migrated from rural areas to Dhaka city, Chittagong and Rajshahi city. This is only for cash income. These incomes help them to live better and for the better management of the next crops.

There are several options for livelihood in the study area including trading, van pulling, handicrafts and nursery establishment. The nursery business and trading contributes significantly to tackle with drought and crop loss. It is expected that the farmers are able to make surplus income through diverse livelihood options and can manage drought better.

The four pathways to loss and damage suggest that policies to address loss and damage must consider:

- Recurrent drought frequency (strong influence on all pathways to loss and damage). Success in avoiding situations in which society faces loss and damage.
- Policies geared towards addressing, restoring or otherwise making up for adaptation costs that are not regained.
- Policies geared toward increasing resilience (such as reducing exposure, addressing underlying vulnerabilities that affect the coping and adaptive capacity of affected people). The research showed that many households surveyed employ a variety of approaches to get by, although many of these have longer-term erosive implications for livelihoods and well-being. If social vulnerabilities to climatic and other stressors are root causes of loss and damage, then improving social resilience provides some of the solutions.

Summary and conclusion

Several factors (variables) are influencing crop loss due to drought. These are drought frequency, support, occupation, agricultural land and locations. Those have more agricultural land and heavily depend on the occupation (agriculture) are more vulnerable and significantly affect crop loss. Drought frequency is the important factor (significant variable) of crop loss due to drought. Finally, questions arise about what policies may be appropriate and needed to address situations where adaptation measures to particular kinds of climatic stressors are no longer possible. In such areas, there are already *limits to adaptation* due to issues such as the scope of the biophysical impact or the degree to which a society can deal with the impact

Chapter 9: Use of Indigenous knowledge in drought prediction and drought management

In the chapter eight it was discussed how various factors influence crop loss during drought. It is very much important to know the drought frequency and knowledge of drought prediction for effective management of drought. Local people especially ethnic people (*Santal*) and elderly people from different religions used few symbols/indications or signs in predicting and managing drought and weather extreme. This chapter eventually discussed all ways of predicting and managing drought by using their local wisdom and indigenous knowledge.

9.1 Indigenous knowledge used to predict drought and weather patterns

The study area is prone to natural disaster (drought) and caused huge damage to the crops, livestock, fisheries, horticultural production and livelihoods. The indigenous knowledge that is unique to every society. Indigenous knowledge is very much useful in local level decision making for agriculture, natural resource management, economic activities, and host of other activities of rural societies. People tried at their best to use nature indication to predict natural disasters and extreme weather event prior to modern technologies. It is the time to integrate indigenous knowledge systems with modern technologies can contribute a lot in managing natural disasters or extreme climate events of Bangladesh. Few methods were used to predict drought and weather patterns in the study areas. The respondents from the study area used few indications based on animal's behavior and few characteristic of weather parameter (Table 9.1).

Table 9.1 Use ofindigenous knowledge in predicting drought and weather patterns

Predictors/sign	Description
Pigeon feathers	Pigeon lying on the ground by spreading its feathers, the indication of drought
Sound of wild cat	If the wild cat make sound with *Dhul/Mul* and people ask to the wild cat and response with *dhul* then drought may occur
Ant's upward movement	If ant starts to move upward from down, rain may come
Red colour in the west sky	If the sky shows bright red colour in the west sky during sunset, drough may come in the following year
Sun light's kid	If sunny days shows illusion like *roder bachha,* droughtmay occur
Thunder in the east sky	If frequent thunder happen in the east sky at night, it indicates drought in the next year
Abundance of termites	When large number termites found in the mound,drought is the immense issue for the year
Visibility of black ant	Appearance of black ants and storing grain and eggs in safer places indicate that the rain follows for couple of days
Hoppers fly	If hopper flies randomly, drought may occur
Frog's cry	At the end of summer, the cry of frog is taken as the indicator of approaching rainfall
Dark clouds on the west sky	The appearance of dark clouds on the west, the immediate hail storm accompanied by thunder, lighting and *kalboishakhi*
Chirping of Fatik bird	The chirping of Fatik bird during October to April is a sign of rainfall
Rain bow	If rainbows come in eastern sky there would be chanceof drought and if it comes in the western sky indicates sure rain.

It was mentioned by the respondents that the lying of pigeon on the ground by spreading its feathers was taken as the indication of drought. The sound of wild cat with dhul was also taken as the sign of drought for the year. Ant's upward movement from down was taken as the indication of immense rainfall. Local peoples were used their indigenous knowledge in predicting drought. If the west sky appear with bright red colour during sunset, that was taken as the indication of drought for the year too. Sunny days with the strong sunlight and high temperature give reflection of rays look like *roder bacchha* (Sunlight's kid) was also taken as the indication of drought. The frequent lighting followed by thunder in the east sky at the night was considered as the sign of drought. Termites den and mound in dry soil was thought as the indication of immense drought. Again, Termites den and mound in wet soil was thought as the indication of immediate rainfall. Black ants accumulating eggs and grains in secure places were also indicated that the rain follows. Blaring/croaking of frogs was taken as the sign of heavy rainfall. If a snail climbs on trees, earthworm crawls plenty in and around; Ants move to safer places, all these were taken as the indication of extreme weather followed by heavy rain. Flying of hoppers was also indication of drought. Swarming of worm over cow dung was taken as the sign of heavy rain. If rainbows come in eastern side that was considered as the indication of drought and if it comes in the western side was taken as the sign of definite rain. Apperance of dark clouds on the west sky during summer was also taken as the indication of cyclone locally known as *Kalboishakhi*. The chirping of *Fatik pakhi* during the period of October to April was taken as a sign of immediate rainfall. These types of indigenous or local knowledge were widely used in the rural communities in the study sites. Older and illiterate people are very much fond of using local knowledge on prediction of drought and weather pattern. Few methods used to predict weather patterns and drought were linked to belief, myths and superstitions and their usefulness were not proven.

9.2 Indigenous knowledge used to protect drought impact and extreme weather

The peoples are eventually habituated with the use of indigenous knowledge system for the management of drought impact and weather extreme management. This knowledge is running over generation to generations. Drought is the severe disaster in the Barind, and the study areas are more vulnerable to drought. Few peoples especially from Hindus family organized frog's marriage to end drought (Table 9.2). The practice is superstitions and its functionality on ending drought has not been proven scientifically, but this was their old aged practice. Another way to protect drought and extreme weather impacts was to use of mulches around fruit trees at their homestead and crop field for horticultural production. The practice conserves soil moisture and reduces the impact of extreme temperature by lowering soil temperature. The other means of protecting drought impacts was establishment of mango orchard. Large numbers of farmers were established mango orchard instead of grain production to protect drought impact on production. The planting of trees believed to be immediate measures to protect drought and extreme weather impact. People in the study areas were planted huge numbers of trees including fruits and timber trees. Homestead agriculture is the common practices in the study areas, especially women were grown vegetables in their homestead for their own consumption and surplus sell to the market. Comparatively it is easy to manage home garden rather than field crops during drought. Eventually few peoples were migrated alone and or along family to the urban areas for short term migration and they returned to their home after immediate end of drought.

Table 9.2 Use of indigenous knowledge in protecting drought impact and extreme weather

Practices	**Description**
Frog's marriage	People in the study areasarranged frog marriage inviting immediate rainfall to end the drought.
Use mulch	Farmers used straw and water hyacinth as the mulch materials in the horticultural production at their homestead to protect drought impact on production.
Orchard establishment	Farmers established mango orchard at their homestead and the crop field to mitigate drought impacts as a whole
Planting of trees	People in the study areas planted trees especially palm trees to reduce drought impacts.
Short term migration	Farmer alone or along with family members migrated to the urban areas for livelihoods and returned to the home after drought effect.
Home gardening	People of the study areas especially the women started vegetables gardening in their homestead to protect drought impact on agricultural production

9.3 Indigenous knowledge used to mitigate drought effects

The common mitigation and coping measures against drought include local methods of storing water, food habits, field practices and use of traditional medicine to treat diseases associated with drought. Drinking water is scarce during drought and it become very warm during drought period. People in the study areas collected drinking water from far away and store it into mud pot to keep water cool during high temperature and drought (Table 9.3). The rural poor people have no refrigerator to make water cool for their essential drink. They used mud pot to make it cool and store drinking water. The farmers used special type hat made of bamboo which is locally known as *mathal* to protect them from extreme sunlight at the time of field works during drought. They were also used moringa leaves as vegetables to protect them from *khora* and balancing body temperature during drought. Local people used brown palm sugar to prepare soft drink (*shorbat*) to keep them cool and sound during drought. Few wild vegetables were consumed by the local people to sustain their livelihood during drought. Eventually the peoplein the study areas wrapped themselves with wet clothes to feel comfort during severe drought and extreme high temperature during day time. Most of them were taken two to three times bath in a day to feel better. They changed their food habits during drought. They ate *kolai ruti* (Bread) to sustain them from long time hunger. They believed that this bread meet their hunger for long time. Drought resistant and drought tolerant crops were grown by respondents when they found signs of immediate drought and low rainfall.

Table 9.3: Indigenous knowledge used to mitigate drought effects

Practices	Description
Use of mud pot	Mud pots (*Matir kolosh*) were used to keep cool and store drinking water during extreme hot days
Use of *mathal*	Farmers were used special hat made of bamboo locally known as *mathal* to protect them from extreme sunlight during drought
Eat moringa leaves	Peoples in the study area were used moringa leaves as vegetable to balance their body temperature
Use palm brown sugar	Peoples in the study area were usually used palm brown sugar to keep them cool during hot event especially during drought
Wrapping with wet clothes	Farmers were used to wrap their body with wet clothes to make them comfortable in the field or home during drought period
Eat *kolai ruti*	Peoples in the study area eat *kolai ruti* (special bread) to meet hunger during drought. This type of bread keeps them away from hunger for long time.

9.4 Local measures taken by rural poor to manage drought and extreme weather patterns

In managing high temperature, they respondents were usually taken two times bath during hot. They drink more water and store water for future use. They applied grasses on the tin roof and provide extra ceiling (made of bamboo or wood or clothes or jute stick) to manage extreme hot. Eventually they planted more trees surrounding their homesteads (Table 9.4). They were purified pond water by using fitkary or boiling water during drought. Advance fishing was done in the early stage of drought and dries them to store for future usability. Few infrastructural measures were adopted by the local people including excavation or re-excavation of ponds, canals or mini-ponds to store water for domestic use and irrigation.

Table 9.4: Drought and weather extreme trends

Extreme weather patterns	Impacts
High temperature	In case of tin shed roof, spread grasses on the roof to keep it cool
	Provide bamboo/wooden ceiling to protect extreme hot
	Drink more water
	Store water
	Planting more trees
Drought	Excavate pond/well or mini-pond to store water
	Treat water before drinking like boiling and use of fitkari
	Preserve all fish before ponds dry

The local knowledge found in rural communities in Barind is a combination ofskillsand techniques gained through experiences to live and survive the own way of life. Not all the local knowledge still has remained relevant. The people have developed a wide array of coping strategies, and their local knowledge and practices provide an important basis for facing the even greater challenges of drought. Though their strategies may not succeed completely, they are effective to some extent and that is why the people continue to follow these. Rural communities will need additional support to cope up with the drought and climate extreme, their expertise will offer a great help for the effective management of natural disasters. The spiritual concept of drought could be broken to support environmentally sustainable practices which can act to reduce drought vulnerability at the local level. It was argued that rural peoples can offer useful solutions to climate adaptation, not only because they are capable of recognizing and interpreting the nature of changes, but also they take up the roles of environmental stewards, based on the notion of theological stewardship, as a God given duty[4].

[4] See Golo and Yaro (2013)

Summary and conclusion

Indigenous knowledge is very much important in drought prediction and weather extreme management. Still now rural peoples used few indications of weather, animals and insects behaviour for drought prediction and used local knowledge for weather extremem management. They believed that this knowledge is very much effective in drought prediction and weather extreme management

Chapter 10: Drought management and mitigation measures

10.1 Mitigation and Coping mechanism

Earlier chapter (Nine) has been discussed on use of indigenous knowledge in drought prediction and management of extreme drought events using their experience knowledge. This chapter discussed how the respondents apply their in hand experience to mitigate drought impacts (loss and other consequences). The coping strategy mainly involved in short term adjustment while adaption is the long term adjustment. Coping is a means of short term response to an immediate impact (for example, one season). The practical implication of coping and adapting is that coping strategies of today are likely to undermine opportunities for adaptation in the future, through unplanned and unwise use of resources.

In advance of adaptations, the respondent from the study areasapplied few coping measures to mitigate drought impacts. The coping measures are often more reactive than the adaptation measures in response to drought. The sale of livestock, borrowing money from others, short term migration to other places and labour sale also to cope with short term shocks. Change of food habits during the drought is one of the coping strategies in the study area. Searching of wage labour in towns, van pulling and minimizing consumption is also other coping strategy of drought management. Drought coping strategies varied from place to place and from household to household based on demography and socio-economic characteristics. Households were practiced various adjustment at the household and community level to cope with drought with the support from several institutions and others. Find out the coping measures through discussion, consultation with the key informants and single respondents using structured questionnaire. Researcher mentioned that loss management is the household survival strategy to assure ability. Eventually he has reported that households in drought prone environments consistently endure series of asset depletion and replenishment. In a sense a household can survive successfully a drought if she/he can keep together all the productive assets. There is wide range of options and only a few have a significant impact and others are options only for specific locations in practice.

10.2 Household level agricultural coping strategies

Cattle, sheep, and goats are the most important means of wealth storage and reproduction in the study areas. Ninety percent of the surveyed households owned at least one of these three. Cows emerge to be the means of wealth storage, as they are kept primarily for their milk, meat and resale value. Chicken and ducks are the only species owned in significant numbers by women for getting eggs, meat and cash earning from sale. Country chicken and sheep are particularly well adapted to survive drought conditions. In all six Villages, most respondents that sold poultry and livestock purchased grain during the drought crisis. To meet survival needs during the month April to August, more farmers sold animals (chicken, duck, goats, sheep and cows). Farmers adopted crop replacement techniques through cultivation of diverse crops including wheat, onion and vegetables instead of rice farming. Vacancy filling and irrigation is very much common in the study area. Vacancy filling is practiced where poor germination was found or seedlings have been died after germination. Re sowing or re-planting is the common practice to cope with crop loss due to drought. Re-sowing is done after *aus* rice have been sown when poor germination may occur due to lack soil moisture. Poor germination may occur due to poor quality of seeds. Replanting is also another adjustment for irrigated rice variety especially for *T. aman*, and *Boro* rice if drought occurs after immediate of planting when the young plants die due to lack of water/irrigation or soil moisture. This practice is not useful if drought take place later stage of crop growth. In this case, farmer can compensate through irrigation where water sources and facility is available. Ponds, canals and *Khari* can contribute as the water reservoirs during the late monsoon. Usually farmer plough their land just immediate after of shower and weed out their crop fields to conserve soil moisture by reducing evaporation and evapo-transpiration. Farmers changed cropping pattern to cope with drought. This was earlier adjustment in their farming but now days they are doing intensive rice farming depend on BMDA irrigation scheme. Department of Agriculture Extension and BMDA are giving suggestion to change their cropping pattern by providing focus on less irrigated crops. Early planting is another option to the farmers to mitigate crop loss due to drought. Eventually farmers are practicing late planting of crops to address drought loss. The above mentioned measures were practiced by the middle class farmers. Results found that this was mainly because of middle and large holding can afford better than poor holdings. The water is the most important solution to manage drought, cope to drought and mitigate impacts of drought. Poor farmers arranged irrigation for short period either using surface water reservoirs (mini ponds, ponds, canal and *khari*). Though the farmers are financially able to invest to dig ponds and well or could get institutional support to do that, there is no certainty the well have enough water because of watertable goes down day by day. 94.46 percent respondents (n=324) managed their crops through irrigation during drought (Table 10.1). 72.60 percent farmers (n=249) coped with drought either early sowing or planting of crops. Only 18.37 percent respondents (n-63) used late planting to reduce crop loss due to drought. In Parisho village, 98.08 percent respondents (n=51) coped with drought by irrigation followed by early sowing, re sowing, planting new crops, applying mulches and late sowing or planting respectively. In case of Chorghorpakhia, 100 percent respondents (n=51) used early sowing followed by irrigation, planting new crops, applying mulches, late sowing and re sowing of crops. Dry season gardening is possible and feasible only where there exist accessible reserves of irrigation water or substantial residual soil moisture. Other options are gathering of wild food including plants and animals, as well as of hunting and fishing.

Table 10.1: Coping mechanism to reduce drought loss

Coping measures	Study locations and measures to reduce drought loss (respondent %)						All (%)
	Rajshahi		Chapainawabganj		Naogaon		
	Parisho n=52	Aye-Hi n=62	Nizampur n=75	Chokghorpakhia n=51	Bhabicha n=63	Mollapara n=40	
Early sowing/planting	(98.08)	(48.39)	(78.67)	(100)	(47.62)	(70)	(72.60)
Late sowing/planting	(3.85)	(50)	(1.33)	(9.80)	(26.98)	(22.5)	(18.37)
Irrigating crops	(98.08)	(96.77)	(94.67)	(96.07)	(98.41)	(77.5)	(94.46)
Applying mulching	(13.46)	(3.23)	(1.33)	(9.80)	(22.22)	(30)	(11.95)
Re sowing/planting	(26.92)	(50)	(5.33)	(7.84)	(42.86)	(55)	(29.74)
Sowing/planting new crops	(23.08)	(8.06)	(2.67)	(70.59)	(25.40)	(20)	(23.03)

Source: Survey data, 2015, multiple responses, Figure in parenthesis indicates percent value,

10.3 Household level non agricultural coping strategies

Wide array of options was practiced by the respondents to cope with drought. It is the tradition to stack the household belongings with them. At first the respondents start cutting back on ritual forms of spending and by clearing up nonproductive assets. Households also collect foodstuff as the aid; this does not generally require individual sacrifices beyond being present when and where the food distributions are taking place.

It is hardly found that the people disposed their belongings in normal circumstances. At first the farmers were tried with their own savings and then borrowing money from friends, relatives and others. If this is not sufficient during prolonged drought then they borrowed money from *Mahajon* or NGOs or bank with interest. The *Mahajan* was charged very high rate of interest with critical payback period. NGOs charged moderately lower than *Mahajan* but higher than Bank. Farmers sold their households assets during extreme food hunger. First time they tried with changing of food habits, followed by compromising with the frequency and quantity. They tried with harvesting of wild food to ensure regular breads for the family. Farmers sold their land or lease out land in the extreme situations. Mortgage of land is the common practice in the study area. Like other disasters, farmers mortgaged out their own land for theirlivelihoods. The rich and middle class farmers are in better position than poor farmer during drought. Many respondents were mentioned that they sell their poultry birds including chickens, ducks and pigeons during drought crisis. Some time they sold their livestocks including buffalo, cows, goat and sheep to meet their family expenses. Few respondents disposed housing structures during drought too. The permanent type of migration of family member is very rare in the study area. Seasonal migration happens to look for new employment to meet the household expenditure during severe drought. Respondents were mentioned that they were shifted them from one profession to another likely van pulling instead of agricultural wage labour. It was less important to sales of assets rather than livestock. In case of larger loans especially from outside was secured by the assuring of land. Usually direct sales of land appear not to have taken place. Respondents mentioned that farm equipment sales were very minimal. Most of the respondents practiced manual agriculture. Hand tools owned by an average household were inexpensive when new and of very low resale value. Inthe months before the new harvest, food aid played a significant role in providing households with nutritional subsistence.

10.4 Individual level coping measures

This depends on lot of factors including income, land holdings, educations and occupations. The small and medium famers made adoption strategy relatively greater than rich people. Most of the respondents were made individual adjustment to cope with drought. In this case, they started with the changing in food habits. Sometimes, members of many households eat less to tackle the crisis. As it was mentioned in the earlier of this section, the adjustment varies from household to household depending aforesaid factors. This adjustment started with the women followed by adult (who have no work during drought) and extended to elderly people. Often they start taking two times foods and then change menu. They ate *kolai ruti* instead of rice. This bread can meet the hunger for long times. They were also reduced the intake quantity of food for their consumption in their daily dish. At the same time they were also cut off their personal expenditure considering priority ranking. The people who are living in the drought prone area especially in Barind Tract were practiced several coping measures to cope with the adverse effect of drought. Considering all, 99.13 percent respondents (n=340) were drunk more water and oral saline to reduce health impacts during drought (Table 10.2). In Chokghorpakhia, 100 percent respondents (n=51) managed their health by taking Doctor's advice during drought followed by drinking more water & oral saline, eating healthy food, bathing two to three times and do nothing during drought. In remote areas, where there is no electricity, the person keeps wrap them with wet clothes to keep their body coo

Table 10.2: Measures to reduce health impacts

Measures to reduce health impacts	Study locations with respondents (%)						All (%)
	Rajshahi		Chapainawabganj		Naogaon		
	Parisho n=52	Aye-Hi n=62	Nizampur n=75	Chokghorpakhia n=51	Bhabicha n=63	Mollapara n=40	
Drinking more water and saline	(100)	(100)	(100)	(98.04)	(98.41)	(97.5)	(99.13)
Taking doctor's advice	(98.08)	(87.10)	(33.33)	(100)	(66.67)	(70)	(73.18)
Bathing 2 to 3 times in a day	(1.92)	(48.39)	(8)	(78.43)	(53.97)	(30)	(35.86)
Wrapping wet clothes	(1.92)	(6.45)	(6.67)	(70.59)	(52.38)	(32.5)	(26.82)
Eating healthy foods	(5.77)	(4.84)	(4)	(86.27)	(41.27)	(50)	(28.86)
Nothing				(1.96)	(1.59)	(10)	(1.75)

Source: Survey data, 2015, multiple responses, Figure in parenthesis indicates percent value

10.5 Institutional support to cope with drought

As per discussion with the respondents, they received support from both inside and outside of their communities. Actually these sorts of support were availed by only few households. Households were received financial support and kind support from both nation building department and non government organizations. Different banks likely Sonali, Krishi and Janata banks were provided cash loan to the drought victims. Different NGOs were provided active support for loan and kind incentives including seeds, poultry and other livestock. Local governments were provided active support in access to the communal resources. Few communities based organizations like club also provided support to the drought victims. The international NGOs who are working in the field of climate change adaptation and disaster risk reductions like Word Vision were also provided cash, inputs and training support for drought.

The continuous flow of river is very much important to ensure availability of surface water. The flow and surface water increase the rate of groundwater recharge. Water flow through river in the study area is very limited. Eventually the Farakka barrage makes the river dry during dry period and over flow causing flood during huge discharge of the rivers. The concern department of the government is negotiating the issues in getting water through the river in regular basis and has been taken initiatives in dredging the river and removes the silt overlay on the bed. Wetland does not exist in the study area but water catchment areas are prevailing there. The drought and existing cropping practices and land use system make it worst by reducing capacity of storage during dry period and discharge efficiency during excess rainfalls.

Summary and conclusion

Mitigation measures are essentially important for drought management. Both individuals and household level peoples used mitigation measures. They tried to tackle at first at the personal level by cost cutting or saving strategies then food consumption pattern. They started with adult one then followed by elderly and children. Quantity, quality and meals per day they might adjust to mitigate drought impacts.

Chapter 11: Sustainable Adaptation Strategies

11.1 Scope of sustainable drought management using SLA, symbolic interaction and social exchange theory

This chapter presents the quantitative and qualitative results from thehousehold survey, interviews with the sample group of households and otherkey informants as well as field observations. Both mitigation measures and adaptation measures are essential for sustainable drought management. The coping and mitigation measures for drought in the northwest part of Bangladesh have been discussed in the chapter ten. The coping measures depend on local context, local wisdom (responses) through the better use of their social capitals (social networks). Almost similar coping measures were practiced among the study locations. The adopted responses are almost interlinked with the sustainable livelihood framework, whereas others are not equally recognized; so far narrated by the Barind peoples' livelihood situation. People respond with innovative ways based on their available resources in drought hardship. As for example, the people performed several activities by using household resources at their best capacity (sustainable resource management), and the types and sources of resources necessary are reasonably vital in realizing their (community) livelihood response. Sustainable drought management aim is the central focus for adaptation measures. Community well-being or empowerment may be one of such goal. This community well-being is a broad theory that can be functional to both an individual and a community. An early assessment to analyse the adaptation potentials of the agriculture is very much essential. Few adaptation options according to types are based on IPCC typology was discussed in the brief report[5]. Bear crop losses are potential when standing total crop is accepted by the cultivars. In reality, it is possible only

[5] See report of the UNEP, 1993

when the cost of adaptation seems to be more compared to the net crop loss (no profitability). Such adaptation is only hypothetical and highly unlikely to take place (no adaptation). Adaptation is the process of adjusting to change (both experienced and expected), which is in longer term (for example, over a decade or longer). In this study, the adaptation and sustainable management options for drought are based on Sustainable Livelihood Approach (SLA), symbolic interaction and social exchange theory which has been discussed in the second chapter. SLA is the best example of multiple capitals where sustainability is the key focus in terms of availability of capitals and context of vulnerability in which these assets exist. Capital is the main concern in the SLA. Five different capitals are given emphasis in this framework. Human capital is one of the important capitals in responding drought for adaptability and sustainable management options available to them. Sustainable Livelihood Approach is essential for the management of drought. In this connection, peoples are applying their best strategy to established sustainable management approaches to drought and make linkages with symbolic interaction and social exchange theory. They have used their physical capital such as infrastructure (transport, vehicles, water supply and sanitation, energy, housing pattern, household appliances, livestock and roads), tools and technology (tools and equipment for production, seed fertilizers, pesticides, local technology), human capitals (health, nutrition, skills, knowledge, capacity to work and capacity to adapt), economic and financial capital (cash money, credits/debt, savings, assets, remittances, pensions and wages), social capital (networks, connections, kinship, patronage, neighborhoods, mutual understanding, support, shared values and behavior, leadership, collective actions, social relations, social associations, societal and political system) and natural capital (land and produce, soil, water and aquatic resources, trees and forest produce, wild life, wild foods, air, river) and environmental services (biodiversity, hydrological cycles and pollution sinks).

11.1.1 Drought adaptation using physical capitals

Drought management through physical capital is essentially important. It seems that it would be quite good to address drought physical vulnerability by addressing exposure through structural measures. In reducing physical vulnerability from beginning to end managing exposure would not be political in nature. The politician works for political gain often showing they are addressing public safety. The structural measures involve huge investments that tend to benefit engineering and construction companies. In Bangladesh, after independence, the government emphasized structural works (channel, rivers and construction of road, culvert bridges and dams) for communication and development. The power was firmly in the hands of bureaucrat and politicians who believed strongly that this was the right approach to take. Construction of *Farakka* barrage and filling of ponds resulted in low /no water holding of huge land tracts and entire communities especially in weak political economy. Both river and wetland ecosystems were destroyed and with them flora and fauna disappeared. Access to infrastructures (water related infrastructure), road communications and drought related technologies all are under physical capitals. Physical capitals are veryimportant for sustainable drought management. It was observed that the respondents from Chokghorphakhia (Shibganj, Chapai Nawabganj District) owned more concrete house than other study village and apparently they could be able to manage drought better by using their physical capitals. Results showed that the lower income groups always bear a uneven share of the losses ; they get, as for example, the least fraction of disaster relief; they are the least likely to be insured; and they live in dwellings which are of the poorest construction and most subject to damage. On the other hand, the respondents from Parisho (Tanore, Rajshahi district) have had more livestock and they could be able to use the earnings from livestock during drought crisis. Maximum respondents (76.68%) reported that drought affected their livestock. Traditionally the more numbers livestock ownership in the study area treat as the wealth and prestige and help them redeem from damage. The people from the study areas always strive to increase the number of their livestock and poultry. Most of the respondents are interested to raise female animals for higher productivity (birth and milk products). Usually the respondents are maintained higher ratio of female animals for increased productivity. Livestock and poultry were considered as liquid assets, still pay crucial role in drought risk management by providing key sources of livelihoods in the study areas. In addition to consumption (meat, eggs, milk and milk products), they earned cash by selling cows, goat, sheep, poultry (duck and chicken) especially during drought crisis and they can manage their livelihoods accordingly and much more better than those have no livestock heard. Maximum participants from Bhabicha (Niamatpur, Naogaon District) owned cows and 95 percent respondents from Mollapara (Porsha, Naogaon) owned chicken and they usually sell it during drought crisis for cash.

11.1.2 Drought adaptation using human capitals

Human capitals contribute labour for numerous diversified livelihood activities (income generation, subsistence for farming, water collection, cattle rising, poultry rearing etc) engaged in by household members. A lot of factors are partly related to human capital including family size, level of education and occupation, age, gender and experience of the members. Household size (number of household member), especially the number of adults, is an important determinant of labour availability for income generation, but is not the only source as labour can be hired. It was reported that maximum average number of household members were recorded from Aye-Hi Village (Godagari, Rajshahi), could be able to better manage of drought by counting their adults member's contribution(cash income, physical labour etc). The respondents reported from Aye-Hi and Parisho village (Godagari and Tanore Upazila, Rajshahi District) that NGO (World Vision) helped them to develop human capital through training on crop diversification and Income Generating Activities (IGA). These are very much helpful for them to adopt better drought management options. Education is essential as it can facilitate with off-farm sources of earnings. The level of education (more educated members) has a better opening to earn a wage or income. The respondents from Chokghorpakhia (Shibganj, Chapainawabganj district) had more diversified livelihood options rather than agriculture, can manage better drought in the study areas. Eventually those had strong secondary occupation in addition to primary occupation; they would be able to manage drought risks better. Respondents were mentioned that they themselves or their family members migrated in groups or individual for short period in the month of April, to harvest summer crops in the suitable location to sustain their livelihood. Most of the respondents reported that who have migrated as the labourer to earn cash rather than foods.

A person having weak livelihood platform, the livelihood strategies are limited for him or her, and the result may be poverty and that closely link vulnerability to assets. At the same time a person who has very strong livelihood base can play diverse role and capable to make safe his or her livelihood in predicament. The critical analysis of socio-economic resources that obstruct peoples' adaptability could help to in-depth understanding of their contextual situation and give us indication on what can be done to build up their adaptability in this study. It was clearly mentioned in the methodological section (chapter Three) to understand all the resources which affect or influence on adaptability, all the study populations are not homogenous. Considering the context, different categories (small, medium, large farmers) and six locations were selected for this study. Gender is the important determinants for human capital. Thirty percent women respondents were selected from the sample populations for this study, there was no significant difference were found between men and women in respect to drought management related activities but women participation in drought management was remarkable. According to Focus Group Discussion, few limitations and barrier were restricted them (women) from drought adaptation activities including access to resources (cash, assets and lands). The relevant factors related to human capitals in the study areas (six locations) were discussed in chapter four.

11.1.3 Drought adaptation using economic or financial capitals

Respondents reported that financial capital is the one of the determinants of social status. Economic or financial capital is crucial to combat drought and its impacts. Cash money, credits/debt, savings, assets etc are the best example of financial capitals. Financial capital may define as stock of liquid financial resources including money, access to credits, savings and non liquid resources likely livestock, foods and mutual claims[6]. Livestock is not only the part of their life, it also the determinants of wealth for the respondents. This is also one kind of saving, provide benefits over bank deposits, as they are not only means of living, as the determinants of status in the society. All the respondents are not equally owned financial capital. It differs from person to person, family to family and locations to locations. Due to good road communications and easy access to the locations, most of the study areas are easily accessible to the service

[6] See report of the DFID, 1994

agencies. Comparing all study locations, Mollapara was not easy accessible like all other locations. Loan providing organizations are available to support people and maintaining their families in normal situations. It is hard to reach them during drought crisis. Two types of money lending system are there such as i) Individuals who provide loan (money) to a person they know; and ii) micro financing. Several agencies including non-governmental organizations (NGOs) and government agencies have come up with their activities in the study locations. Eventually Barind Multipurpose Development Authority (BMDA) has come with several activities to support the drought victims as well. Several NGOs are providing support to the respondents to lead their livelihoods. Supports like access to the micro credits eventually a great help for the respondents. World Vision one of the leading NGO in the study areas are providing food stuffs, seeds and other cash incentives to combat natural disasters like drought. Relatives and friends are also assisted them during drought crisis. Usually they used support received from relatives, friends or neighboring people to purchase food or to recover agricultural activities. The respondents who have more savings can utilize it during the drought crisis and purchasing food or inputs for agricultural activities. Furthermore, assets could be means of assessing ranking of wealth in the community. It was useful to explore income and expenditure by a household in the past. Monthly average income of the respondents from Mollapara is more than other study villages. Therefore, it could be said that the respondents from Mollapara could be able to manage drought better than other villages. The household members are reasonablydisliked to disclose details all of their sources of income. Generally they are more than willing to expose their enormous amount of expenditures stressing the crisis. The result is given typically a much higher value for household's expenditure than income pertaining to health costs, school fees, food etc. can be remembered.

11.1.4 Drought adaptation using natural capitals

The strongest natural capital composed of land, farming and trees. There is no significance differences were found among the locations based on total land holdings of the respondents. Considering agricultural land, there is significant difference among locations and respondents. The respondents, who have more agricultural land, could be able to manage drought better than other respondents. They can go for cultivation of diverse crops using their land avoiding single or mono crops. Another interpretation could be drawn, who have more agricultural land, and there is great risk of crop damage due to drought. In case of holding more land, they usually give lease out their land for cultivation and risk goes to others. Who have a piece of land and cultivated by themselves, have limited scope for crop diversification and they do not able to manage drought in sustainable manner. In few cases, respondents give mortgage out their land to meet family and household necessity during severe drought. The person who makes the loan, give ownership to other to cultivate the land until the farmer repaid the money. Eventually this practice makes the poor more vulnerable than others. At first the person go for selling of livestock for repayment or coping with drought crisis, then mortgaged land and at the eleventh hour, sale land to repay money or to manage crisis. Water is also other important natural resources for the study areas. It is indeed important for crop cultivation; the area which one is under well managed irrigation scheme, could be able to provide irrigation to the crops during drought. The study villages especially the Mollapara (Porsha, Naogao District) and Nizampur (Nachole, Chapai Nawabganj District) have limited access to irrigation and were not able to manage drought using natural capital. Respondents mentioned that ethnic people (*Santal*) usually consume wild food (animals and plants) round the year. *Santals look* for wild foods during drought crisis due to lack of normal food. Eventually they hunted several wild animals (wild cat, fox, rats, squirrel), wild birds (dove, wood peaker, *bok* etc) and aquatic foods (tortoise, crabs, snails, *kuchia*) from nature. They do this to sustain their lives by consuming these types of wild animals. Wild fishes are the common food for the rural poor, though water body is scarce during drought, but they search from the last one. Wild plants including leafy vegetables, fruits etc were collected from natural sources for their consumption during drought crisis. There are four categories of land found in the study areas locally known as *dying/dhanga/chara* means high land, *char kandur* means medium land and *kandur* means low land and *jaoi* means plain land. These four types of land were categorized by the people of Godagari. High land (*dying*) is suitable for vegetable farming; medium land (*char kandur*) for other crops and low land (*Kandur*) for rice farming with minimal irrigation. At Niamatpur, farmers were classified their land into four groups including *Danga* (high land), *Jaoi* (plain land), *Kandur* (elevated land) and *Haor* (*Beel* or low land). As told the respondents that they were used only low land for rice farming before BMDA intervention. They were grown less irrigated rice varieties for farming. Till now the farmers are developingcrops cultivation plan considering land type to minimize drought impacts on agricultural production. Institutionally, the Department of Agriculture Extension (DAE) and Barind Multipurpose Authority (BMDA) advised the farmers to grow crops as per land classification and total capacity of irrigation. This was calculated based on the requirements of irrigation for the previous years and expected irrigation requirements for the year. Early cropping and late cropping both systems were followed by the farmers. Farmers were used early varieties for early cropping and late varieties for late cropping. These types of practices could be reduced water stress on irrigation during drought. Land use planning can play an important role for adaptation measures for drought as mentioned by the FGD participants. Land use planning and zoning may also reinforce existing differences in wealth and vulnerability between different geographical areas. The options include stratification of land or zoning the physical structure of the land. Table 11.1 represent four types of land zoning in the study area likely *Danga* (high), *Char Kandur* (medium high), *Kandu*r (medium low) and *Jaoi* (plain land).

Table 11.1: Local classification of land

#	Local classification of land	Description	Sources of information
1	*Danga or Chara*	High land is known as chara	FGDs& Informal discussion
2	*Char Kandur*	Medium high land	FGDs & Informal discussion
3	*Kandur*	Medium low to low land	FGDs & Informal discussion
4	*Jaoi*	Plain land	FGDs & Informal discussion

Source; Field work, 2015(FGD)

Table 11.2: Local classification of land and cropping pattern

Local classification of land	Cropping pattern	Cultivated crops
Danga or Chara	3 crops (Rabi-kharif-1 & Kharif-2)	Mustard, Lentil, wheat, *T. Aman* and tomato
Char Kandur	3 crops (Rabi-kharif-1 & Kharif-2)	Mustard, Lentil, wheat, fallow and *T. Aman*
Kandur	3crops (Rabi, Kharif-1, Kharif-2)	Mustard, *Boro* and *T. Aman*
Jaoi	3crops (Rabi, Kharif-1, Kharif-2)	All crops

Source: Field work 2015 (FGD)

Double and triple cropping pattern were observed in Barind Tracts. Double cropping pattern is the common feature for *chara* or *danga* land, in the some extent triple cropping pattern were noticed for drought management. In *kandur* zone, triple cropping pattern is highly appreciable.

Respondents mentioned that Rabi crops (mstard, lentil, wheat) harvested in the month of March followed by fallow (*Kharif-1*) then *T.Aman* (May-September) then go for advanced tomato cultivation (Table 11.2).In the *Char kandur* land, almost similar to *chara or danga*, *Rabi*crops (Mustard, Lentil, wheat) harvested in the month of March followed by fallow (*Kharif-1*) then *T.Aman* in the period of May to September.*Rabi* crops (Mustard) broadcasted in the month of Nov-Dec and harvested in February then *Boro* (BR 28, *Jirashail*) followed by *T.Aman* (June-July) in the *Kandur* land. All crops were grown well in *Jaoi* land.

11.1.5 Drought adaptation using social capitals

Respondents mentioned that social capitals are interlinked with the several factors. They don't have equal access to the social capitals. The social capital covers networks and connections (Patronage, neighborhoods, kinship), relations of trust, and mutual understanding and support, formal and informal groups, shared values and behaviours, common rules and sanctions, collective representations, mechanism for participation in decision making and leadership. The key issue of symbolic interaction is to understand people through relationship. In this regard, people usually seeking help from kinship then neighboring people then from society and community or outsiders. Observers think that the growth of the capitalist economy since the nineteenth century has diminished the mutual self-help and all trust attributes of the conventional "moral economy" of village social structures. It was reported by the respondents that there exist various adaptation measures at the household and community level, there is need of stronger patronties, and the national government policy support to coping with drought. The reason is that disaster suffering households might spin to local prominent and rely more strongly on collectiveethicalcompulsions; they were less likely to be forced to liquidate their own productive resources to an unreplenishable level. In managing drought, peoples are adopting symbolic interaction theory for the betterment of their situation. According to social exchange theory, the adopted measures are being under right or bad choice. It also depends on location, time scale and family resident. The management options are also determined by their livelihood strategies. Those who have huge land are performed better than small land holdings. Social networks is the another important element for social capital. In every society there are few networks including clubs, *samity*, credit groups and youth groups. Either these are faith based or savings/credit based. The respondents used their own networks in managing drought risks and its impacts in the study locations. At first, they used their close relatives (brother, sister, uncle, brother in law, father in law etc.) then they seek assistance from friends, neighbouring people, elite people from the village or union. Generally the support is likely for cash (Loan), foods (rice, wheat etc). Eventually they took loan from their *samity* and clubs during drought risks. The samity or clubs provided only minimum amount of loan. They also take loan from NGOs and Bank. Almost all of the respondents have easy access to the NGOs but limited access in Bank loan. The extreme poor people are not able to get access in loan (either from relatives, friends, and neighbouring people, NGOs or Banks). Only they have access to the money lenders (*Mahajan*) with high interest rate for minimum times. Barind poor people could nourish themselves for only three to nine months, and had to adopt alternative diverse livelihood strategies including wage labour, small trading, crafts, van pulling, and livestock husbandry and migrate in order to make a better living during drought. All people are poor and lived in cluster and populated areas, and hence had social interaction among them. Moreover, due to inaccessible and lack ofpoor communication& networks, they are all deprived from social development services (government and NGO). Commencement of the BMDA that developed road networks to connect all project villages encouraged several NGOs to conduct activities such as education, credit, livestock rearing, sanitation, water supply, and farming in the project areas. Several good adaptation practices have been identified by the farmers against drought. The adaptation measures for sustainable drought management has covered several aspects and at different level and scale. This could be at individual, household, community, farmand at the system level. The initial reactions involve foregoing special kinds of consumption and intensifying habitual dryseason incomegenerating activities, such as: (1) suspension of unnecessary consumption, e.g., ceremonies, (2) gathering of "wild foods" from the natural environment, (3) dryseason gardening, (4) the sale of gathered hay and firewood, (5) sales of handicrafts, (6) borrowing of grain from kin, and (7) temporary migration for wage labour. The second group of response measures explicitly involves the management of asset losses. These include: (1) livestock sales, (2) borrowing from merchants (often with land serving as collateral and its usufruct serving as loan interest), (3) selling domestic assets, (4) selling land, and (5) permanent immigration. In addition, household members eat less. Many also receive food aid; however, this does not generally require individual sacrifices beyond being present when and where the food distributions are taking place. Although there have a wide range of alternatives, in practice, only a few have a significant impact and onlysuitable for specific locations. Dry season gardening is feasible where exist accessible reserves of irrigation water or substantial residual soil moisture. Other options are gathering of wild foods (plants and animals).

11.2 Individual level adaptation

Diversified livelihood adaptation can play important role in drought management at individual and household level (small trading, handicrafts, nursery business etc). Livelihood diversification is the key strategies to drought adaptation measures.

Table 11.3: Livelihood options

Livelihood options (respondents %)	Study locations with respondents (%)						All (%)
	Rajshahi		Chapainawabganj		Naogaon		
	Parisho n=52	Aye-Hi n=62	Nizampur n=75	Chokghorpakhia n=51	Bhabicha n=63	Mollapara n=40	
Small trading	(100)	(88.71)	(97.33)	(100)	(79.36)	(95)	(93)
Van pulling	(100)	(85.48)	(70.67)	(98)	(68.25)	(95)	(84.26)
Migration to other place	(34.62)	(43.55)	(68)		(7.94)	(45)	(34.69)
Nursery	(98.07)	(19.35)	(1.33)		(49.20)	(75)	(36.44)
Homestead gardening	(98.07)	(87.09)	(80)	(80.39)	(50.79)	(62.25)	(76.68)
Animal rearing	(100)	(91.94)	(92)	(56.86)	(66.67)	(67.5)	(80.47)
Handicrafts	(50)	(12.90)			(42.86)	(17.5)	(20.12)
Orchard	(78.85)	(40.32)	(57.33)	(86.27)	(42.86)	(60)	(59.48)

Source: Field survey 2015 (multiple responses), Figure in parenthesis indicates percent value

The livelihood strategies are divided into broadly two categories such as climate sensitive strategy and non climate sensitive strategy. The climate sensitive strategies or climate smart strategies embrace mainly crop farming (vegetables and fruits production in the homestead), poultry, egg production and livestock rearing. Most of the respondents like to engage themselves in nonclimate sensitive activities likely small trading, van pulling, casual labour, fixed term salaried employment (Table 11.3). Other activities cover harvesting of wild vegetables, wild fruits, local crafting (bamboo slat and basket making, net making and *pakha* making) using local resources (bamboo and palm tree). Few respondents opined that drought victims do business with *horek mals* (different types of products especially plastic products, low cost ornaments, toys etc) to sell in urban, peri-urban and rural areas by travelling round the months.

11.3 Household level adaptation

11.3.1 Homestead Agriculture

The homestead agriculture is one of the important options in drought crisis management. This type of gardening is managed by women and ensures food security by adding additional income and enhancing poor livelihood. These adaptations are widely practiced in Nachole, Porsha, Gomasapur and Sapahar[7]. Vegetables varieties with low water requirements are highly recommended in the drought prone areas in Barind tract. Household members can contribute a lot in homestead gardening by engaging themselves for physical labour and cares. They used household waste water and kitchen waste for gardening. Farmers are cultivating high valued fruit crops (mango, litchi, guava and jujube) instead of rice farming. As mentioned by the respondents, it requires low water and has high value in the markets. High valued fruit trees are also recommended in managing drought impacts by DAE and BMDA. These can be regular bread of the affected farmers during drought. Farmers can meet their demand by consuming fruits and can sell surplus to the market. They can earn regular income during drought crisis from homestead production. Malnutrition is one of the crucial issues in the drought prone areas. It was mentioned that farmers faced several problems including food defecit and nutrition crisis due to insufficient yield of vegetables, rice and other crops due to water scarcity and high temperature. More over kankong (*Ipomea aquatic*), *batishak* (Chinese cabbage) and stem amaranth are grown well in the drought prone areas and it requires low soil moisture. On Farm Research and Development (OFRD) station at the Barind, Rajshahi also developed a homestead vegetable production model which is known as Barind model, which needs to replicate and

[7] See report of FAO, 2009

disseminated the model to other places (as mentioned by the Key Informants'). Homestead vegetable gardening is the well recognized practices in drought prone areas of Bangladesh. Earlier it was mentioned that the production is lead by the women and family members. The practices ensure good and regular income for the household earnings. Results showed that home gardening is the common practice in Godagari, Tanore, Nachole, Porsha and Niamatpur. Farmers are growing leafy type vegetables including *kangkong*, *batishak*, sweet tasting stem amaranth (*katua danta*) in thehomesteads. It was mentioned by the respondents that homestead gardening is the well adapted system in the Barind Tract.

11.4 Community level adaptation

Drought management options exist in the wide arena of water management including irrigation efficiency, structural measures, behavioural changes, groundwater, surface water, rain water harvesting and watershed management. Now the peoples in the study areas are reducing groundwater abstraction for the milieu of sustainable drought management. They are trying it at two folds likely the best and efficient use of surface water for irrigation instead of ground water; and reduced ground water wastage. This has been done by cultivating water efficient (less water demand) crops in their cropping instead of *boro* rice. The surface water is also treated as the scarce resources during drought; so it is essentially important to take care of water to protect from pollution. The community people and pond owner have been committed to no use of poultry litter and harmful chemicals in the pond. They used water for bathing, washing and other household activities as the common property resources. They organized themselves for the re excavation of *khas* pond with the assistance of NGOs and contributed seed money with the aided assistance from NGO (DASCOH). The responsibilities remain on the representative members of the community. This is happening due to symbolic interaction among the communities. Waste water is also great source for re use especially during the period of drought, people preserved waste water and used it for homestead gardening with special care. Ground water recharging is the important factor for sustainable drought management. The infiltration rate in the Barind tract is much more less than other part of the country. In this case, addition of organic matter is essentially important to improve soil porosity. Cultivation of green manure crops (d*haincha, m*ung, k*hesari* etc) is getting importance in the study area. Farmers were also used rotten cow dung and other compost to increased organic matters in to the soil. Another dilemma is also mentioned by the respondents, as drought increased livestock is lacking from green grasses and straw. In this regard the number of livestocks is decreasing in the drought prone areas. The major fuel (crop residues and fire wood) is being scarce in the study location and peoples are using dry cowdung for cooking. This practices lead to the nutrients diminishing and creating shortfalls in organic manures.

11.5 Farm level adaptation

Several options deployed by the respondents at the farm level to manage drought. These include cultivation of increased resistance varieties to drought, by changing cropping pattern (*Boro* to wheat, mustard or other suitable crops to reduce water requirement), shifting in planting date (either early or late planting depending on drought), revisit of crop calendar, mulching, homestead vegetable gardening and mixed fruit gardening.

11.5.1 Drought resistant and suitable cultivars

Some good rice varieties were identified in agriculture against drought. Both drought tolerant and suitable crops were grown by the farmers. They cultivated other crops instead of rice farming. According to On Farm Research and Development (OFRD), Bangladesh Agricultural Research Institute (BARI), chickpea, barely, sesame, linseed, stem amaranth, coriander and mung bean were found promising crops for drought situations. In Rabi, farmers cultivated wheat, mustard, lentil and sweet potato as because these type of crops can grow with little or no irrigation. They also produced sesame, *Kaon*, jute and local rice varieties to reduce drought impact on production during *Kharif 1*. In Bangladesh, the usual rainfall occurs in *Kharif 1* which is essential for agricultural production. The above mentioned crops do not require extra irrigation. Such crops can survive in drought condition. As stated by the respondents that *aus* rice requires sufficient soil moisture during pinnacle formation and such requirement can be meet by rainfall during the period. Cultivation of resistance variety to drought is one of the adaptation measures for drought management. Minor crops are locally important in cropping pattern; maize, sesame and nut sedge may also enter in to the cropping pattern. Farmers cultivated BRRI *dhan-47* variety (the variety developed by Bangladesh Rice Research Institute) that requires less water and striving capacity to dry soil is quite high. It is well known to the farmers that BRRI dhan-56 and 57 are short duration rice varieties and feasible in drought prone areas of the Northwest region of Bangladesh especially in Barind tract likely Rajshahi, Chapai Nawabganj and Naogaon Districts (Table 11.4).

Table 11.4 Drought tolerant and suitable rice varieties for adaptation

1	Variety	Characteristics	Time required(days)	Yield (Ton/ha)	Cropping season
1	BRRI *Dhan* 42	Drought tolerant	100	3.5	*Aus*
2	BRRI *Dhan* 43	Drought tolerant	100	3.5	*Aus*
3	BRRI *Dhan* 55	Drought tolerant	105	5.2	*Aus*
4	BRRI *Dhan* 56	Drought tolerant	106	4.4	*T.Aman*
5	BRRI *Dhan* 57	Drought tolerant	100	4.0	*T.Aman*
6	BRRI *Dhan* 33	Growth duration less than 130 days	118	4.5	*Aman*
	BRRI *Dhan* 39	Same as before	122	4.5	*Aman*
	BRRI *Dhan* 46	Same as before	124	4.7	*Aman*
	BRRI *Dhan* 53	Same as before	128	4.5	*Aman*
	BRRI hybrid *Dhan*4	Same as before	118	6.5	*Aman*
	BR6	Growth duration less than 150 days	140	4.5	*Boro*
	BRRI *Dhan* 28	Same as before	140	6.0	*Boro*
	BRRI *Dhan* 36	Same as before	140	5.0	*Boro*
	BRRI *Dhan* 45	Same as before	145	6.5	*Boro*
	BRRI *Dhan* 55	Same as before	145	7.3	*Boro*
	BRRI hybrid *Dhan*2	Same as before	145	8.0	*Boro*
	BRRI hybrid *Dhan*3	Same as before	145	9.0	*Boro*

Source: BARI &Survey data, 2015

Drought tolerant NERICA cultivation is getting preference in the study area. Cultivation of Early variety *T.Aman* (BINA *dhan 7*) is another suitable species in the study areas. People are cultivating this early variety considering drought characteristics. Irrigation facility has not been equally available in and around Bangladesh due to high and low groundwater. As a result, 20 percent of the land suffers from drought. The north-western part of Bangladesh is treated as a drought-prone area due to poor and erratic rainfall. It is one of the major abiotic constraints for rice grown (5.7 m ha) under rain-fed conditions in Bangladesh and causes a substantial reduction of yield. In this case, BRAC introduced and disseminated a short duration (115–118-day) rice variety, e.g., BRRI dhan33, BRRI *dhan*39, and *BINADHAN* 7, which can escape the terminal drought if they are transplanted by July 15th in the drought prone area. Few *aman* (wet season) varieties suc as BRRI *dhan*56 (110 d), BRRI *dhan*57 (105 d), and BRRI *dhan*62 (100 d), being high zinc rice, can be grown within 100–110 days in order to avoid drought and give space for a second crop, perhaps a non-rice variety, such as an early potato, vegetable, or mustard, in profitable rice-based cropping systems. OFRD, BARI has demonstrated the outfit results of BARI gram 26. The variety is suitable for late planting and resistant to rust and blight disease. It gives high yield with high number of effective tillers in drought conditions. Now the respondents from the study area are cultivating these varieties to cope with drought situation.

11.5.2 Changes in cropping pattern

Changes in crop cultivation from *Boro* to wheat, maize, mustard or other suitable crops can reduce the demand of water requirement during cultivation (mentioned by the FGD participants). Wheat requires less water and irrigation for its production during *Rabi* season. Now the farmers are cultivating wheat and introducing it in their cropping pattern. The common cropping pattern is wheat followed by Mung bean and then *T.Aman.* Farmers are growing *T. Aman* using rain water in the study areas. In the some extent (incase of less or erratic rainfall) it requires little irrigation only. Key informant's and participants from FGD mentioned that the following crop combinations are the best suited in the study locations:

Wheat –Mung bean-*T. Aman*; wheat-Linseed-*T.Aman*; Onion-Mungbean-*T.Aman*; Water Melon-Mungbean- *T.Aman*; Mustard –Mungbean-*T.Aman*; Chick pea-Mungbean-*T.Aman*. Chick pea cultivation in *T.Aman* field and introduction it in the cropping pattern is promising for drought.

Table 11.5: Adaptation measures to drought

Measures to reduce drought losses	Study locations with the respondents (%)						All (%)
	Rajshahi		Chapainawabganj		Naogaon		
	Parisho n=52	Aye-Hi n=62	Nizampur n=75	Chokghorpakhia n=51	Bhabicha n=63	Mollapara n=40	
Changing cropping time	(50)	(72.58)	(98.67)	(92.16)	(30.16)	(57.5)	(68.22)
Planting of drought tolerant crops	(98.07)	(57.69)	(78.67)	(50.98)	(93.65)	(47.5)	(71.14)
Using compost/cow dung	(53.85)	(82.26)	(57.33)	(96.08)	(80.95)	(70)	(72.89)
Cultivate drought resistant species	(44.23)	(12.90)	(6.67)	(64.71)	(73.02)	(50)	(39.36)

Source: Field survey 2015 (multiple responses), Figure in parenthesis indicates percent value

Four crops based cropping pattern practiced by few respondents with the help of OFRD and DAE. According to Key Informants, DAE official informed that few farmers in the Barind Tract are cultivating four crops instead of two or three crops in a year. Four crop based cropping pattern including lentil (BARI *Masur*-6) during the period of November to February followed by Mung (BARI Mung-6) in the month of March to April, *T.Aus* (BARI *dhan* 48) during May To July and *T.aman* rice (BARI *dhan*-56) in the month of August to October. The other four crop based cropping pattern include Mustard (BARI *Sharisha-15*) in the month of November to February, followed by Mung (BARI Mung-6) during March to April, *T.Aus* (BRRI *dhan-48*) May-July and *T.Aman* rice (BRRI *dhan -66*) during August to October. Four crop based cropping pattern including Potato (Diamond) during the period November to February, followed by Mung (BARI Mung-6) in the month of March to April, *T.Aus* (BRRI *dhan-48*) during May to July and *T.Aman* (BRRI *dhan-66*) in August to October. People are making changes in crop planting date (Table 11.5) either earlier or later depend on drought prediction/forecast to manage the drought. In predicting drought they were used indigenous knowledge (this was discussed in chapter nine). According to symbolic interactionism theory, peple collect planting materials (rice seedlings) from others for early or late planting those who have had their own seedlings. Based on predicted drought and impacts of previous drought, farmers started to revisit their crop calendars to adjust months and days to minimize production impacts (Table 11.3). Homestead vegetable gardening is the well recognized practices in Drought prone areas of Bangladesh. The production is lead by the women. The practices ensure good and regular income for the household earnings. It is widely practiced in Godagari, Tanore, Nachole, Porsha and Niamatpur. The leafy type vegetables including *kangkong*, *batishak*, sweet tasting stem amaranth (*katua danta*) are grown in homesteads. Local high value fruit crops like litchi, citrus, mango, etc can be produced in small scale homestead areas in the drought prone area to reduce drought impacts and ensure crop production. It was mentioned by the respondents from In-depth Interview that intercrop is possible in the mixed fruit garden that is also provided additional income and nutrition to households by ensuring women participation in the production process.

11.5.3 Crop diversification

Crop diversification is one of the important adaptation strategies of drought in the study area. Crop diversification is an old aged practice to reduce drought risk. This system is contributing in cropping pattern with yield and cropping intensity. Growing of a single crop in the whole farm is associated with the risk of crop loss. It is suggested that divide your lands and grow diverse crop to mitigate drought risks. Farmers usually did this to cope with drought. Mixed cropping and intercropping is an effective and successful strategy for crop diversification on a single piece of land where several crops are grown simultaneously or sequentially in the same unit of land. It is wise to do intensive use of land essentially important survival strategy against drought.

11.5.4 Tree plantation

As opined by the respondents the area that was covered by plenty of trees (mature tree) having little problem with drought. They felt that only few mature trees exist in the study locations. Tree plantation is one of the best suited solutions of drought management. Respondents believed that trees can enhance precipitation and can reduce drought impacts substantially. Plantation could be raised along the canal, *khari*, roads and at the homestead. Dyke plantation may be one of the options for sustainable drought adaptations and management. It needs careful selection of tree species for dyke plantation. More attention needs to be paid on tree plantation including institutional plantation, social forestry program and individual plantation. Moringa plantation can be essential plantation for their economic progression through regular cash income and at the same time it may be sources of nutrition. Respondents are performing tree plantations scheme either in their homestead (tiny to medium and large), road side, along khari, ponds, institutions (school, college, madarsha, eid gah, play ground, mosque) and crop land and dykes.

11.5.5 Agro forestry

The raising of trees and crops simultaneously at the same unit of land is known as agroforestry. Farmers raised agro forestry in their homestead and extended crop land and adjacent to their homestead to reduce drought impacts. The systems keep them cool and give substantial benefits during drought. The systems provides benefits to the residents in many ways as mentioned by the respondents such as i) Lowering the temperature; ii) earning extra income; iii) increasing trends of rainfall; iv) conserve soil moisture; v) maintain nutritional benefits; vi) add fertilizers after decomposition of leaf litters; vii) supply fuel for cooking; and viii) provide insurance against crop failure. The system is essentially important in maintaining ecological balance.

11.5.6 Organic farming

Low water holding capacity of Barind soils are reducing crop yields due to low moisture and inadequacy of nutrients. Farmers have been paid attention on it and using organic manure to improve physical properties of soil. Seepage is the common issue during rainy season in Barind, resulting loss of field water. This increases water demand for crop growth. Organic farming approaches can reduce water demand in crop production in the drought prone areas. Organic farming approach build soil health and increase soil water holding capacity as mentioned by the respondents. Organic fertilizers ameliorate soil by increasing soil porosity, conserving soil microorganisms and can enrich soil nutrients. It develops humus gradually and improves soil properties. The ultimate result is that the crops grown organically can sustain in drought condition. It also reduces the water requirement during drought and crops can survive with little irrigation. The inputs requirements in organic farming is locally available with no or little cost including cow dung, compost, vermicompost, kitchen waste, crop residues and other organic matters. Few farmers used organic matters for their faming in addition to chemical fertilizers. Only few farmers are doing farming with cow dung or compost only and did well during drought crisis. The numbers of organic growers are very limited. Eventually most of the people are using cowdung as a fuel (form of *ghute* or dry cow dung or *doila*) due to lack of fire wood or fuel for cooking. They mentioned that there is acute problem of cooking fuel (crop residues, fire wood and others) in the study locations.

11.5.7 Less tillage or zero tillage

Respondents are vulnerable to droughts during of March to April when *boro* cultivation affected due to lack of soil moisture andwater. The second crisis starts from July to August when drought affects seedlings that leads to delay transplantation of *T-Aman*. The third crisis begins in between September to October when both tillering and flowering of *T-Aman* affected by drought. Agricultural wage laborers become more vulnerable and decline employment opportunities during the period of May to June due to prevailing drought conditions. The respondents opined that less tillage or zero tillage is helpful in managing drought crisis. Deep and frequent tillage make soil dry by reducing soil moisture and exposing soil to the sunlight during drought. Few farmers are growing pulses (k*hesari*) without any tillage in the rice field or low land.

11.5.8 Crop rotations

Tenanat farmers are growing crops in their land rotionally. They bring changes in crops in the same land considering types and root depth. Growing of same crops at the same unit of land, several times is not wise decision. Alternatives crops are to be expected to harvest soil nutrients eventually from different layer. The growing of diverse crops alternatively in the same unit of land is known as crop rotations. Crop rotations can minimize the drought impacts on agricultural production. Few farmers are growing crops rotationally where maximum numbers of farmers are cultivating only rice for several years continuously. Crop rotation contributes in improving soil fertility, restraining erosion, reducing pests out breaks, mitigating riskof weather changes in terms of yield variation, lighting dependence on agricultural chemicals. Crop rotation is notonly can it reduce cultivation costs; it has numerous ecological gains, including the conservation of water, the improvement of soil quality, contributing to climatechange mitigation and reducing input dependency.

11.5.9 Mixed fruit gardening

Local high value fruit crops like litchi, citrus, mango, etc can be produced in small scale homestead areas in the drought prone area to reduce drought impacts and ensure crop production. Few respondents are raising mixed fruit garden with high value fruit species. Most of the respondents are not aware about it and they are doing mono gardening. It was reported that farmers are growing intercrop in their garden with fruit trees (both mono and mixed gardening). Eventually they mentioned that intercroping is also provided additional income and nutrition.

11.5.10 Mulching

Mulching is very common in the homestead, fruit orchard and potato field. Mulching means cover the soil at the base of the crops with easy decompose materials including dry grasses, straws, composts, crop residues to keep soil moisture into the soil. It provides many benefits as mentioned by the respondents. It conserves soil moisture during drought and hot days; it also reduces the water requirements (watering and irrigation); it reduces soil temperature and adds fertilizers after decomposition. It was widely practiced in horticultural production in the homestead and mango orchard. In case of potato production, farmers were used straw and water hyacinth for mulching. The practices reduced irrigation requirement in a greater extent. Less tillage and mulching were also found to mitigate drought challenges. Organic mulches when used, it increases soil water holding capacity, which enhance microbial functions. The practice also reducing the need for tillage to control weeds, conserve soil microorganisms. Organic mulches assist surface rooting by improving oxygen and moisture at the soil surface. Organic mulch not only suppresses weeds, also store soil moisture at high level that affect weed germination and growth.

11.5.12 Relaying Sweet Gourd with *T.aman* Rice

Relay crops can contribute a lot in framing in drought area. Seedlings of sweet gourd are transplanted 12-15 days (spacing: 2m x 2m) before harvest of *T. Aman* rice (Figure 11.1). The yield of relay cropping has been recorded excellent. It also reduces water requirement for production. Rice crop residues provide mulching benefits through soil moisture conservation and add organic matters after decomposition. No tillage is required for this crop and it can save tillage cost.

Figure 11.1: Relay cropping sweet gourd with T.aman Rice (photo courtesy OFRD)

11.5.13 *Dhaincha* as green manuring

Green manuring practices are old aged practices in the study areas. This is done by growing leguminous crops including *Sesbania grandiflora (doincha*), sun heamp (*shonpat*) and Mung. The growing of *Dhaincha* is common practice in Bangladesh. After first rain in the month of

April/May, the farmers broadcasted *dhaincha* seeds following single tillage and allow them one month for its growth. It reaches 1.5 feet to 2.5 feet in a month. The farmers usually plough the land before flowering of the *dhaincha* and mixed with the soil then they go for cultivation of other crops. The practice is very much helpful in the drought prone area. The practices eventually enrich soil by adding organic matters and increase water holding capacity of the soil. Farmers can grow their crops using less water and there is no need of use extra chemical fertilizers especially urea for crops growth.

11.5.14 Cultivation of gram through priming in less soil moisture

The technology was developed by the OFRD.In this method, seeds were soaked into water for eight hours and sowed to the field accordingly. Key Informants told thatthis technique helps in quick germination and enhance growth of the plants (2-4 cm) resulting 2-3 more fruits and crops become mature in advance of normal sowing (5-7 days earlier). Eventually this increased 21 percent yield than traditional cultivation.

11.5.15 Potato cultivation by using mulches

This practice needs no or little irrigation for potato production. After harvesting of *T.Aman*, the land has been ploughed 2 times immediately to keep soil moist. The potato should be planted along the line with the help of plough and tine. After planting of potato, the line should be covered with the straw or water hyacinth at a thickness of 15-20 cm. It keeps moisture into the soil. The practices reduce extra labour cost for the preparation of soil tunnels. Farmers use single irrigation just after mulching instead of double irrigation. The participants from FGD reported that this method is very much applicable in the High Barind Tract in managing drought impacts.

11.5.16 *Mung* in fallow land after wheat or potato harvest

Key Informats mentioned that cultivation of BARI Mung-6 in fallow land is the best method to increase cropping intensity in Barind Tract after wheat or potato production. This is High Yielding Variety (HYV) and become mature at a time. As this is the cheapest cultivation method and can ensure the best uses of fallow land by increasing soil fertility and cropping intensity as well as creating new employment for the poor, few farmers are cultivating Mung bean.

11.5.17 Strengthening of field bunds

Farmers usually preserved water by strengthening field bund during rains. They usually go to the field to observe leakage of bunds during heavy rains and make new bund or repair old bunds surrounding his/her fields. The FGD participants mentioned that few of them usually go to the field in the time of raining or just immediate after rain to check *dhore* in the *ayle* (leakage in bund) and repair it or make it strong to prevent seepage (wastage of water) from their fields. Usually this tasks performed by the men. The ultimate goal is to store water for longer time and use it for crop growth.

11.6 Institutional adaptation

Both private and government institutions are playing great role on adaptation measures for the wellbeing of the communities as mentioned by the respondents. Few local and nationalNGOs are implementing climate resilient activities to combat drought with the financial support from PKSF. Eventually the Barind Multipurpose Development Authority is being contributed a lot since its inception. The DASCOH one of the leading NGO is implementing IWRM project on drought adaptations. Department of environment and Department of forest are also implementing few projects to combat drought. It was mentioned by the few respondents that they received capacity building training and support from DAE, BMDA and NGOs for drought adaptation.

11.7 System level adaptation

Another important drought management options through system integration including less tillage, adoption of water management technologies (rainwater harvesting, on farm water management, irrigation efficiency through AWD and supplementary irrigation). Farmers are adopting new technologies (irrigation efficiency and switiching from groundwater to surface water irrigation) with the help of DAE & BMDA.

11.7.1 Technological innovation for irrigation efficiency

Now they have been introducing improved irrigation technology (pre paid card and meter system and application of AWD). Another important intervention is control of pollution by reducing water pollution through rationale use of chemicals during cultivation and prohibits microbial pollution of pond, canal, tube well, dug well and other water sources. Eventually peoples are doing these by constructing tube well platform to reduce water wastage and pollution. Use of irrigation is the last resort of drought management. Both groundwater and surface water irrigation were used by the farmers. Surface water irrigation was done by using canal, *khari*, pond and river water. In this regard, the Barind Multipurpose Development Authority is helping the farmers in accessing surface water irrigation. The BMDA has re-excavated lot of *khas* ponds, canals and *khari* to store the water during the season and drought. Re charge well is one of innovation of BMDA, it provides benefits to the farmers during drought. The participants of FGD opined that they need more water body including pond, mini pond, canal and *khari* could the best option for drought management. This is not only the sources of irrigation, very helpful for ground water re-charging.

11.7.2 Supplementary irrigation using mini pond

Excavation of mini pond at the corner of crop field can contributes as the sources of supplementary irrigation during drought. The dimension of the pond is twelve meter long and 12 meter width with three meter depth. The pond can harvest runoff water and save the yield of one hectare land (Figure 11.2). Farmers are adopting this adaptation measure but they think that this measure leads towards wastage of cultivating land. The small holdings and lease farmers are not interested in using mini pond by wasting land. The reason is that small holdings owned tiny pices of land and lease farmers have no option to do these on others land.

Figure11.2: Mini pond using surface water (photo courtesy OFRD)

11.7.3 Surface water

It is well known to all thatsurface water sources in High Barind Tract is limited. Surface water scarcity is found at the end of rainy season and beginning of winter. In addition to that the low water retention capacity and limited stream flow of rivers make it so critical, and the whole Barind Tract become like a desert. According BMDA, there are 70,000 ponds in 14 Upazilas of Barind Tract, is much higher than other parts of Bangladesh. The huge numbers of ponds indicate that there was water related problems from earlier. The main sources of surface water are ponds, canals and *khari* in the study locations. The poor numbers and storage capacity of ponds, canals and *kharies* have lost their water storage capacity, resulting reduced water structures and blockage of water flow. Now the people are re-excavating their traditional pond, canals and *kharies* to improve water storage facilities during dry spell of the year.

11.7.4 Ground water management

Groundwater is not an infinite, constant and endless reserve, which can be pinched on substantially and lacking consequences. Taking away water has connotations, either internally in the groundwater system or in the linked systems that collect or contribute flow from/to groundwater or both. Limiting the requirement for groundwater abstraction is the most difficult managing strategies. Possibly the most commonly argued approach for groundwater demand management in agriculture is the acceptance of "watersaving knowledge", such as drips and sprinklers irrigation systems. These skills offer enhanced application effectiveness by cutting down evaporation and seepage losses.

11.7.5 Alternate Wetting and Drying

Alternate wetting and drying (AWD) method is very much effective in irrigation especially in drought area. The method saves irrigation water during water crisis and provides benefit to the farmers. It increase rice yield with low irrigation. Farmers are becoming familiar with AWD irrigation system to adopt drought strategy and minimizing drought risks. AWD is a water-saving irrigation practice that reduces drought impact on dry season rice production through low water usage, and potentially increases yield (figures 11.3a and 11.3b).

Figure 11.3a AWD (Dry) **Figure 11.3b AWD system (Wet)**

11.7.6 Rain water harvesting

Reuse of water is very much unique in the drought prone areas. Rainfall is the great source of water for reuse. People are harvesting rain water for reuse. Usually they are doing this by re excavating ponds and canals to create more surface area and store rainwater for fishery, livestock and agricultural production. They are also collecting rain water for household and community uses. People are paying more attention on increase physical capacity of water bodies through constructing check dam for preserving rain water during rainy season.

11.7.7 Excavation and re-excavation of water body

Excavation of pond and mini pond is essentially important in the study areas as said by the respondents from FGD. The people who have enough land, they are excavating ponds on their own land. The dilemma is like that the land owners are not cultivating by themselves. Either they are doing this through lease system or through share cropping. T he most farmers (lease or share cropper) are not able to excavate water body (pond) on other lands. Eventually the tasks require huge money and this restrict themselves. Barind Multipurpose Authority (BMDA) and Bangladesh Water Development Board (BWDB) are helping community people to excavate private and *khas* ponds, canals and *kharies* in creating surface reservoir to store rainwater. Eventually few NGOs (DASCOH, Ashrai etc) are working in this field. Community participation is the main concern in this regard. Re-excavation of ponds, canals, rivers and *bheel* are equally important to reduce the impact of hydrological drought. Few respondents were re-excavated their personal ponds to store rain water. BMDA already has been completed such activities including re-excavation of ponds, canals and *khari* for hydrological drought management. The initiatives make farmers increased access to surface water for irrigation. It also acts as the reservoir of groundwater. Surface water eventually makes cool surrounding environment and crops by carrying water vapor from the reservoir.

Figure 11.4: On-Farm water management (Photo courtesy OFRD)

Summary and conclusion

Sustainable livelihood approach, symbolic interaction theory, social exchange theory and social networks are very much important and sustainable approaches for sustainable drought management. It was evident that those respondents can manage their five capitals (human, natural, physical, financial & economic and social) efficiently they can manage drought crises efficiently. Social network is the important determinants for drought crises management. The farmers, those have better social networks, can manage drought better than counterparts.

Chapter-12: Case studies of women as drought resilience

12.1 Women as resilient

The demography including gender, education, occupation and income, drought scenario, drought perception, groundwater table, factors influencing drought, local wisdom used in weather extreme management, mitigation and adaptation measures in drought management has been discussed in the previous chapters (chapter Four to chapter Eleven). Quantitative or statistics have been used to describe the situation or results. Several case studies are presented in this chapter based on women's experiences. The case studies were focused on womne's gender baseddrought perspectives: how women combat drought and suffer from drought impacts. The real facts of their lives were selected for this study.

[8]Fulbhanu

Fulbhanu lives in Aye –Hi Village. She is 45 years old and belongs to poor family. She performed household works and eventually she worked for others agricultural field as the agricultural labour. She came from neighboring union after marriage. She helped her father a lots in the field at her childhood as because her father was very poor. She did planting, sowing, weeding, harvesting, tending of cattle and poultry. She carried food and water to the field for her father from long distance. Eventually she helped her mother for cooking, cleaning and washing. After marriage, she has been living in this village. Initially she got relief from the stress by doing outside work. Her Husband died 22 years back. There was no savings and assets to maintain the family during that time. The sale of agricultural labour was seasonal in the normal period. She has three kids (two daughters and one son). She has no lands except her husband's

[8]Real name is not used to protect their original identity

bari (homestead) of five decimals. She is the only earning member in her family. She was restricted by social and religious norms from working into the fields because she was treated as a "widow" and "village wife" (*gramer bou*). Eventually she needs to maintain social customs (*pardah*). She passed crucial time during 1995 drought. She worked hard and better than men but she got low wage as compare to men. She reported that usually men get BDT 300 but she got BDT 150-200 per day. The only reason is that she is a woman. The drought of 1995 caused huge damage to the crops, fish, livestocks and poultry. She sold her household goods (*Almirah & Alna*) for foods. She also sold her small but pretty ornaments (*sona*) to marry off her elder daughter. She received these ornaments from her parents at the time of her marriage. No one is able to help her during drought crisis from her parents. She sold trees from her homestead to maintain her family. Fulbhanu also explained her experience during 1995 drought: Observing high temperature, so hot and sunny day, no rainfall over a month. There was no water in to the *pukur* (pond), *khari* (canal) and no water was lifting through shallow or hand tubewell. Few Deep tubewells were working but can pump only little water during the period. All the agricultural activities (production, tending of cattle and poultry and fishing) were affected severely during the period. There was no water for bathing and cooking nearby. She needs to carry water from distant source for cooking, drinking, washing and cleaning and other household activities. She, her son and daughter usually go to long distance for bathing. In the study area, women are responsible for the collection of water. Her son was so little at that time and usually she did not sent her daughter to collect water from distant source due to social issues. It takes almost 2 hours in collecting water from distant source due to drought and *lomba* line (Waiting). The conflict was the regular event at that time. Hot talk, *Galagali* (slang language), *Hatahati* (battle) was the regular phenomenon during water collection. Few men tease women especially beautiful women, teen and young girls. One day Fulbhanu was affected by the women. They made quarrel and bite her ear and neck during collection of water. Even they pushed her on the earth and kicked her. Bloods come out after bite and she needed treatment for the incidence. Fulbhanu prepared herself to fight drought especially through the preparedness like harvesting of rainwater and storage into the container. She used *motki or kolshi* (large earthen pot) to store water. She made a hole in a shady place and keeps the *motki* inside the hole to keep water cool during hot especially during drought. She had to do different types of works from fields to households. She also compromised with foods. She ate only once a day but she tried to give at least two meals to her family members. She and her daughter collected green vegetables from the homestead and wild food from wild sources. Mostly they ate *fen, sada jau, jhal jau,chhatu, kochu, bon kochu, and bichi kola* during drought crisis. She faced gender discrimination in the society in case of employment, access to common property resources and rights and entitlements. She did her works very carefully but had to be afraid about herself and grown up daughters. She was worried about her daughters in getting good bridegroom. Eventually she wanted to protect them from any danger.

Gender perspectives

It is evident that how Fulbhanu was drought resilience during crisis. She performed several tasks like man do. She faced problems and made easy solution in the harsh situation. As she did agricultural works before marriage but these was restricted after marriage due to social and cultural norms. Fulbhanu has played a great role (like man) in her household sustenance. She has managed food and water for her children with the new storing system of water during drought crisis.

[9]Minoti

Minoti is 39 years old and she lives in Bhabicha Village. She is from ethnic group (*Santal*). She had been married to a land less agricultural labour. She came from nearby village under same Union. Due to poverty, her father gave marry off her to a young man. Minoti mentioned that her husband tortured her for dowry continuously. She asked her father to do something. Her father compelled it by selling his livestocks (cows). When she received it (cash money), her husband built a new house for happy living. Now Minoti is agricultural labourer and she worked in the fields almost round the year. She has two daughters, a twenty five years old and nine years old. Minoti and her husband both worked hard to ensure education for them. The younger one is studying at the government Primary school.

Minoti explained the sufferings of the 2005 drought. She usually made some savings for the drought crisis. As she told that drought is the common and devastating event in the study area. She knows well that people become jobless due to drought like natural disaster. She was the only earning member for her family as because her husband fallen in road accident just before the drought crisis. She spent her all savings for the treatment of her husband. She also sold her household assets for better treatment. The drought made her jobless, affecting agricultural activities including ploughing, planting, weeding, harvesting and threshing. The price of rice was also increased during drought crisis. Food crisis was the acute problem for her to maintain her family with children and husband. She was lacking from foods and employment at the time of drought. At first she tried to compromise with food quality herself then extended to the family members. Later, she reduced quantity of food. She ate food once a day and served two

[9]Real name is not used to protect their original identity

meals per day to her husband and children. She tried to collect wild food from wild sources (both plants and animals). Foods from plants including *bon kocu* (wild arum), *kolmi shuk* (water spinach), *panch mishali shuk* (Mixed leaves), *bichi kola* (Banana) etc were collected from wild sources (road side, pond side, alongside from *khari*, marshy land and from marginal and fallow land). Several animals including fish, rat, porcupine, jackle, birds, insects, snake, frogs, *kuchia* and rabbits were collected from wild sources and consumed as food during drought. She was injured during collection of wild food in case of wild animals. People also from rich and middle income group insulted her regularly. She was also harassed by men during collection of wild food. Along wild food she needs to collect fuel for cooking lavish food. Minoti never mind it and she continued her extended support to her children and husband. She managed her family with famine foods (*fen, jau, chhatu*) during harsh condition. Though Minoti did not have any staple food in her store but she managed wild food and cooked that for the regular bread of her family. This was great challenge for her as like a man not for woman. She sacrificed all happiness to combat drought. She did not participated any occasional ceremony and cut off unwanted expenditure through the hardship. It was mentioned by Minoti that her husband is not able to do work. She is looking after her family for food, clothes and education for children. She stated that she face same problem almost each and every season and year. She was also faced acute water crisis for drinking, household activities and bathing. She needs to collect water for household uses and bathing for her husband. She did not get any financial or food support from their neighboring people as because they are also very poor and vulnerable to drought. Few rich people could be ready to help her with undue activities. She has the experience of drought for couple of years and seasons. Drought makes them unemployed, sick and insecure to foods. She wiped out her eyes during explain drought experiences. She also reported that climate change, erratic or less rainfall, lack of soil moisture (*matir ros*) shifting to irrigated rice production and huge abstraction of groundwater is the major concern of increased frequency of drought.

Gender perspectives

Minoti is a woman has been suffered from drought and teased by rich people. This is happening due to her poverty and she is a woman. She used natural capitals to combat drought and significantly played an important role to combat drought and family sustenance.

[10]Roksana

Roksana is 35 years old. She lives in Nizampur village. She was married at the age of 12 years. She has five members in her family. Her husband has been paralyzed and died after long sufferings. She looked after her children and family at the time of her paralyzed husband. She also took care about childrens' education regularly. She has one daughter and two sons. Her mother in law also lives with them. She earned through home-gardening and performing as the agricultural wage labour. She had been put her best effort to survive during crisis. Her suffering was unexpected during drought. She shed tears in describing the 1995 droughts. As per several studies it was mentioned that children, aged person, disabled and women are more vulnerable to disasters like drought. All categories of people lived in her family and she had been tried at best to lead their livelihoods.

She has a tiny *bari* (homestead) with an area of 30 decimals. She has been traditionally practice home-garden in her homestead. She stated that home-gardening is a traditional land use practice which carried out around a homestead consisting of several species of plants, vegetables, spices and fruits. This garden are grown and maintained by the family members with the primary objective of family consumption and to sale for regular cash earnings. She got training on homestead gardening from World Vision (NGO) and from Department of Agriculture Extension (DAE) and received inputs (seeds and fertilizers) for home-gardening. She knew about improved and short duration vegetables, crops, fruits, spices and compost preparation from the training.

[10]Real name is not used to protect their original identity

She explained her experience to fight 1995 drought. Crops were damaged in the field. People were not hired agricultural labour at that time. Rokshana was in huge trouble at that time. How she managed the crisis? She described in following ways. She had no food in her home and no options to sale labour in the field. She sold a Jackfruit tree with minimum price from her homestead. She bought rice from market with high price. She mentioned that price was increased 3 *taka* to 5 *taka* per kilogram at that time. She thought about home-gardening and how to bring changes using knowledge. She applied her knowledge regarding home-gardening. Her little children and mother in law helped her lots. She grew very short duration crops including data *shuk*, *lal shuk, kolmi shuk, misti alu, pui shuk, lau, misti kumra* using marginal land and shady places. She used living trees, roof top (*ghorer chala*) and *macha* for homestead production. She used waste and waste water for watering in the homesteads. Waste water means water use in cleaning plate, bowl and others. She stored water after cleaning and use in home-gardening. She also put all kitchen wastes into certain pit and allowed it for decomposition. After decomposition she used it for home-gardening as the compost. Normally less vegetables were found in the market during drought and it come from other parts of the country. Roksana sold her vegetables and received good price from market as well as from neighborhood. She also planted sajna (Drumstick) in marginal land. She used both pod and leaves as curry in her family meals. She told the researcher during field work that she sold *sajna* (pod) *taka* forty per kilogram and earned a lot from her homestead during single season. It also gives few fruits after next year of planting. It also grows well in the drought prone area like Barind Tract as she told.

Now she is growing vegetables round the year considering season specific varieties and demand in the market. During June to September, she grows a variety of vegetables in the homestead such as pumpkin, gourd, brinjal, Indian spinach etc. She also applied mulches in water and weed management especially in potato cultivation, fruit tree and water management in the homestead. Her children were also helped her a lot by watering, weeding and harvesting of vegetables. Her Mother in law takes care about the protection of homestead from animals like cows, goats and chicken. She told me that home-gardening is the best options for drought adaptation. She can manage tiny homestead through wide array of options including selection of good varieties for drought (less water required crops), efficient water management (waste water management and mulching) and by engaging family labour for the production.

Gender perspectives

As a woman Roksana was very vulnerable after her marriage. Nobody helped her at that time. This story also gives us glimpse of gender and how a woman can survive in drought conditions. She also managed drought crisis by using her knowledge, networks and family members. She was very confident during harsh and deployed herself as the leader through her own motivation.

[11]Bindu

Bindu lives in chokghorpakhia Village under Satrajitpur Union in Shibganj Upazila. She was the daughter of famous family. Her father was the elite person in the village. Everybody obeyed her father as the head of a solvent family. She completed her secondary and higher secondary education. She was very intelligent and beautiful girl. She had been married for 25 years. Her husbands' family had huge land when they were in joint family. Her husband got 2 acres of land after isolation of the family. The land includes homestead, pond and crop lands. She had three children. She looked after them, do household activities, home-gardening, tending cattle and poultry. She often took care on fish in the pond. Her husband cultivated crops and fish regularly. Rice was the main cultivated crop in their farms. Previously rice farming was completely reliant on rain but with the passes of time rain fed rice farming has been replaced by irrigated rice farming and heavily depend on groundwater irrigation. Frequent drought and huge withdrawal of groundwater affected rice production. Bindu is well known about drought, it causes huge impacts on agriculture, health, society and livelihoods. She made regular communication with the Department of Agriculture Extension office, BMDA office, and NGOs (like World vision) and accumulated information on drought and vulnerabilities. She knew about the causes of drought, how to reduce drought risks, drought tolerant crops, crops diversification, crops that require less water, health impacts and impacts of groundwater abstraction. Bindu explained her experience on several droughts of 1995, 2005 and 2014. Hot and high temperature made them uncomfortable to stay at home. She drunk more water and advised every one especially at home to do it. Eventually she served *shorbot* (soft drink) to the family members made from water and brown palm sugar or sugar molasses. The *shorbot* keep

[11]Real name is not used to protect their original identity

them cool and maintain body temperature during extreme hot. She took two times bath at that time and asked for others too. She also made special dish with *sajna* leaves and consumed accordingly during lunch and dinner. She also advised others accordingly. She learnt that this food can maintain body temperature during extreme heat and can reduce the risk of heat stroke. She also asked her husband to switch to other crops from rice. According to her discussion, husband cultivated *Rabi* crops (potato, mustard, lentil and wheat), mung, seasame and *aus* or rain fed transplanted *aman*. She also asked her husband to use compost for home-gardening and field crops. She asked her husband not to use chemicals in the pond so that everyone can use pond water during drought crisis safely. She consumed *chhatu* as well as offered for the family members. She mentioned that *chhatu* keeps them free from risk of dysentery during extreme heat or severe drought. She also used grey water for home-gardening and asked family members to minimize wastage of water. Considering scarcity of water she harvested rainwater during rainy season and stored it accordingly for using later. She used mulch at the base of tree crops at the homestead. She also used improved cook stove to reduce fuel consumption and less contribution in carbon emission. She mentioned that all these knowledge she gathered through communication with the concerned departments and NGOs. She struggled a lot within the family as well as in the society. She was able to reduce drought risks due to her preparedness and response to the drought. She mentioned that controlled withdrawal of groundwater, crop diversification, rain-fed agriculture and awareness on drought management could be reduced drought risk.

Gender perspectives

As the family member, Bindu has been played drought educator to reduce risks. She also contributed a lot to teach us and disseminate drought information and how to manage drought risk for the family sustenance. She gave drought relevant information to the society as well. As a woman how she adopted and worked for the family as a man.

[12]Renu

Renu resides in Parisho Village. She is 30 years old and belongs to small holding family. She had married at her early age. She lived with her husband and father and mother in law in the rural village. After marriage she was gave birth two daughters in the following consecutive years. The areas were heavily dependent on irrigation and chemical agriculture. They used groundwater for irrigation and chemical fertilizers and chemical insecticides for crops production and protection. Renu and her husband both of them worked hard in the field for agricultural production. Before 2005, the rice production was good but after 2005 the groundwater table depletion was accelerating at alarming rate. She told me her experience during drought and how she managed it with organic production.

In 2005, crop production failed due to drought. There was no water for irrigation from surface sources. Irrigation was done using shallow and deep tube well but due to severe drought all the shallow tube well had gone out of work and the deep tube well can pumped little water that was not enough for irrigation. Her rice crop was damaged totally. She asked help for food (rice) from relatives and rich people. Nobody helped her during her crisis as because they were also in trouble due to drought. She sold her goats with low price and bought food for her family. Farmers were not hired any labour at that time. She and her husband both were jobless at that time. Renu thought about cowdung and kitchen wastes. She usually used compost made of kitchen wastes, crop residues, poultry litters and cowdung for her *bari* (homestead) production. She observed that she needs little or no water for homestead productions. This brought change

[12]Real name is not used to protect their original identity

in her mind. She also noticed that the produces are the tastier (*Shaad*) than chemical production. She decided that she will go for organic production at the field by changing crops. She also observed from her childhood that village women burn dry cowdung for cooking and boiling of rice. She told me about the drying of cow dung: preparing *ghute (*piece of cow dung*)* and *dhoila* (made of jute stick and cow dung). The village women spread the solid cow dung on the mud wall and after drying they collect it and store in certain place. They used it for cooking and boiling of ricein the convenient time. These are the great organic fertilizers as she told me. She had a milk cow with a calf. She sold milk and deposited cow dung for the preparation of compost. She decided to grow crops organically. She prepared compost in the usual manner. The necessary materials for making composts are cow dung, cooking ash, small quantities of dry straw and banana plants. For making compost, at first dig a 7-8 feet deep hole on the ground with 9-10 feet dia and then 8/9 months continued to accumulate cow dung, cooking ash and other materials. She divided their lands for organic and chemical production. Initially she was afraid about risks of organic production. After production, she noticed significant difference between the use of organic manure and chemical fertilizer: organic manure increase the yield of crop and reduce disease infestation and insect attack. Organic fertilizer increases water retention capacity compared to the chemical fertilizer. And also chemical fertilizer is more costly than organic fertilizer. Renu stated that, by using organic manure in the *Aman* season, paddy yield was 2160 kilograms per acre. On the other hand chemical farming yielded 1200 kilogram per acre only. In *Boro* (*chaitali*) season, the use of organic compost has increased paddy yield from 2160 kilograms to 3000 kilograms per acre whereas, paddy yield has increased from 1440 kilograms to 1800 kilograms per acre by using chemical fertilizer. She also observed that less irrigation required in organic production as compared to chemical production. She believed that compost can retain more water into the soil than chemicals. The soil in the study village gets harder and compacted for chemical production. Water can't penetrate into the soil and reduce infiltration capacity during rain and runoff. This could be improved through organic production. She mentioned that she found more earthworms in organically grown soil. Earthworm is the plough of nature as she said. Organically grown soil is capable to retain more water and conserve *ros* (soil moisture) during drought, as she perceived it. She also harvested good yield of wheat, mustard, lentil, potato and other vegetables growing organically. She saved lot of money avoiding chemical fertilizers and insecticides for crop protections. She engaged her family members for compost preparation through collection, processing and application in the field. She also cut off irrigation cost reducing irrigation frequency and time. Now she has converted production strategy and growing crops organically in managing drought.

Gender perspectives

As the gender dimension, she showed her innovation related to organic production. She also used all of the locally available low cost resources for composting. She engaged her family members in organic production. Her innovation may be one of the best strategies for sustainable drought adaptation measures. The poor farmers may get benefits through organic production and can reduce production cost and drought effects.

[13] Zoyna

Zoyna is 28 years old. She lives in Mollapara of Porsha Upazila. She is from middle holding family. She got married at the age of 15 years. She comes from Tetulia from same Upazila. Her father was farmers and occupied in farming profession. Zoyna had experience in farming from her childhood. She used to go to the field and carry food and water for her father. She gained experience on how to plant, weed out, tending fruits and crops. Her husband was a tenant farmer of middle holdings and cultivated grain crops especially rice and wheat in some extent. After marriage she was happy with her family. Gradually drought caused huge damage to her family by reducing rice production. Her husband sold his land to meet with drought crisis several times. She shared her previous experience regarding fruit garden with her husband. As she said fruit garden or orchard could be established in the drought prone area at it needs only little irrigation. She asked her husband to shift from rice to fruit garden. In the mean time she experienced drought 2005 and 2009. She motivated her husband for fruit gardening. She converted agricultural land to orchard. She also identified that drought is the main cause for crop losses because it increase the cost of production. On the other hand, to established an orchard initial cost is higher than agriculture but the maintenance cost is comparatively low because it requires minimum labour, fertilizer and water. They converted one acre for plum orchard, two acres for mango orchard and pomegranate orchard. They planted two years mature seedlings those were purchased from nearby nursery to establish orchard. It takes only two years to provide yield. It gives fruit next to the planting year. Zoyna told me that to establish a plum orchard it requires 600 plum seedlings per acre. Locally it is known as *Apple kul* and very popular in Bangladesh. The initial cost to establish plum orchard is around 30000 *taka* per acre. Mango orchard requires

[13]Real name is not used to protect their original identity

60 *khirshapat* and *gopalvog* variety seedlings and 150 *amrupali* variety seedlings per acre, and the initial cost is around 24,000 taka. The pomegranate orchard requires 150 pomegranate seedlings per acre with the initial cost of 22,500 *taka*. She explained from her experience, she can earn at least 150000 taka in a year from one acre orchard whereas; she can earn at best 75000 taka per acre from agricultural crops in a year. Zoyna said that agricultural crops can be grown easily within mango and pomegranate orchard at the first six to seven years of establishment, which helps to earn extra money from the same land. She explained that her living area is highly drought prone area. The amount of annual rainfall is not sufficient for agriculture of this area because the soil is so much dry. For this reason, maximum agriculture lands are not suitable for the cultivation of agricultural crops. Nevertheless it is still growing, but the production costs are much higher than profit. To minimize this problem farmers do not practice only agriculture in their lands, they practice agriculture with mango orchard. Few farmers have been practiced small portion of land through agriculture for basic family need, and the rest of lands for mango orchard. She has three types of mango orchard such as established mango orchard (more than 10 years old orchard), moderate mango orchard (less than 10 years old orchard) and newly planted mango orchard. She also mentioned that it requires low management cost (10,000 *taka* per acre) and gives high output and additional income from intercropping. She said that orchard created more employment opportunity for the agricultural labourers and engaged family members for active contribution. It also makes linkage with regional and national linkages for cash income. Zoyna is now happy with her family members for providing education, nutrition and for good income.

Gender perspectives

Zoyna as woman has contributed lot in family sustenance. She has created example for drought adaptations measures. It is evident that orchard is the vital strategy for drought adaptation measures. Zoyna as she said, the option is good for family income, drought management, family labour engagement and creation of job for the agricultural labour.

Summary and conclusion

Woman is a woman, not a man and poor is the poor no other identity in the society and in our social process. Above mentioned case studies were reflected clearly the biological gender discrimination in the society. Women, children, aged or eldery people, widow, person with disability, girls and poor peoples have been suffered more than others from drought impacts. It was observed that how a woman can survive in drough crisis and contribute in family sustenance. As woman and poor, she struggled a lot during drought from cash income, fetching water from long distance and taking care of family members. Women are harazed by the men at the time of hardship due to their poverty. They started with compromise of food ration (both quality and quantity) then reduced meal per day. They were also teased during water collection. Eventually they sold their ornaments (gift from parents or from relatives and often from husband at the time of marriage). Women sold their beloved livestocks and poultry during hardship at low cost to the neighbouring people. It was evident that women played great role in reducing health impact as the health educator during adverse situation. Few innovative adaptation jmeasures (homegardening, organic agriculture, water management, orchard farming, concept of grey water use etc) developed and implemented by the poor women.

Chapter 13: Discussion

Drought is interlinked with two essential features of uncertainty and ongoing climate change in disaster management. Climate change argued equally irregular disaster events expected drought, finally results causing slow changes in the seasonal temperature and precipitation patterns. Several droughts related studies suggested that ownership of capital is the main element in determining how farmers take action to drought in drought prone areas. Jodha proposed two fold drought survival tactics to appraise farmers' response to the drought. The measures should have following attributes; (1) reduce from ability to generate in the future, and (2) allows the quickest potential recovery of dynamic assets (Jodha, 1978). As defined by the respondents, drought is the severe dry spell and exists for long time due to lack of rainfall with extreme temperature and causes severe stress in soil moisture. According to Jarawura (2014), drought happens when limited rain is multiplied by insufficiency of water and soil moisture that exists for elongated time to badly influence on crop yield and growth of the plant. Drought is sporadic in the study area and local people have developed approaches to combat it. Crop adjustments are the central focus of risk management strategies (Jallow, 1995; 28). Soil degradation is another indicator of drought vulnerability. Farmers mentioned that poor soils have the low water holdings ability and supply low nutrients for vigorours growth of the plants an the drought prone area. It was reported that soil in the study areas already exhausted (low fertility due to low nutrients and organic matters in soil). It is assumed that increased frequency and intensity of drought occurrence will worsen agricultural activities and livelihoods. Drought is a multi dimensional phenomenon. Normally, the country (government) is responsible to reduce sufferings of the distressed poor by arranging humanitarian relief, loan supports and reserving employment opportunity for drought victims. As opined by the respondents that government initiatives are very limited in this regards. Similarly, reportshowed that the national government was addressed only 21 percent of the respondent households in mitigating the drought effect in northwestern part of Bangladesh through financial supports. Supply of emergency relief goods and creation of employment opportunity to the drought victims were absent. The government did not give any attention at the beginning of drought; the government denied the scale, ferequency, intensity and hazards of drought in the country. Thus, it is quite inadequate support to drought and late that provided by the government. The variations among disasters are contextual and differ from scale of impacts and vulnerability of locations, population characteristics and their livelihood pattern. It is quite impossible to predict the interaction between social, economic, ecological and the political dynamics, particularly the dynamics of climate change. Sound policy may be lacked to direct local capacity to pick up and adapt, if the future cannot be consistently anticipated. Resilience is the reverse term of vulnerability. According to IPCC (2013), "resilience is the ability of a social or ecological system to absorb disturbances while retaining the some basic structure and ways of functioning, the capacity for self organization, and the capacity to adapt to stress and change" (quoted in Pellling, 2010: 55). The most common problem of local capacity is the ritualistic involvement of community or neighborhood groups and political hostility toward NGOs and the low capacity of NGOs (Wisner and Utitto, 2009 cited in Surjan *et al.*, 2011). Occupation is the key factors that associated with crop loss due to drought. Who belongs to agriculture is very much susceptible to crop loss and impacted more. Literature suggested that there is linked of extrinsic factors that includes financial status and occupation (Parry *et al.*,.2007; Portier *et al.*,.2017; Cal EMA and CNR, 2012). Several researches reported that the climatic shocks or drought hazard is not affecting the socio-economic groups equally. In South Africa, the poor households are the most vulnerable population group to climate change (Juana *et al.,* 2012). It was mentioned that climatic shocks are worsening households' welfare. The rural poor groups who depend on agriculture for their livelihood existence are the most vulnerable group. It was reported that the increased probability of adaptation depend on level of education, age, sex and household size of farmers significantly (Deressa *et al.,* 2008). The drought patterns (frequency and scale) are almost similar among the study locations considering SPI values but the extent and occurrence year of drought are different for different locations. It was observed that drought frequency and scale has been increased but the management capacity drought is also imparted now a days. It is too difficult to draw inference on drought frequency and scale based on SPI value. Similarly Rafiuddin *et al.,* (2011) has mentioned that it is not easy to identify drought year or month for the particular locations by using SPI. Frequency and time scale or drought magnitudes are more extreme in Porsha and Nachole that other Upazila. Several researchers have been conducted study on impacts of drough on agriculture, economy and society in Bangladesh (Mazid *et al.,* 2005; Shahid & Behrawan, 2008). Drought is the ultimate results of continuous or consecutive dry spells and from extended periods of less rainfall. As opined by the farmers that, drought frequency is increasing day by day. Eventually it will be increased in near future especially in Barind Tract. Few gave their opinion on no change and few mentioned that drought will be decreased in the coming years. People's adaptive behavior may change based on prediction of climate extreme events (Davies, 1996; Adger *et al.,* 2009). There are three opinions on drought occurances and drought risks were obtained: drought risk will (1) increase, (2) decline and (3) remain the same. According to study of Jarawua (2014), "farmers who perceived increase drought risk within the next thirty years also perceived an increase in drought vulnerability, largely based on expected increase in the frequency of drought occurrence."

Farmers mentioned that they have perceived long duration of the hot season, a shorter duration of rainy season with erratic or less rainfall. Similarly in another study, farmers also perceived an increase drought frequency (Nyanga *et al.,* 2011). This study found that groundwater table is decreasing in the study area. 343 (100%) respondents mentioned that groundwater is depleting over the period of time. Results showed that the highest groundwater table is depleting in the study area in Nachole (3.39 feet/year) and the lowest in Shibganj. The following reasons have been mentioned by the FGD participants for this event; lack of rainfall, huge abstraction of groundwater; quick runoff during rainfall; excessive irrigation for rice production; lack of streamflow; soil characteristics (low organic matters, low water holding capacity and infiltration) and low recharge of groundwater. The hard soil surfaces do not allow rainwater to percolate affecting the groundwater recharge systems in the Barind Tract. It was reported by Shiklomanov (1997) that, Africa has experienced a 2.8 times decrease water accessibility during the period 1970 to 1995. Rivers' discharge has been dropped by 40-60 percent since 1970 in West Africa. Few factors including drought frequency, income, locations, occupations, support and land holdings are significantly affecting crop loss due to drought in this study. Uddin *et al.*, (2014) mentioned that six factors are statistically significant for adaptive strategies. The factors include age, family size, farm size, education, family income and cooperative involvement. On the other hand, three factors (credit received, extension training and access to market) are not statistically significant. In a study, Juana *et al.*, (2012) reported that agriculture is a primary drought impact sector, economy are also provoked effect from the agriculture sector. It was observed that different studies have been used several methods to analyze the socioeconomic determinants for adaptations to drought and climate change in Africa. Several studies showed similar significant determinants including gender, age, farming experience, size of the households, level of education, credit facilities, access to extension services, off-farm income generating activities for adopting drought adaptation measures (Kurukulasuriya & Mendelson, 2006; Deressa *et al.,* 2008; Mertz *et al.,* 2009; Acquah-de Graft & Onumah, 2011). It is found that there are significant changes in rainfall and temperature that affect agriculture. There is a projected significant reduction in food security; worsening water security; decrease in fish resources in large lakes due to rising temperature; and rising water stress are the long term impacts of climate change impacts (African Partnership Forum [APF], 2007). Local people and ethnic people used few sign from nature (plants, animals and weather) in case identification and prediction of drought in the study area. Most of the people believed that drought is the God given disasters and people don't have control on it. Similarly, a section of the people believed that it was not possible and that the Supreme Being (God) and the deities strategically kept this away from humankind (Jarawura, 2014). Respondents in the study area recognized drought by observing high temperature, absence of precipitation, more sunshine and low soil moisture. Another key determinant of drought is the crops wilting point in the growth stage and flowering or maturity stage. Similarly the visible negative effects reported by Jarawura (2014) that include crops wilting, poor flowering and or total failure of flowering. It may take up to two weeks for a drought to set in after rainfall deficiency, depending on the type of soil and the type of crops as mentioned by the farmers. Another ways of identifying drought is the absence of soil moisture: 'drought began at the time when the soil had no sufficient moisture for plants in the presence of extreme heat. Major changes observed in the climate events: less and erratic rainfall that means shortening of rainfall and prolonged dry spell round the year. Jarawura (2014) also mentioned that it is difficult to differentiate between drought and ending of rainy season due to shortening of the rainy season. People in the study area believes that drought is the punishment for sins of the people that provided by the God. Similarly Jarawura (2014) pointed that this is true based on the argument that drought is a God's punishment and the deities for the sins of the people. Almost eighty eight percent respondents adjusted at the household level using their household resources to cope with the drought. Local Government and several NGOs also worked for mitigation of drought. Drought victims mentioned that they received vital support from friends and kins (own or outside community). Various supports they received, it helped them to survive with drought and also resisted them not selling of their belongings at nominal prices. It was reported that drought affects poor and rich farmers. The poorer group suffered more than other groups though they adopted adjustment strategiest. It was mentioned by the respondents that they consume less quantity of rice and coarse wheat bread, *kolai ruti*, vegetables, and wild foods during the period of drought. They are not habituated with the famine foods because the affected area produces enough rice. They managed it by consuming food from their previous year's stock which was stored for selling in the market. It was reported from focus group discussion that 80 percent respondent households sell their assets to cope with the shocking effects of drought. Maximum numbers of respondent households (n= 245; 71%) borrowed money from others during drought crisis. As the second option, 184 (54%) respondent households sell their livestock to cope with the drought, 75 (22%) respondents by spending their savings, 51 (15%) respondents by mortgaging-out their land and 25 (7%) respondents by selling their land. Only three members from respondent households migrated to another area. Few respondents sold poultry birds and housing stuctures in extreme drought situations. It was reported by the participants (female) of Focus Group Discussions that they sold their ornaments (valuable jewelery) to cope with the drought. Respondents reported that they cut off ceremonial expenditure or denied the ceremonial occassion. It is difficult to estimate actual value for necessary ceremonial expenditure where people participated or “scarce food" consumed at home during crisis. Most household respondents stopped purchases of clothes and luxury items during the drought crisis. Respondents usually sell and mortgage out land in extreme cases. It wass found that all respondents deployed in the same way for agricultural adjustments and non-agricultural adjustments. Farmers adopted diverse adjustment at the individual level than service and businessmen occupations. Businessmen and service occupations are in a better position due to their better educational status. Farmers received less support from various sources due to their low educational attainment. This is the reason, they can make little adjustments at the individual level to cope with drought crisis. Landholding size and pattern (tenancy) is the key determinants of individual level adjustments to cope with drought crisis. It was mentioned that the small and middle farmers adopted more adjustments than the large farmers. Results showed that only ten percent respondents were migrated themselves during drought crisis and twelve percent respondents reported that their family members migrated during drought. Some drought affected households received support from relatives, friends, government, bank, NGOs, samity or club and community. As many 183 (53%) respondents reported that they got support from relatives, 164 (48%) respondents from NGOs, 116 (34%) from friends, 69(20%) from government, 21(6%) from *samity*, 15(4%) from bank and only 3(1%) from community. The majority 202(59%) respondents received support as the loan followed by 150(44%) donation, 57(17%) housing materials, 56(16%) seeds, 14 (13%) clothes, 33(10%) foods and 24(10%) cash. Only 2 (1%) respondents reported that they received labour support during drought crisis. The study found that 206 (60%) household respondents’ received financial supports and other forms of support from several sources (government and nongovernmental sources) to tackle the drought. The respondents utilized seven different sources of support and 132 (38%) respondent households didn't receive any support. The main support is provided by the relatives for the respondent households. The government provided seeds to the drought victims to recover drought loss, those are not get cash loan through public banks including Janata Bank, Sonali Bank, and Krishi Bank. They received other supports from friends, NGOs, villagers, and local government. Few friends and relatives live in the villages rather than victims' ones. They approached assistance from informal sources during environmental and other expected hazards. They received support in different forms such as donation (cash), loan, housing materials, food, cash, seeds, clothes, and labour. The loan amount provided by the informal sources (friends, relatives, and other villages) is much lower than the loan amount provided by the formal sources (bank, NGOs). The business and service occupation groups are more educated and also have had their strong network and connections with local local administration (government officials, bank managers and othe key officials) and have regular contact and/or personal relationship with them who involved in providing support to mitigate drought loss. Eventually they received larger amounts of support due to their connections and influence than the farmer groups. It was mentioned by the FGD participants that those owning moderate and large landholdings are more influential than their counterparts. As many 342 (100%) respondents reported that health problem occurs during drought includes diarrhea, heat stroke, skin diseases, and dysentery. Usually they drunk more water and took doctors advice during drought problems. The study area suffered from the shortage of irrigation water during drought. The drinking water sources were less affected by the drought. Drinking water problem has been solved by the installation of tubewell, which is the main source of drinking water in the study area. Respondents were not able to mention the adjustment practices of the other parts of Bangladesh. Similarly a number of agricultural adjustments practiced during the drought period in other parts of Bangladesh were not reported by the respondent households. Many households did not perform farming modification due to lack of financial resources. Households who adept farming modification implemented crop replacement plan. As an alternative of rice, they cultivated *kaon*, jute, wheat and onion. Few practices including irrigation, gap-filling, and intercultural operation for wheat and *kaon*, each practiced at the individual level. The gap filling is practiced where earlier germination has performed with the poor or patches of seedlings have died. Farmers usually provided occasional irrigation for the retention of soil moisture if drought occurs at the time of early *kharif* (March-April). At the end of irrigation, they quickly plough and hand weeds their fields. Such activities reduce moisture losses, and get ready the soil to absorb water deeply. Respondents mentioned that resowing of crops is the usual practice. Resowing is another adjustment that takes place if drought occurs in April after *aus*, *aman*, and jute have been sown. Juvenile crops may die due to lack of moisture during drought month. Farmers often resow the crops in May and June to tackle the situation. No effort is made to search the association between the adjustment and respondents characteristics. It is found from focus group discussion that the lease farmers were practiced agricultural adjustment compared middle and large holdings. In practicing irrigation and re sowing, farmers require surplus money, which poor households may perhaps unwell to pay for drought. Farmers used two distinct water sources for irrigation. They irrigated their crop field by fetching water from close sources including wells, tanks, or hand pump tube wells. The other way is to mount a deep or shallow tube well in the field. Both measures require extra labor and huge capital investment. Farmers are getting support from the institution to sink a well from BMDA. At present there is no assurance of water in the well due to groundwater depletion. In normal situation, assets (household and personal) are not sold or disposed. At the time of drought crisis food stocks declined, farmers give more importance to raise their cash through the sale of assets. The erratic or little rains retained no or low moisture in the soil where home gardening is expected, it was not a choice. The oddest measures were the grain borrowing and labor sale through temporary migration. Loan settlement through which land was assured as security may cause negative consequences for productivity. There should be agreement with the borrower's successive income and the conditions of reimbursement. Lend in kind (Rice) can be given back in the next crop season if the crop is good. Loans (cash) are creating new difficulties in relations to good yield, which may fall crop prices and expected income. Combined measures including sales of livestock, temporary migration, non agricultural activities (loans and food aid) permitted practically all respondents considered successfully to tackle the drought. It is complex to get better if lost: family member, land and equipments but they do well by keeping intact the productive resources. There should be government policy to provide support in gathering assets by farmers. Surplus production is the most positive approach to restrain for hardship. Juna *et. al.*, (2012) reported that farmers' experiences, entrance to good extension services and markets are key measures for drought adaptation. The study also found that several reasons such as lack of information (drought impacts, adaptation technologies) access to finance and shortage of lands are creating problems for drough adaptations. Farmers education level, age, sex and household size were found to be significant determinants of adaptation to drought in the Africa. Nhemachena and Hassan (2007) mentioned that use of varieties, crop diversification, altering planting dates, shifting occupation from farming activities to off-farm activities, irrigation efficiency, and improved water and soil conservation practices are the means of adaptation measures for the farmers of South Africa. The study also found that most farmers perceive increase temperature as a result the region is getting drier, with the changes raining and drought frequency. Acquah-de Graft and Onumah (2011) reported that 60 percent respondents use one or more adaptation measures and the rest 40 percent did not adopt any adaptation measures. He reported that farmers adopted few adaptation measures such as changing planting date, using diverse varieties, planting trees, water harvesting and soil conservation management practices. Thus, the main factors such as information gap, lack or inadequate extension services, information on drought prediction and improved crop varieties, ineffectiveness of indigenous methods, no subsidies on planting materials (seeds/fertilizers), limited knowledge on adaptation measures, low institutional capacity, and absence of government policy on climate change that limit farmers from adapting to drought impacts (Juana *et al.*,2012). de Wit (2006) examined and reported that significant number of farmers across the 11 countries opined that average temperatures have increased while precipitation has decreased. Few reported that they have experienced a irregular raining. Adaptation strategies of these countries varied from planting several varieties, changing the planting dates, increased use of irrigation, water and soil conservation techniques. Farmers mentioned that late planting, irrigation, soil conservation, planting different crop varieties are the common measures used for adaptation (Sofoluwe *et al.,* 2011). It was seen that women can perform better adaptation practices to combat drought by applying both local and updated knowledge. The farmers reported that lack of inputs, lack of knowledge on adaptation options and no or little access to water are the main climate change adaptation constraints. Lack of credit and lack of information about climate change, high cost of adaptation and insecure property rights are the barriers for adaptation. Additionally, results revealed that high level of willingness to pay for mitigation among the farmers. Farming experience (years), farm and land ownership, farm size and other income are significant probability to pay for climate change mitigation. Nze adibe *et al.,* (2011) pointed that respondents expect the involvement of the country through policy support is very important in assisting climate change adaptation.

Chapter 14: Conclusion and Recommendations

Study findings have essential implications both for theory and policy towards the Barind Tract. The Sustainable Livelihood Approach (SLA) has guided this study. Eventually in academia, the Sustainable Livelihood Approach is very reliable theoretical framework for the study and investigation of suitable adaptation measures among Barind people. It is more effective to modify the framework for the improvement and for its effective use in analyzing Barind peoples' livelihoods. A key finding is that Barind people use their conceptual knowledge for drought crisis management before choosing any strategy based on their previous experiences and intellectual interpretation of calamity. Study results have also allowed a better theoretical grasp of drought adaptability. Like other places, Barind people have discovered and possess adaptive mechanisms which they apply during economic hardship. They manage social environment to take full advantage of gains, which helps them to reduce the consequences of drought food crisis. Hence, study findings contribute in developing the literature on Barind peoples' social response to drought. These are useful findings, yet we had no detailed information on how the Barind people deal with drought problems using their indigenous knowledge and social activities. The results imply that every drought does not predictably lead to food crisis, loss of life from starvation and hunger related diseases. This study demonstrates that the socio-economic environment is crucial. The people who live in a distressed environment suffer more, while those who reside in friendly and resource enriched environment suffer less. Finally, six villages under this study use approaches that might be suitable for use as a drought management system in the Barind Tract. The study recommends a number of adjustments in development policies and strategies that, applied to this area, may lead to a sustainable management and adaptive strategy.

Methods adopted by respondents to mitigate the effect of drought have been discussed in this study. Drought victims adjust in various ways to cope with the drought at the time of delayed public response and inadequate support and services to the affected population. The availability of diversified livelihood options and profitability of adaptation measures are crucial for sustainable drought management. Several adaptation measures adopted by the drought victims, but their miseries were enclosed, especially for the poor. It is hard for such communities to insulate themselves against adversity with limited resources. In managing drought, the government should be better prepared for its onset. Projects should be developed prior to the drought considering implementation challenges and drawbacks at the time of drought crisis. Study findings may well give valuable information on the drought survival strategies used at the individual and community level. The study's conceptual framework was developed based on mitigation techniques adopted by drought victims and the support they received from different sources. The framework can provide vital insights concerning different levels of vulnerability and victims' response to an extreme natural event (drought). The adaptation strategies (measures) should be flexible, cost effective, reliable and accessible to the adopters. Diverse measures should be considered for resource poor groups, including short and long term benefits, with effective linkages between local and national administration. This study shows that an SPI calculation over the study location presents better uniformity of drought circumstances compared with single location information. Farmers experienced frequent droughts with drier soil conditions, erratic and reduced rainfall and shorter rainy seasons. It indicates that farmers need to adjust crop management practices to ensure the efficient use of rainfall, soil moisture and access to ground and surface water resources. A wide array of options exists for sustainable drought management including at the individual, household and farm level and as relates to policy. Farmers relied mostly on their past experiences related to drought and other climatic extreme events. They believe that the increased frequency of drought is linked with climate change. There is a clear connection between farmer's perceptions and the science of climate change and drought. It was mentioned that there is evidence of worldwide increase drought frequency, with the worst consequences stemming from high exposure and low adaptive capacity (IPCC, 2007; Burroughs, 2007; Dalby, 2009; Foresight, 2011). Both strengths and weakness are reflected in the farmers' perception on adapting to drought. In fact, local and indigenous climate knowledge is incredibly valuable in understanding the capacity of local communities to cope with drought (McCarthy & Long, 2005; IPCC, 2013). It is essentially important to facilitate participatory methods that permit farmers to share their understandings with others (government and NGOs etc.). The scientific explanations are important to extend their knowledge. The respondents who live adjacent to Shibganj Upazila town state that they can engage themselves in more jobs to earn cash income and dealt with the urban people, which was key to their resilience to devastating drought. The people who live at Bhabicha village, a distant rural area, conversely suffered more because they did not have this access to diverse income-generating activities. Drought management and adaptation strategies passed through the pre, during and post drought crisis cycle.

Based on study findings and conclusions, the following recommendations should be considered for better addressing drought in the Barind Tract:

- Considering Barind peoples' existing ability to adapt and respond to drought, policies should be built to enhance the support provided to them.

- New drought policy could be drawn from study findings to enhance Barind peoples' capacity for managing future drought risks. The issues that should be addressed by government are appended:
- The study revealed that Barind people have tackled drought by adopting a range of livelihood strategies, social networks and knowledge but which also resist the newest opportunities outside their world.
- The responses are difficult, lively and practical. A correct policy response is important to recognize the realities of the way people face both established practices and the latest opportunities.
- According to the need of existing networks, policies should focus on the requirement to re-establish such linkages, either ending the conflict with the neighboring [incomplete sentence].
- Eventually, Barind people can adapt new and appropriate options for drought risk management in collaboration with external actors outside. It was observed that respondents (households) used their own strategies effectively by sending children away to school or migrating for work in other regions temporarily during extreme drought. The situation could be better through interventions various administrative levels, from local to national.
- It was noticed that those who have easy access to social networks and the non-agricultural sectors of the economy were better able to manage drought than those engaged in agriculture. There is an immediate need to encourage them to diversify their agricultural activities (economy).

- It is also essential to put renewed emphasis on drought as a national problem in Bangladesh, with a higher priority. In reducing drought impacts, there is a need for Bangladesh to establish a 'Drought Research Institute', especially for the Barind Tract. The nation is not sufficiently attuned to the consequences of impending droughts, thus in controlling the situation the establishment of such a research institute is important.
- It is crucial to have a water infrastructure policy, cropping policy and land use policy in Barind Tract.
- Drought insurance and incentives for organic agriculture should be established in the study areas for the better management of drought

References

Acquah, H. D., & Onumah, E. E. (2011).Farmers perceptions and adaptations to climate change: Anestimation of willingness to pay. *Agrison-line Papers in Economics and Informatics, 3*(4), 31-39.

Adhikary, S. K., Sharif, A. A., Das, S. K., & Saha, G. C. (2014). Geostatistical analysis of groundwater level fluctuations in the shallow aquifer of northwestern Bangladesh.In *Proceedings of the 2nd International Conference on Civil Engineering for Sustainable Development* (pp. 14-16).Khulna, Bangladesh:KUET. ISBN: 978-984-33-6373-2.

Adger, W. N., Dessai, S., Goulden, M., Hulme, M., Lorenzoni, I., Nelson, D. R., & Wreford, A. (2009). Are there social limits to adaptation to climate change? *Climatic change*, *93*(3), 335-354.

Adnan, S. (1993).Living without Floods: Lessons from the Drought of 1992.*Research and Advisory Services, Dhaka*.

AFP, (2007).Climate Change and Africa.*8th Meeting of African Partnership Forum*, Berlin, Germany, 22-23 May, 2007.

Agrawala, S., Ota, T., Ahmed, A. U., Smith, J., & Van Aalst, M. (2003). *Development and climate change in Bangladesh: focus on coastal flooding and the Sundarbans* (pp. 1-49). Paris: OECD.

Ahmed, A. U. (2000). Adaptability of Bangladesh's crop agriculture to climate change: Possibilities and limitations. *Asia Pacific Journal on Environment and Development (Bangladesh)*, *7*(1), 71-93.

Ahmed, R. and Bernard, A.(1989). *Rice Price Fluctuation and an Approach to Price Stabilization in Bangladesh* (Rice Report 72). Washington, D.C.: International Food Policy Research Institute.

Ahmed, A. U. (2006). *Bangladesh Climate change impacts and vulnerability: A synthesis*. Climate Change Cell, Department of Environment Comprehensive Disaster Management Programme, Government of the People's Republic of Bangladesh.

Ali, M. Y., Ahmed, S., Johansen, C., Harris, D., & Rao, J.V.D.K. (2007). *Root traits of different crops under rainfed conditions in the High Barind Tract of Bangladesh*. *J.Plant Nutr.Soil Sci*, 170, 296-302.

Ashley, C., & Carney, D. (1999).*Sustainable livelihoods: Lessons from early experience* (Vol. 7, No. 1). London: Department for International Development.

Bangladesh Agricultural Development Corpora-tion (BADC). (2010). *Minor Irrigation Survey Report 2009-10*. Dhaka: Ministry of Agriculture

Banglapedia .(2003). Banglapedia: National encyclopedia of Bangladesh. In: Islam, S (ed) Asiatic society ofBangladesh, Dhaka

Bangladesh Agriculture Research Council (BARC). (2001). Impact of Land Degradation in Bangladesh: Changing Scenario in Agricultural Land Use, Karim, Z., and Iqbal, M.A. (Eds.), Soils Publication No: 42, BARC, Dhaka. 106p

Bangladesh Bureau of Statistics (BBS). (2010). Cropping Intensity of Bangladesh. Retrieved from ***http://www.brri.gov***

Bangladesh Bureau of Statistics (BBS). (2011). *Population & Housing Census 2011: Preliminary Results*. *July 2011*,Dhaka, Bangladesh: Bangladesh Bureau of Statistics, Statistics Division, Ministry of Planning, Government of the People's Republic of Bangladesh

Bangladesh Bureau of Statistics (BBS). (2014). *Statistical Pocketbook of Bangladesh-2013*. Dhaka, Bangladesh: Bangladesh Bureau of Statistics, Statistics Division. Ministry of Planning. Govt. of the People's Republic of Bangladesh.

Belay, K., Beyene, F., & W. Manig. (2005). Coping with Drought among Pastoral and Agro-Pastoral Communities in Eastern Ethiopia. *Journal of Rural Development28*, 185–210.

Benson, C., & Clay, E. (1994). The impact of drought on sub-saharan african economics. *IDS Bulletin*, *25* (4), 24-32.

Blau, P. (1964). *Power and exchange in social life*. *New York: J Wiley & Sons*, *352*.

Blumer, H. (1986). *Symbolic interactionism: Perspective and method.* Berkeley, Los Angeles, London: Univ of California Press.

Barind Multipurpose Development Authority (BMDA). (2006). *Borandro Authority Past-Present.* Rajshahi: BMDA.

Barind Multipurpose Development Authority (BMDA). (2011). http://www.bmda.gov.bd/

Brammer, H. (1999). *Agricultural disaster management in Bangladesh*. University Press Limited. pp. 273-74.

Brown, L. R. (2002). *Water deficits growing in many countries*: *Water shortages may cause food shortages.* Rutgers University, *Earth Policy Institute:* Retrieved from http://www.earthpolicy.org/plan_b_updates/2002/update15

Bruce, J. P. (1994). *Natural disaster reduction and global change*. *Bulletin of the American Meteorological Society*, *75*(10), 1831-1836.

Burroughs, J.W. (2007). *Climate Change: A Multidisciplinary Approach*. Cambridge: Cambridge University Press.

Barton, D., Morton, J., & Hendy, C. (2001). Drought contingency planning for pastoral livelihoods. *Natural Resources Institute Policy Series (15)*. Natural Resources Institute, Chatham, UK. ISBN 0859545377.

Cahn, M. (2002). *Sustainable livelihoods approach: Concept and practice.* Massey University.

California Natural Resources Agency (CNR). (2012). California climate adaptation planning guide; Planning for Adaptive Communities. California Emergency Management Agency & California Natural Resources Agency.

Carney, D. (1998). *Sustainable rural livelihoods: What contribution can we make?* London: Department for International Development.

Chambers, R. (1983). *Rural development: Putting the last first.* London: Pearson Education Limited.

Chambers, R. (1987). Sustainable rural livelihoods: A strategy for people, environment and development. In C. Conroy & M. Litvinoff (eds), *The Greening of Aid: Sustainable Livelihoods in Practice*. London: Earthscan.

Chen, M. A. (1991). *Coping with seasonality and drought*. Sage Publications

Chowdhury, A.M., Quadir, D.A., Neelormi, S., & Ahmed, A.U., (2003). Climate change and its impacts on water resources of Bangladesh. In A. Muhammed (ed.*), Climate change and water resources in South Asia* (pp. 21-60), Islamabad: Asianics AgroDEV International.

Chowdhury, D.N., Elias, S.M., & Ahmed, N.U. (1996). *Indigenous technologies used by women in Bangladesh.* A draft paper presented at the workshop on "Achievements of the Gender Research and Training Project". 25-26th May, 1996. Bangladesh Agricultural Research Council (BARC), Dhaka, Bangladesh

Chowdhury, M. H. K. & Hussain, A. (1981). Aridity and Drought Conditions of Bangladesh.Tropical Droughts (Meteorological Aspects and Implications for Agriculture).*Journal of WMO Program on Research in Tropical Meteorology*, 73-80.

Clark, P. U., Alley, R. B., & Pollard, D. (1999). *Northern Hemisphere ice-sheet influences on global climate change. Science*, *286*(5442), 1104-1111.

Dalby, S. (2009).*Security and Environmental Change*. Cambridge: Polity Press.

Davern, M. (1997). Social networks and economic sociology: a proposed research agenda for a more complete social science. *American Journal of Economics and Sociology*, *56*(3), 287-302.

Davies, S. (1996). Adaptive livelihoods: Coping with food insecurity in the Malian Sahel. London: MacMillan.

Darkoh, M. B. K. (1995). The deterioration of the environment in Africa's drylands and river basins. *Desertification Control Bulletin*, (24), 35-41.

Deressa, T., Hassan, R.M., Alemu, T., Yesuf, M., & Ringler, C. (2008). *Analyzing the Determinants of Farmers' Choice of Adaptation Methods and Perceptions of Climate Change in the Nile Basin of Ethiopia*; IFPRI Discussion Paper 00798; International Food Policy Research Institute (IFPRI): Washington, DC, USA.

Department for International Development (DFID). (1994). Sustainable Livelihoods Guidance Sheets Retrived January 31, 2015 from http:/www. Livelihoods.org/info/info guidance sheets.html.

Department for International Development (DFID). (2001). Sustainable Livelihoods Guidance Sheets Sustainable Livelihoods Guidance Sheets Retrived January 31, 2015 from http:/www. Livelihoods.org/info/info guidance sheets.html.

Department for International Development (DFID**)**. (2004). Disaster risk reduction: A development concern. A scoping study on links between disaster risk reduction, poverty and development. DFID, London.

Ellis, F. (2000). *Rural livelihoods and diversity in developing countries.* New York: Oxford university press.

Ericksen, N. J. (1994). Socio-economic implications of climate change for Bangladesh (No. 4). Bangladesh UnnayanParishad.

Ericksen, N. J., Ahmad, Q. K., & Chowdhury, A. R. (1997). *Socio-economic implications of climate change for Bangladesh* (Briefing Document No. 4). Dhaka, Bangladesh: Bangladesh Unnayan Parishad (BUP).

Food and Agriculture OrganizationM (FAO). (1983). Guidelines: Land evaluation for Rain fed Agriculture (*FAO Soils Bulletin 52)*, Rome: FAO.

Food and Agriculture Organization (FAO). (2009). *Climate Change in Africa: The Threat to Agriculture*. Gamel Abdul Nasser Road, Accra: FAO Regional Office for Africa. Retrieved from ftp://ftp.fao.org/docrep/fao/012/ak915e/ak915e00.pdf.Accessed on 25/12/2015

Feldman, S., & McCarthy, F. E. (1983). Purdah and changing patterns of social control among rural women in Bangladesh.*Journal of Marriage and the Family*, 949-959.

Foresight.(2011). *Migration and Global Environmental Chang: Final Project Report*. London: The UK Government office for Science.

Gebrehiwot, T., & van der Veen, A. (2013). Farm level adaptation to climate change: The case of farmer's in the Ethiopian highlands. *Environmental Management*,52(1), 29–44.

Golo, B.K., & Yaro, J.A.(2013). Reclaiming Stewardship in Ghana: Religion and climate change. *Nature and Culture*, 8(3), 282-300.

Government of Bangladesh. (2005). National action programme (NAP) for combating desertification. Dhaka, Bangladesh: Ministry of Environment and Forests, Government of the Peoples Republic of Bangladesh, BangladeshSecretariat. Retrieved from http://www.doe-bd.org/nap_2006.pdf.

Gulliver, P. H. (1951). A preliminary survey of the Turkana: A report compiled for the Government of Kenya (No. 26). University of Cape Town.

Gulliver, P. H. (2013). *The family herds: A study of two pastoral tribes in east Africa*. The Jie and T. Routledge.

Havnoe, K. & Hansen, A. M. (2009, February). Adaptive measures for coping with increased floods and droughts in Bangladesh, IOP *Conference* Series: Earth and Environmental Science *(EES)*, *6*(29), 1. doi:101088/1755-1307/6/29/292001

Hays, Jeffrey. (2008). Water shortages in China. Retrieved from http://factsanddetails.com/china.php?itemid=390&catid=10&subcatid=66.

Heim Jr, R. R. (2002). A review of twentieth-century drought indices used in the United States. *Bulletin of the American Meteorological Society*, *83*(8), 1149-1165.

Hewitt, K. (1997). *Regions of risk: A geographical introduction to disasters*. London: Rutledge. https://www.taylorfrancis.com/books/9781317894179

Hogg, R. (1986). The new pastoralism: Poverty and dependency in northern Kenya. *Africa*, *56*(03), 319-333.

Homans, G. C. (1974). Social behavior: Its elementary forms.

Homans, G. C. (1961). Social Behavior: Its Elementary Forms. New York: Harcourt, Brace.

Hossain, M. (1990). Natural calamities, instability in production and food policy in Bangladesh. *The Bangladesh Development Studies*, 33-54.

Hudson, H. E. & Hazen, R. (1964). Droughts and low streamflow. In V. T. Chow (Ed.), *Handbook of Applied Hydrology*. New York: McGraw-Hill.

Intergovernmental Panel on Climate Change. (2007). *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge, United Kingdom: Cambridge University Press.

Intergovernmental Panel on Climate Change. (2013). *Climate Change (2013): The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T. F., D. Qin, G.-K. Plattner, M.

Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge, UK: Cambridge University Press.

Islam, M. M. (1996). *Farmers' use of indigenous technical knowledge in the context of sustainable agricultural development*. M.Sc. Thesis, Department of Agricultural Extension Education, Bangladesh Agricultural University, Mymensingh, Bangladesh.

Islam, A. (2012). *Khana*. In Banglapedia: National Encyclopedia of Bangladesh (2nd ed.), Bangladesh. Retrieved from http://en.banglapedia.org/index.php?title=Khana

Islam, M. N. (2013). *Overview of Urbanization in Bangladesh*. Paper presented at the Urban Dialogue, Organized by Habitat for Humanity Bangladesh, 1 September 2013, Dhaka.

Jabbar, M. A., Chaudhury, M. U., & Huda, M. H. Q. (1982, January). Causes and effects of increasing aridity in Northwest Bangladesh. In proceedings of *First Thematic Conference on Remote Sensing of Arid and Semi-Arid Lands*, 1195-1204, Cario, Egypt.

Jabbar, M. A. (1990, August). Causes and effects of drought/aridity in Bangladesh using remote sensing technology. In proceedings of *ESCAP workshop on remote sensing technology in application to desertification/vegetation type mapping*, Tehran.

Jallow, S.S. (1995). Identification of and response to drought by local communities in Fulladu West District, the Gambia. *Singapore Journal of Tropical Geography 16*(1), 22-41.

Jansen, E. G. (1986). *Rural Bangladesh: Competition for scarce resources*. Oslo: Norwegian University Press.

Jarawura, F. X. (2014). Perceptions of drought among rural farmers in the Savelugu district in the northern Savannah of Ghana. *Ghana Journal of Geography*, *6*(1), 102-120.

Jodha, N. S. (1978). Effectiveness of farmers' adjustments to risk. *Economic and Political Weekly*, A38-A48. Retrieved from http://www.jstor.org/stable/4366744

Johnson, S. H. III. (1982). Large-scale irrigation and drainage schemes in Pakistan: A study of rigidities in public decision making. *Food Research Institute Studies, 18,* 149-180. ISSN: 0015-6566.

Juma, R. O. (2009). *Turkana livelihood strategies and adaptation to drought in Kenya* (Doctoral dissertation). Victoria University of Wellington, New Zealand. Retrieved from http://researcharchive.vuw.ac.nz/bitstream/handle/10063/1063/thesis.pdf?sequence=1

Juana, J. S., Mangadi, K. T., & Strzepek, K. M. (2012). The socioeconomic impacts of climate change on water resources in South Africa. *Water International, 37*(3), 265-278. Retrieved from *http://dx.doi.org/10.1080/02508060.2012.687505*

Juana, J. S., Makepe, P. M., & Mangadi, K. T. (2012, September). *Empirical analysis of the impact of drought on the Botswana economy*. Paper Presented at the AERC/UNU-WIDER Climate Change Workshop, Helsinki, Finland.

Karim, Z., Ibrahim, A., Iqbal, A., & Ahmed, M. (1990). *Drought in Bangladesh agriculture and irrigation schedules for major crops* (Publication No. 34). Dhaka, Bangladesh**:** Bangladesh Agricultural Research Center (BARC).

Karim, Z., & Iqbal, A. (2001). *Impact of land degradation in Bangladesh: Changing scenario in agricultural land use*. Dhaka, Bangladesh: Bangladesh Agricultural Research Center (BARC).

Kataki, P. K., Hobbs, P., & Adhikary, B. (2001). The rice-wheat cropping system of South Asia: Trends, constraints and productivity - A prologue. *Journal of Crop Production, 3*(2), 1-26.

Khan, M. F. A., & Islam, M. S. (2013). *Vulnerability to climate induced drought: Scenario and impacts*. Comprehensive Disaster Management Programme (CDMP II), Ministry of Disaster Management and Relief (MODMR), Dhaka, Bangladesh.

Kijne, J. W., Barker, R., & Molden, D. (Eds.). (2003). Improving water productivity in agriculture: Editors' Overview. In J. W. Kijne, R. Barker, D. J. Molden (Eds.), *Water productivity in agriculture: Limits and opportunities for improvement*. Wallingford UK: CABI Publishing.

Kates, R.W., Ausubel, J. H. & Berberian, M. (Eds.). (1985). Climate Impact Assessment: Studies of the interaction of climate and society. New York: John Wiley & Sons, Inc.

Kurukulasuriya, P., & Mendelson, R. (2006). *Crop Selection: Adapating to Climate Change in Africa* (CEEPA Discussion Paper No. 26). Pretoria, South Africa: Centre for Environmental Economics and Policy in Africa. University of Pretoria.

Mazid, M. A., Mortimer, M. A., Riches, C. R., Orr, A., Karmaker, B., Ali, A., . . . Wade, L. J. (2005). Rice establishment in drought-prone areas of Bangladesh. In K. Toriyama, K.L. Heong, B. Hardy (Eds.), *Rice is life: Scientific perspectives for the 21st century*. Manila, Philippines: International Rice Research Institute.

McCarthy, J. J., & Martello, M. L. (2005). Climate change in the context of multiple stressors and resilience. In C. Symon et al. (Eds.), *Arctic Climate Impact Assessment* (pp. 945–988). Cambridge: Cambridge University Press.

Mertz, O., Mbow, C., Reenberg, A., & Diouf, A. (2009). Fermers' perceptions of climate change and agricultural adaptation strategies in rural Sahel. *Environmental Management, 43*(5), 804-816.

Mikkelsen, B. (2005). *Methods for development work and research: A new guide for practitioners*. New Delhi, India: Sage Publications Limited.

Milly, P. C. D., Wetherald, R. T., Dunne, K. A., & Delworth, T. L. (2002). Increasing risk of great floods in a changing climate. *Nature*, *415*, 514-517.

Moser, C. O. N. (1989). Gender planning in the Third World: Meeting practical and strategic gender needs. *World development*, *17*(11), 1799-1825.

Murshid, K. A. S. (1987). Weather, New Technology and Instability in Foodgrain Production in Bangladesh. *The Bangladesh Development Studies 15(1),* 31-56. Retrieved from http://www.jstor.org/stable/40795270

Nandargi, S., Dhar, O. N., Sheikh, M. M., Enright, B., & Mirza, M. M. Q. (2010). Hydrometeorology of Floods and Droughts in South Asia – A Brief Appraisal. In A. P. Mitra & C. Sharma (Eds), Global Environmental Changes in South Asia (pp. 244-257). Dordrecht: Springer.

In *Global Environmental Changes in South Asia* (pp. 244-257). Springer Netherlands.

Nasreen, M. (1995). *Coping with floods: The experience of rural women in Bangladesh* (Unpublished doctoral Dissertation). Massey University, NewZealand.

Nasreen, M. (2012). *Women and girls: Vulnerable or resilient?* Dhaka, Bangladesh: Institute of Disaster Management and Vulnerability Studies, University of Dhaka, Bangladesh. ISBN: 978-984-33-5649-9

Nasreen, M. (2015). *Effectiveness of 'Resilient Livelihood Framework' of Christian Aid*. *Institute of Disaster Management and Vulnerability Studies, IDMVS, Dhaka, Bangladesh*.

National Drought Mitigation Center (NDMC). (2008). GoB. *Drought.* Retrived from https://drought.unl.edu/

Nhemachena, C., & Hassan, R. (2007). *Micro-level Analysis of Farmers' Adaptations to Climate Change in Southern Africa* (IFPRI Discussion Paper, Series Number 714. Washington, DC: International Food Policy Research Institute (IFPRI) & Centre for Environmental Economics and Policy in Africa (CEEPA).

IFPRI, Environment and Production Technology Division. International Food Policy Research Institute.

Nyanga, P., Johnsen, F., Aune, J., & Kahinda, T. (2011). Smallholder Farmers' Perceptions of Climate Change and Conservation Agriculture: Evidence from Zambia. *Journal of Sustainable Development*, *4*(4), 73-85. DOI: 10.5539/jsd.v4n4p73

Nzeadibe, T. C., Egbule, C. L., Chukwuone, N. A., & Agu, V. C. (2011). *Farmers' Perceptions of Climate Change Governance and Adaptation Constraints in Niger Delta Region of Nigeria* (African Technology Policy Network, Research Paper No. 7). Nairobi, Kenya: African Technology Policy Studies Network.

Oba, G. (2001). The importance of pastoralists' indigenous coping strategies for planning drought management in the Arid zone of Kenya. *Nomadic Peoples, 5*(89), 89-119.

Obasi, G. O. P. (1994). WMO's role in the international decade for natural disaster reduction. *Bull. Am. Meteorol. Soc. 75 (9)*, 1655–1661.

Okoko, E. (2006). *Quantitative techniques in urban analysis*. Ibadan: Krafy Books Limited.

Olaleye, O. (2010). Drought Coping Mechanisms: A Case Study of Small Scale farmers in Motheo District of the Free State province (M.S. thesis), Department of Environmental Management, University of South Africa. Retrieved from uir.unisa.ac.za/bitstream/handle/10500/4032/dissertation_olaleye_o.pdf

Paul, B. K. (1995). Farmers' and public responses to the 1994-95 Drought in Bangladesh: A case study (Quick Response Research Report #76). Boulder, Colorado: Natural. Hazards Research and Applications Information Center, University of Colorado.

Paul, B. K. (1998). Coping mechanisms practised by drought victims (1994-95) in North Bengal, Bangladesh. *Applied Geography*, *18*(4), 355-373.

Parry, M., Parry, M. L., Canziani, O., Palutikof, J., Van der Linden, P., & Hanson, C. (eds.). (2007). *Climate change 2007: Impacts, adaptation and vulnerability* (Working group II contribution to the fourth assessment report of the IPCC). Cambridge, U.K. and New York, NY: Cambridge University Press.

Pelling, M. (2010). *Adaptation to climate change: From resilience to transformation*. London: Routledge.

Surjan, A., Takeuchi, Y., & Shaw, R. (2011). *From disaster and climate risk to urban resilience: Approaching through community based environmental improvement*. Singapore: Research Publishing Service.

Portier, C. J., Thigpen, T. K., Carter, S. R., Dilworth, C. H., Grambsch, A. E., Gohlke, J., ... & Maslak, T. (2017). *A human health perspective on climate change: A report outlining the research needs on the human health effects of climate change*. Research Triangle Park, NC: Environmental Health Perspectives / National Institute of Environmental Health Sciences. doi:10.1289/ehp.1002272.

Putnam, R. D., Leonardi, R., & Nanetti, R. Y. (1994). *Making democracy work: Civic traditions in modern Italy*. Princeton, New Jersey: Princeton university press.

Rafiuddin, M., Dash, B. K., Khanam, F., & Islam, M. N. (2011, April). Diagnosis of drought in Bangladesh using standardized precipitation index. *2011 International Conference on Environment Science and Engineering*, IPCBEE vol.8 (pp. 184-187). Singapore: IACSIT Press.

Rahman, A. & Biswas, P.R. (1995). Devours resources. *Dhaka Courier*, *11*(42), 7-8.

Rahman, A. A., Alam, M., Alam, S. S., Uzzaman, M. R., Rashid, M., & Rabbani, G. (2008). *Risks, vulnerability and adaptation in Bangladesh* (Human Development Report, 2007/08). Human Development Report Office Occasional Paper, 2007/13, UNDP.

Rahman, M. M., & Mahbub, A. Q. M. (2012). Groundwater depletion with expansion of irrigation in Barind Tract: A case study of Tanore Upazila. *Journal of Water Resource and Protection*, *4*(08), 567-575.

Ramamasy, S., & Baas, S. (2007). *Climate variability and change: Adaptation to drought in Bangladesh. A resource book and training guide*. Asian Disaster Preparedness Center and Food and Agriculture Organization of the United Nations (FAO)

Rasheed, K. B. S. (1998, April). Status of land resource use and desertification, drought and land degradation in Bangladesh: Obstacles and effective policy options and measures for sustainable use of land resources. *Proceedings of the national awareness seminar on combating land degradation/desertification in Bangladesh*. Dhaka.

Reardon, T., Matlon, P., & Delgado, C. (1988). Coping with household-level food insecurity in drought-affected areas of Burkina Faso. *World Development, 16*(9), 1065-1074.

Reilly, J., Tubiello, F., McCarl, B., Abler, D., Darwin, R., Fuglie, K., … & Rosenzweig, C. (2003). US agriculture and climate change: New results. *Climatic Change*, *57*(1-2), 43-67.

Saleh, A. F. M., Mazid, M. A., & Bhuiyan, S. I. (2000). Agrohydrologic and drought-risk analyses of rainfed cultivation in northwest Bangladesh. In T. P. Tuong (Ed.), *Characterizing and understanding rainfed environments* (233-244). Manila (Philippines): International Rice Research Institute.

Schafer, J. (2002). *Supporting livelihoods in situations of chronic conflict and political instability: Overview of conceptual issues* (Working paper: 183). London: Overseas Development Institute.

Scoones, I. (1998). *Sustainable rural livelihoods: A framework for analysis* (IDS Working Paper 72). Brighton: IDS.

Schutz. A (1970). *Phenology of Social Relations:; Selected Writings. Edited and with an Introduction by Helmut. R.Wagner.* Chicago: University of Chicago Press.

Sen, D. (2008). Impact of Khana's Vachan on traditional Agriculture in Bengal. *Asian Agri-History, 12(3),* 211-214.

Shahid, S., Chen, X., & Hazarika, M. K. (2005). Assessment aridity of Bangladesh using geographic information system. *Gis Development*, *9*(12), 40-43.

Shahid, S., & Behrawan, H. (2008). Drought risk assessment in the western part of Bangladesh. *Natural Hazards, 46*(3), 391-413.

Shamsudduha, M., Taylor, R. G., Ahmed, K. M., & Zahid, A. (2011). The impact of intensive groundwater abstraction on recharge to a shallow regional aquifer system: Evidence from Bangladesh. *Hydrogeology Journal, 19,* 901-916.

Shiklomanov, I. A. (1997). *Assessment of water resources and water availability in the world*. Background Report for the Comprehensive Assessment of the Freshwater Resources of the World. Geneva: World Meteorological Organization and & Stockholm: Stockholm Environment Institute.

Sinclair, J., & Ham, L. (2000). Household adaptive strategies: Shaping livelihood security in the western Himalaya. *Canadian Journal of Development Studies/Revue canadienne d'études du développement*, *21*(1), 89-112.

Sofoluwe, N. A., Tijani, A. A., & Baruwa, O. I. (2011). Farmers perception and adaptation to climate change in Osun State, Nigeria. *African Journal of Agricultural Research*, *6*(20), 4789-4794.

Sohrab, A. M. (2015). *Bangladesh National Action Program for Combating Desertification, Land Degradation and Drought, 2015-2024*. Department of Environment (DoE), Government of the People's Republic of Bangladesh.

Soja, E. W. (1968). *The geography of modernization in Kenya: A spatial analysis of social, economic, and political change* (No. 2). Syracuse, N.Y.: Syracuse University Press.

Stephen, L., & Downing, T. E. (2001). Getting the Scale Right: A Comparison of Analytical Methods for Vulnerability Assessment and Household-level Targeting. *Disasters, 25*(2), 113-135.

Szép, I. J., Mika, J., & Dunkel, Z. (2005). Palmer drought severity index as soil moisture indicator: physical interpretation, statistical behaviour and relation to global climate. *Physics and Chemistry of the Earth, 30*, 231-243.

Stryker, S. (1973). Fundamental principles of social interaction. In N. J. Smelser (Ed.), *Sociology: An Introduction* (pp. 495-547). New York: Wiley.

Tessema, Y. A., Aweke, C. S., & Endris, G. S. (2013). Understanding the process of adaptation to climate change by small-holder farmers: The case of east Hararghe Zone, Ethiopia. *Agricultural and Food Economics*, *1*(1), 13.

Thomas, D. S. G., Twyman, C., Osbahr, H., & Hewitson, B. (2007). Adaptation to climate change and variability: Farmer responses to intra-seasonal precipitation trends in South Africa. *Climate Change, 83*, 301–322.

Thomas, W. I., Znaniecki, F., & Strübing, J. (1984). *The polish peasant in Europe and America*. Urbana: University of Illinois Press.

Uddin, M. N., Bokelmann, W., & Entsminger, J. S. (2014). Factors affecting farmers' adaptation strategies to environmental degradation and climate change effects: A farm level study in Bangladesh. *Climate*, *2*(4), 223-241.

Udofia, E. P. (2008). *Fundamentals of social science statistics*. Uyo: Immaculate pub. Ltd.

United Nation Development Programme (UNDP). (1982). The hydrogeological condition of Bangladesh (Groundwater Survey Technical Report DP/UN/BGD-74-0071). New York: United Nation Development Programme.

United Nation Development Programme (UNDP). (1997). *Ghana human development report 1997*. New York & Oxford: Oxford University Press.

United Nations Environment Programme (UNEP). (2001). *Bangladesh: State of the environment 2001*. Thailand: UNEP RRC.AP. ISBN: 92-807-2017-1.

United Nations Environment Programme (UNEP- UN Environment). (1993). Good news in the fight against desertification. *Desertification Control Bulletin,* 22, 3.

United Nations Environment Programme (UNEPEP-UN Environment). (1993). Good news in the fight against desertification. *Desertification Control Bulletin*, 22, 3.

United Nations ISDR. (2004). *Living with risk: A global review of disaster reduction initiatives*. New York & Geneva: United Nations ISDR.

United Nations. (2004). *Living with risk: A global review of disaster reduction initiatives*. New York & Geneva: United Nations ISDR.

United Nations International Strategy for Disaster Reduction (UNISDR). (2009). *UNISDR Terminology on disaster risk reduction*. Geneva, Switzerland: UNISDR.

Wade, L. J., Fukai, S., Samson, B. K., Ali, A., & Mazid, M. A. (1999). Rainfed lowland rice: physical environment and cultivar requirements. *Field Crops Research*, *64*(1), 3-12.

Wagner, H. R. (Ed.). (1970). *Alfred Schutz on phenomenology and social relations* (Vol. 360). Chicago & London: University of Chicago Press.

Water Resources Planning Organization. (2001). *National water management plan* (Vol. 2, Main Report). Dhaka, Bangladesh: Water Resources Planning Organization (WaRPO), Ministry of water resources, Government of the People's Republic of Bangladesh.

Wilhite, D. A., & Glantz, M. H. (1985). Understanding the drought phenomenon: The role of definitions. *Water International*, *10*(3), 111-120.

Wilhite, D. A. (2000). Drought as a natural hazard: Concepts and definitions. In D. A. Wilhite (Ed.), *Drought: A Global Assessment* (pp. 1–18), vol. 1 . New York: Routledge.

William, T., & Znanieki, F. (1974). *The Polish peasant in Europe and America*. New York: Octangon Books.

Wisner, B. G. (1978). *The human ecology of drought in eastern Kenya*. University Microfilms.

Wisner, B. (1977). *The human ecology of drought in eastern Kenya*. Ph.D. Dissertation, Wooster, MA: Clark University.

Wisner, B., & Uitto, J. (2009). Life on the edge: Urban social vulnerability and decentralized, citizen-based disaster risk reduction in four large cities of the Pacific Rim. In H. G. Brauch et al. (Eds), *Facing global environmental change* (pp. 215-231). Berlin Heidelberg: Springer.

World Bank. (1998). Water resource management in Bangladesh: Step towards a new national water plan (Report No. 17663-BD). Dhaka: The World Bank Bangladesh.

World Bank. (2000). *Bangladesh: Climate change and sustainable development* (Report No. 21104 BD). Washington, DC: World Bank. Retrieved from http://documents.worldbank.org/curated/en/906951468743377163/Bangladesh-Climate-change-and-sustainable-development

World Commission on Environment and Development (WCED). (1987). *Our common future.* WECD. Oxford, New York: Oxford University Press.

Zuberi, M. I. (1998). *Combating desertification in Bangladesh: Case studies, lesson learned from experiments, constraints, and opportunities* (Report of the National Awareness Seminar on Combating Land degradation and Desertification in Bangladesh).

APPENDICES

Appendices

Appendix-1: Selection of Upazilla according to Drought vulnerability ranking

#	Districts	Upazilla	Rabi rank	Kharif-1 rank	Kharif-2 rank	Combined rank	Severity class	Severity rank
1	Nagaon	Niamotpur	7	5	3	15	Very severe	1
		Porsha	4	3	16	23	Very severe	4
2	Nawabganj	Nachole	9	7	4	20	Very severe	3
		Shibganj	11	8	14	33	Very severe	9
3	Rajshahi	Tanore	6	2	11	19	Very severe	2
		Godagari	13	11	15	39	Very severe	12

Source: Khan & Islam, CGEIS Report, 2013

Appendix-2: Determination of Sample size for Household survey

Z score for 95% confidence level is 1.96

Sample Size = $\{(\text{Z score})^2 \times \text{StdDev} \times (1\text{-StdDev})\} \div (\text{margin of error})^2$

$= \{(1.96)^2 \times 0.5 \times (1\text{-}0.5)\} \div (0.05)^2$

$= (3.8416 \times 0.25) \div 0.0025$

$= 0.9604 \div 0.0025$

$= 384.16$

≈ 385 respondents are needed

Sample Size with population $= \dfrac{SS}{1+(\frac{SS-1}{Population})}$

$$= \frac{385}{1+(\frac{385-1}{3064})}$$

$$= \frac{385}{1+\frac{384}{3064}}$$

$$= \frac{385}{\frac{3448}{3064}}$$

$$= \frac{385 \times 3064}{3448}$$

$$= 342.12297$$

≈ 343 respondents

Now,

For Aye- Hi, $\frac{343\times552}{3064}$ = 61.7937337≈ 62 respondents

For Parisho, $\frac{343\times463}{3064}$ = 51.8306136 ≈ 52 respondents

For Nizampur, $\frac{343\times674}{3064}$ = 75.4510444 ≈ 75 respondents

For Chak ghorapakhia, $\frac{343\times460}{3064}$ = 51.4947781 ≈ 51 respondents

For Bhabicha, $\frac{343\times562}{3064}$ = 62.9131854 ≈ 63 respondents

For Molla para, $\frac{343\times353}{3064}$ = 39.5166449 ≈ 40 respondents

Appendix 3: Total Household and sample for Household survey

District	Upazila	Union	Village	Total household	Sample		
					Total	Male	Female
Rajshahi	Godagari	Godagari	Ayi hai	552	62	43	19
	Tanore	Kamargaon	Parisho	463	52	36	16
Chapai Nowabganj	Nachol	Nizampur	Nizampur	674	75	52	23
	Shibgonj	Chatrajitpur	Chak ghorapakhia	460	51	36	15
Naogawn	Niyamotpur	Bhabicha	Bhabicha	562	63	44	19
	Porsha	Ghatnogor	Molla para	353	40	28	12
			Total=	3064	343	239	104

Appendix 4: questionnaire for household survey

Household Survey
Form No. Date : ....
Sustainable Approaches to Drought Management: Exploratory Study on Selected Northwest region in Bangladesh
I'm Md. Shafiqul Islam, I am conducting a study titled '**Sustainable approaches to Drought Management: Exploratory Study on selected regions of Northwest in Bangladesh**. Information provided by you will be kept strictly confidential and will only be used for research purpose. It is absolutely your discretion whether you will agree or not to be interviewed. You can refuse to answer any or all the questions. Thank you in advance for your cooperation. Do you want to know anything else about this study? Can we start the discussion now?

1. Personal Information:

(A)Name:	(B)Father's/Spouse'sName:
(C)Mother'sName:	(D)Village:
(E)Union:	(F)Upazila:
(G)District:	(H) Male=1 , Female=2

2. **General Information about household members :**

	Name of the Member	Age	Male/ Female	Occupation		Relationship with household	Marital status	Education Qualification	Disability
1	2	3	4	Primary 5a	Secomdary 5b	6	7	8	9
1.									
2.									
3.									

4.									
5.									
6.									
7.									
8.									
9.									
10.									

Notes:

(4) Male=1, Female=2

(5) Agriculture=1, Business=2, Small trade=3, Labor=4, Van/Rickshaw puller=5, Auto/nosimon driver=6, Mechanics=7, Home maker=8, Servant=9, Handicrafts=10, Fishing=11, others (specify) =12

(6) Self=1, Wife/Husband=2, Son=3, Daughter=4, Grandfather/Grandmother=5, Grandchild=6

(7) Unmarried=1, Maried=2, Widower=3, Divorcee=4, Seperated=5

(8)Children under 5 years=0, Class1-9=1-9, SSC=10, HSC=12, Graduate=15, Masters=16, Trade course=66, Diploma=77, No formal education=88

(9) Disable=1

3. Residence Status:		
(1) Concrete	(2) Semi concrete (Tin roof)	(3) Clay wall & roof of Tin
(4) Thatched wall and roof with tin	(5) Cottage	

4. Ownership of Land:

Description	Dwelling house (in decimal)	Cultivated land (in decimal)	Uncultivated Land (in decimal)	Pond (in decimal)	Total (in decimal)
Own property					
Leased property					
Mortgaged in property					
Mortgaged out property					

5. Description of moveable property:

Description	Shallow Machine	Power Tiller	Motorcycle	Television	Sewing Machine
Own Property					

6. Description of Domestic animals:

Animal	Count in number
Cow	
Buffalo	
Goat	

Sheep	
Duck	
Hen	
Pigeon	
Others (Specify)	

7. Agricultural related activities performed by household members:

	Agricultural activities	Woman	Man	Children	
				Son	Daughter
(a)	Planting crops/seeds				
(b)	Weeding				
(c)	Watering				
(d)	Composting				
(e)	Mulching				
(f)	Irrigation				
(g)	Harvesting				
(h)	Transplanting				
(i)	Per-boiling				
(j)	Threshing				
(k)	Nursery				
(l)	Cultivation of vegetables				

(m)	Homestead gardening				
(n)	Fish farming/ catching fish				
(o)	Raising Poultry				
(p)	Keeping cows and goats				

8. Other activities performed by household members:

	Agricultural activities	Women	Man	Children	
				Son	Daughter
(a)	Cooking				
(b)	Cleaning				
(c)	Clothing				
(d)	Handcrafts production				
(e)	Sewing				
(f)	Marketing				

9. Household expenditure:

Monthly expenditure (in BDT)	Domestic spending	The cost of children's education	Others	Total =

10. Household income from all sources:

Monthly income (in BDT)	Source of income – 1 …………………	Source of income – 2 …………………	Source of income – 3 …………………	Total =

11. Source of drinking water:		
(1) Deep Tube well	(2) Tube well	(3)Tap Water / Pipeline Water
(4) Well	(5) River/Pond water	(6) others (specify)

12. Own source of drinking water	Yes	No

13. Time require to collectand distance of drinking water source:

	Time	Distance
(1)	Less than 3o minutes	
(2)	30-60 minutes	
(3)	More than 60 minutes	

Part 2

1. What do you understand by drought?

2. What are the causes of drought?

(1)	Lack of soil moisture
(2)	Erratic rainfall
(3)	High temperature
(4)	Less rainfall
(5)	Lack of ground water
(6)	Environmental hazards
(7)	All of above
(8)	Others (Specify)

3. How often does drought occur in your locality?

(1)	Every year
(2)	After 2-4 years
(3)	After 5-9 years
(4)	After 10 years
(5)	More than 10 years

4. When did the last drought occur in your area? Specify the year:

5. Were your crops damaged due to drought?

Yes	No

6. If yes, what percentages of the total acreage were damaged due to the recent last drought?

Aus:	Aman:
Boro:	Jute:
Other Crops (specify):	

7. What percentages of production loss due to last drought?

Aus:	Aman:
Boro:	Jute:
Other Crops (specify):	

8. How can you identify drought by observing damages?

(1)	Burning of crops
(2)	Splitting of soil
(3)	Dries of river/pond/canal
(4)	Others (specify)

9. Considering drought damage and severity which drought year was more severe (last 20 years)?

10. What measures did you take to reduce crop loss?

(1)	Early sowing/planting
(2)	Late sowing/planting
(3)	Irrigating crops
(4)	Applying mulching
(5)	Re sowing/planting
(6)	Sowing/planting new crops

Did nothing (specify reasons):

11. Have you suffered from any health related problem due to drought?

Yes	No

12. What are the health hazards created by drought?

(1)	Skin diseases
(2)	Dysentery
(3)	Diarrhea
(4)	Heat stroke
(5)	Others (specify):

13. What measures did you take to reduce health hazard?

(1)	Drinking more water and saline
(2)	Taking doctor’s advice
(3)	Bathing 2 to 3 times in a day
(4)	Wrapping wet clothes
(5)	Eating healthy foods
(6)	Nothing

14. What were other damages due to drought?

	Damages	Costs
(1)	Economic loss	
(2)	Asset loss	
(3)	Livestock loss	
(4)	Loss of employment	
(5)	Other (Specify):	

15. What measures did you take to reduce the losses?

(1)	Changing cropping time
(2)	Planting of drought tolerant crops
(3)	Using compost/cowdung
(4)	Cultivate drought resistant species
(5)	Other (Specify):

16. List items damaged due to the last drought rather than crops?

(1)	Livestock
(2)	Poultry
(3)	Health
(4)	Other (Specify):

17. Have you received any support to mitigate drought loss?

Yes	No

18. If yes, what type of support did you receive? (Specify by types and sources):

Supports	Sources							
	Gov.	Relatives	Friends	Samity/club	Bank	NGOs	Company	Others
Donation								
Loan								
Housing materials								
Food								
Cash								
Seeds								
Clothes								
Labour								

19. What are the other measures did you adopt to cope with the last drought?

	Measures	
(a)	Sale of land	
(b)	Sale of livestock	
(c)	Mortgaged land	
(d)	Dismalted housing structure	
(e)	Borrowed money	

(f)	Spent savings	
(g)	Family member migrated to other areas	
(h)	Other (specify)	

20. Have you ever been experienced seasonal migration due to drought (if yes then specify with reason and alternatives for earning)?

Yes	No

21. Have your neighbors/household members, friends or any relatives migrated due to drought?

Yes	No

22. What are the existing alternative livelihood options in your locality?

(1)	Small trading
(2)	Van pulling
(3)	Migration to other place
(4)	Nursery
(5)	Homestead gardening
(6)	Animal rearing
(7)	Handicrafts production
(8)	Orchard
(9)	Others (specify):

23. Do you think drought intensity is increasing?

Yes	No

24. Do you think water table is going down?

Yes	No

25. If yes, how do you recognize this?

26. Who are the most affected in relation to drought effect?

(1)	Children
(2)	Boys
(3)	Girls
(4)	Man
(5)	Woman
(6)	Older people
(7)	All of them

27. Is drought loss increased or decreased than the previous drought?

Increased	Decreased

27(a). If decreased, what is the percentage of decreasing rate?

(a) 5-10%	(b) 15-20%	(c) 25-30%	(d) 35-40%	(e) 45-50%

28. What steps would you suggest for the better management of drought related crisis?

Self	Govt.	Community	NGO's	Others

Name and signature of interviewee: Mobile number (if available)	…………………………………………………………
Name and signature of interviewer:	…………………………………………………………

Appendix-5: Questionnaire for in-depth interview

In-depth Interview

Form No: Date : ....

Sustainable Approaches to Drought Management: Exploratory Study on Selected Northwest region in Bangladesh

Salam/ Adab. I'm Md. Shafiqul Islam, I am conducting a study titled **'Sustainable approaches to Drought Management: Exploratory Study on selected regions of Northwest in Bangladesh'**. Information provided by you will be kept strictly confidential and will only be used for research purpose. It is absolutely your discretion whether you will agree or not to be interviewed. You can refuse to answer any or all the questions. Thank you in advance for your cooperation. Do you want to know anything else about this study? Can we start the discussion now?

29. Personal Information:

(A)Name:	(B)Father's/Spouse'sName:
(C)Mother'sName:	(D)Village:
(E)Union:	(F)Upazila:
(G)District:	(H) Male=1 , Female=2

30. **General Information about household members :**

	Name of the Member	Age	Male/ Female	Occupation		Relationship with household	Marital status	Education Qualification	Disability
1	2	3	4	Primary 5a	Secondary 5b	6	7	8	9
1.									
2.									

3.									
4.									
5.									
6.									
7.									
8.									
9.									
10.									

Notes:

(4) Male=1, Female=2

(5) Agriculture=1, Business=2, Small trade=3, Labor=4, Van/Rickshaw puller=5, Auto/nosimon driver=6, Mechanics=7, Home maker=8, Servant=9, Handicrafts=10, Fishing=11, others (specify) =12

(6) Self=1, Wife/Husband=2, Son=3, Daughter=4, Grandfather/Grandmother=5, Grandchild=6

(7) Unmarried=1, Married=2, Widower=3, Divorcee=4, Separated=5

(8)Children under 5 years=0, Class1-9=1-9, SSC=10, HSC=12, Graduate=15, Masters=16, Trade course=66, Diploma=77, No formal education=88

(9) Disable=1

3. Residence Status:		
(1) Concrete	(2) Semi concrete (Tin roof)	(3) Clay wall & roof of Tin
(4) Thatched wall and roof with tin	(5) Cottage	

4. Ownership of Land:

Description	Dwelling house (in decimal)	Cultivated land (in decimal)	Uncultivated Land (in decimal)	Pond (in decimal)	Total (in decimal)
Own property					
Leased property					
Mortgaged in property					
Mortgaged out property					

5. Description of moveable property:

Description	Shallow Machine	Power Tiller	Motorcycle	Television	Sewing Machine
Own Property					

6. Description of Domestic animals:

Animal	Count in number
Cow	
Buffalo	
Goat	
Sheep	

Duck	
Hen	
Pigeon	
Others (Specify)	

7. Agricultural related activities performed by household members:

	Agricultural activities	Woman	Man	Children	
				Son	Daughter
(a)	Planting crops/seeds				
(b)	Weeding				
(c)	Watering				
(d)	Composting				
(e)	Mulching				
(f)	Irrigation				
(g)	Harvesting				
(h)	Transplanting				
(i)	Per-boiling				
(j)	Threshing				
(k)	Nursery				
(l)	Cultivation of vegetables				
(m)	Homestead gardening				

(n)	Fish farming/ catching fish				
(o)	Raising Poultry				
(p)	Keeping cows and goats				

8. Other activities performed by household members:

	Agricultural activities	Women	Man	Children	
				Son	Daughter
(a)	Cooking				
(b)	Cleaning				
(c)	Clothing				
(d)	Handcrafts production				
(e)	Sewing				
(f)	Marketing				

9. Household expenditure:

Monthly income (In BD)	Domestic spending	The cost of children's education	Others	Total =

10. Household income from all sources:

Monthly income	Source of income –1 …………………	Source of income – 2 …………………	Source of income – 3 …………………	Total =

11. Source of drinking water:

(1) Deep Tubewell	(2) Tubewell	(3)Tap Water / Pipeline Water
(4) Well	(5) River/Pond water	(6) others (specify)

12. Own source of drinking water	Yes	No

13. Time require to collectand distance of drinking water source:

	Time	Distance
(1)	Less than 3o minutes	
(2)	30-60 minutes	
(3)	More than 60 minutes	

Part 2

1. Do you think drought is a serious environmental hazard?

Yes	No

If yes, then explain

2. What are the causes of drought?

31. What are the symptoms of drought?

32. How often does drought occur in your locality?

33. When did the last drought occur in your area? Specify the year:

34. Considering drought damage and severity which drought year was more severe (last 30 years)?

35. What are the main agricultural crops in this area?

36. What are the cropping seasons in this area?

37. Which season is mostly affected by drought?

38. Were your crops damaged due to drought?

Yes	No

39. If yes, what percentages of the total acreage were damaged due to the recent last drought?

Aus:	Aman:
Boro:	Jute:
Other Crops (specify):	

40. What percentages of production loss due to last drought?

Aus:	Aman:
Boro:	Jute:
Other Crops (specify):	

41. What measures did you take to reduce crop loss?

42. How cropping season and pattern is changing due to drought?

43. Which crops are suitable in your drought prone area?

44. What are the measures did you take to conserve soil moisture?

45. Which type of fertilizers did you use for agricultural production?

46. Do you know the impacts of chemical fertilizers and chemical pesticides on drought?

Yes	No

47. Do you know about organic farming? If yes, how it contributes in drought management?

48. Do you know about agroforestry? If yes, how agroforestry contributes in drought management?

49. What are impacts of drought on fish species and fishers livelihood?

50. What are the health hazards created by drought?

51. What measures did you take to reduce health hazard?

52. What about the health facilities in your area?

53. What were other damages due to drought?

(1)	Economic loss
(2)	Assets loss
(3)	Livestock loss
(4)	Loss of employment
(5)	Other (Specify):

54. What measures did you take to reduce the losses?

(1)	Changing cropping time
(2)	Planting of drought tolerant crops
(3)	Using compost/cowdung
(4)	Other (Specify):

55. List items damaged due to the last drought rather than crops?

(1)	Livestock
(2)	Poultry
(3)	Health
(4)	Other (Specify):

56. What measures did you take for cattle, poultry and fish farming during drought?

57. How did you predict on drought?

58. How can you identify drought by observing damages?

59. How did you manage drought?

60. What are the local (indigenous) practices of drought management?

61. Did you receive any support?

Yes	No

62. If yes, what type of support did you receive? (Specify by types and sources):

Supports	Sources							
	Gov.	Relatives	Friends	Samity/club	Bank	NGOs	Company	Others
Donation								
Loan								
Housing materials								
Food								
Cash								
Seeds								
Clothes								
Labour								

63. What are the other measures did you adopt to cope with the last drought?

(a)	Measures	
(b)	Sale of land	
(c)	Sale of livestock	
(d)	Mortgaged land	
(e)	Dismalted housing structure	
(f)	Borrowed money	
(g)	Spent savings	
(h)	Family member migrated to other areas	
(i)	Other (specify)	

64. Did you ever been experienced seasonal migration due to drought (if yes then specify with reason and alternatives for earning)?

Yes	No

65. Did your neighbors/household members, friends or any relatives migrated due to drought?

Yes	No

66. What are the existing alternative livelihood options?

(1)	Small trading
(2)	Van pulling
(3)	Migration to other place
(4)	Nursery
(5)	Homestead gardening
(6)	Animal rearing
(7)	Handicrafts

(8)	Orchard
(9)	Others (specify):

67. Do you think drought intensity is increasing?

Yes	No

68. How did you manage water during drought?

69. Do you think water table is going down?

Yes	No

70. Who are the most affected in relation to drought effect?

(1)	Children
(2)	Boys
(3)	Girls
(4)	Man
(5)	Woman
(6)	Older people

Appendix 6: Descriptive statistics of rainfall in Niamatpur Upazila

Year	Annual	Mean	Median	S.D	Variance	Skewness	Kurtosis	Min	Max	Range
1976	1116	93.7	13.5	128.4	16499.3	1.18	0.2	0	368.6	368.6
1977	1774	147.8	72.5	192.4	37013.7	1.65	2.26	0	618.9	618.9
1978	1318.4	109.9	51	141.1	19922.3	1.42	1.56	0	445.1	445.1
1979	1263	105.3	41.7	174.2	30333.8	2.32	5.6	0	588.4	588.4
1980	1633.6	136.1	110.3	141.4	19983	0.08	-2.31	0	305.4	305.4
1981	1172.8	97.7	47.3	132.8	17645.5	1.92	3.97	0	448.7	448.7
1982	1017.4	84.8	7.6	121.4	14745.9	1.18	-0.12	0	331.6	331.6
1983	1627.2	135.6	94.9	125.1	15647.9	0.54	-1.24	0	344.1	344.1
1984	1706.7	142.2	42.7	148.1	21919.5	0.42	-1.57	0	376.9	376.9
1985	1073.5	89.5	36.1	101.9	10380.5	0.88	-0.39	0	299.4	299.4
1986	1416.8	118.1	81.2	135.1	18255.9	1.2	0.3	0	387.8	387.8
1987	1977.7	164.8	42.7	243.4	59257.7	1.4	0.34	0	651.6	651.6
1988	1734.6	144.6	101.6	164.3	27002.2	1.61	2.51	0	551.1	551.1
1989	1382.5	115.2	23.3	177.4	31480.2	1.7	1.64	0	487	487
1990	1809.3	150.8	70.8	224.5	50400	2.21	5.08	0	764	764
1991	1847.9	154	125.3	151.1	22825.2	0.44	-1.46	0	400.9	400.9
1992	1331.7	111	59.5	124.7	15555.6	0.66	-0.96	0	347.1	347.1
1993	1191.5	99.3	76.6	91.1	8300.9	0.74	-0.89	0	266.8	266.8
1994	1074.1	89.5	85.5	84.2	7086.5	0.22	-1.74	0	211	211
1995	1504.1	125.3	34.3	191.7	36766.9	1.95	3.65	0	625	625
1996	1125.6	93.8	31.5	133.6	17856.2	1.28	-0.11	0	347.5	347.5
1997	1151.7	96	40.5	104.7	10958.8	1.07	-0.49	0	283	278
1998	1590	132.5	140.4	118.2	13974	0.29	-1.29	0	340.9	340.9
1999	1475.1	122.9	45	160	25613.1	1.15	0.08	0	437	437
2000	1711.9	142.7	61.3	181.7	33015.5	1.52	1.7	0	575.3	575.3
2001	1728	144	75.5	163.3	26668.5	0.47	-1.59	0	393	393
2002	1863.5	155.3	56	186.9	34939.4	0.88	-0.83	0	512.5	512.5
2003	1681.5	140.1	117	131.3	17227.8	1.15	1.09	0	434.7	434.7
2004	1759.2	146.6	103.5	174.8	30538.6	1.2	0.36	0	484.7	484.7
2005	1804	150.3	101.7	183.2	33562.3	1.2	0.21	0	528	528
2006	1208.8	100.7	69.3	102.7	10538.8	0.88	-0.12	0	312	312
2007	1605	133.8	18	170.6	29097.2	0.78	-1.19	0	440	440
2008	1046	87.2	22.5	108.6	11785.4	0.9	-0.95	0	283.5	283.5
2009	1222.8	101.9	39.8	120.5	14529.3	0.77	-1.29	0	293.6	293.6
2010	1261	105.1	77	128.3	16456.4	1.64	2.79	0	427	427
2011	1632.2	136	80.1	161.7	26148.1	0.95	0.27	0	490	490
2012	1047	87.3	60	106.2	11278.9	1.51	1.59	0	329	329
2013	1074	89.5	58	101.5	10299.4	0.92	-0.4	0	291	291
2014	1490	124.2	35	153.1	23431.6	0.66	-1.71	0	334	334

Appendix 7: Descriptive statistics of rainfall in Nachole Upazila

Year	Annual	Mean	Median	S.D	Variance	Skewness	Kurtosis	Min	Max	Range
1976	1336.1	41.8	36	144.9	20988.7	1.13	0.12	0	419	419
1977	2116.2	176.3	114.4	194	37621.2	0.64	-1.19	0	496.5	496.5
1978	1254.5	104.5	89.4	107.6	11583.7	0.86	0.16	0	335.8	335.8
1979	1322.6	110.2	22.4	164.8	27145.1	1.79	3.03	0	530.4	530.4
1980	1438.5	119.9	60.5	144.4	20854.3	1.03	0.2	0	432	432
1981	2432.8	202.7	34.2	207.8	43184.4	1.06	0.28	0	615.6	615.6
1982	796.2	66.4	17.5	96.2	9247.3	1.5	1.36	0	290.2	290.2
1983	1329.9	110.8	50	131.5	17298.7	0.84	-0.89	0	359.8	359.8
1984	1329.9	110.8	54.5	132.3	17503.3	1	0.03	0	392.7	392.7
1985	1343.6	112	45.2	132.8	17630.1	0.81	-0.98	0	346	346
1986	1729.7	144.1	89	170.7	29125	0.99	-0.44	0	474.8	474.8
1987	1559.1	129.9	30.4	180.6	32626	1.47	1.37	0	552.5	552.5
1988	1796.2	149.7	119.3	152.4	23215.9	0.81	-0.55	0	422.1	422.1
1989	1279.3	106.6	39.8	147.1	21647.6	1.25	0.04	0	385.9	385.9
1990	1553.2	129.4	108.5	137.2	18836.9	1.57	3.21	0	480.8	480.8
1991	1576.2	131.3	123.3	118.2	13966.4	0.17	-1.85	0	294.2	294.2
1992	1342.3	111.9	38	150.2	22563.4	1.16	-0.11	0	411.6	411.6
1993	1495.1	124.6	128.4	108.3	11739.7	0.07	-1.95	0	277.1	277.1
1994	986.7	82.2	15.2	108.9	11867.7	1.42	1.89	0	347.3	347.3
1995	1514.4	126.2	28.9	174.1	30300.5	1.3	0.63	0	509.6	509.6
1996	979.9	81.7	10.9	125.9	15854.2	1.39	0.4	0	324.1	324.1
1997	1115	92.9	58.1	98.8	9752	0.95	-0.1	1.2	300.1	298.9
1998	1844.3	153.7	97.9	169.9	28867.2	1.3	0.68	0.7	509.1	508.4
1999	2615.4	217.9	51.3	283.8	80553.2	0.94	-0.8	0	729.7	729.7
2000	1827.8	152.3	79	204.3	41718.5	1.87	3.77	0	687.8	687.8
2001	1569.3	130.8	50.6	154.1	23736.1	0.69	-0.95	0	428	428
2002	1536.6	128.1	70	138.6	19221.2	0.62	-1.39	0	354	354
2003	1443.7	120.3	61.7	131	17163.1	0.98	-0.13	0	384.8	384.8
2004	1875.8	156.3	72.2	194.7	37918.7	1.14	0.1	0	550.8	550.8
2005	1379.7	115	52.8	132.5	17551.2	0.92	-0.75	0	370.9	370.9
2006	945.2	78.8	7.2	133	17697.8	1.94	3.61	0	425.6	425.6
2007	1732.5	144.4	6.5	211.4	44675.1	1.25	0.39	0	607.6	607.6
2008	992.6	82.7	22.8	130.1	16936.7	1.83	2.61	0	401.2	401.2
2009	1212.3	101	21.3	131.8	17383.1	1.18	0.58	0	396.8	396.8
2010	905.7	75.5	45.3	73.5	5407.3	0.27	-2.03	0	179.5	179.5
2011	1480	123.3	33	167.4	28034	1.12	-0.27	0	455.5	455.5
2012	886.4	73.9	72.5	67.9	4609.9	0.21	-1.61	0	187.2	187.2
2013	1158.2	96.5	52	118.6	14066.3	1.23	0.65	0	357.3	357.3
2014	1023.4	85.3	38.9	103.7	10757.7	0.89	-0.74	0	287.5	287.5

Appendix 8: Descriptive statistics of rainfall in Godagari Upazila

Year	Annual	Mean	Median	S.D	Variance	Skewness	Kurtosis	Min	Max	Range
1976	997	83.1	38.5	105.2	11077.1	1.29	1.06	0	322.2	322.2
1977	1627.9	135.1	107.1	149.2	22269.9	1.33	1.81	0	494.4	494.4
1978	1259.5	105	46.1	136.1	18520.4	1.35	0.58	0	387	387
1979	1267.3	105.6	40	134.6	18129	1.18	0.05	2.5	387.9	385.4
1980	1435.4	119.6	95.3	127	16128.5	0.74	-0.55	0	373.8	373.8
1981	1543.9	128.7	67.2	136.5	18632.6	1	-0.2	0	406.5	406.5
1982	956.8	79.7	80.5	68.5	4691	0.71	0.11	0	219.1	219.1
1983	1265.2	105.4	62.3	114.2	13048.4	0.52	-1.57	0	287.1	287.1
1984	1343.7	112	53	124.5	15496.6	0.64	-1.16	0	334.7	334.7
1985	1379	114.9	92.7	117.7	13848.4	0.75	-0.98	0	296.5	296.5
1986	1662.3	138.5	92.5	140.8	19829.3	0.49	-1.39	1.3	386	384.7
1987	1700.4	141.7	39.8	206.6	42681.2	1.57	1.42	0	617.2	617.2
1988	2180	181.7	131.3	191	36477	1.22	0.69	0	603.6	603.6
1989	1496	124.7	41.1	166.7	27784.2	1.11	-0.43	0	424.8	424.8
1990	1277	106.4	96	107.3	11506.1	0.65	-0.68	0	316.6	316.6
1991	1528.5	127.4	69.8	148.6	22071.1	1.12	-0.03	0	428.6	428.6
1992	973.3	81.1	38.5	103.5	10720	1.31	0.98	0	315.9	315.9
1993	1536.4	128	65	147.2	21673.8	1.07	0.34	0	444.8	444.8
1994	1530.7	127.6	50.6	168.1	28272.8	1.5	1.34	0	504.3	504.3
1995	1449.2	120.8	51.5	158.2	25025.3	2.09	4.82	7.2	550.9	543.7
1996	986	82.2	65.8	91.7	8417.8	0.74	-0.42	0	269.7	269.7
1997	1284.7	107.1	31.9	140.7	19796.1	1.33	0.08	0	369	369
1998	1395.2	116.3	74.2	130.1	16930.2	1.33	0.79	0	388	388
1999	1632.7	136.1	56.3	166.7	27800.1	0.78	-1.45	0	398.4	398.4
2000	1692.9	141.1	81.9	175.9	30932.5	2.32	6.31	0	639.2	639.2
2001	1469	122.4	94.8	128	16391.7	0.36	-1.7	0	327	327
2002	1152.6	96.1	101.3	95.7	9153.5	0.8	0.08	0	297.8	297.8
2003	988	82.3	62	80.6	6500.4	0.98	0.12	0	250.5	250.5
2004	1377	114.7	84	122.1	14908.1	0.7	-0.62	0	357.6	357.6
2005	1413.33	117.8	87	153.6	23601.1	1.96	4.21	0	525.2	525.2
2006	1214.8	101.2	36	121.8	14826.3	0.94	-0.69	0	337.1	337.1
2007	1291.8	107.7	8.3	147.7	21819.6	1	-0.7	0	385.6	385.6
2008	1132	94.3	37	152.1	23127.2	2.27	5.45	0	514.9	514.9
2009	1047.2	87.3	37.2	98.2	9650	0.48	-1.72	0	250.1	250.1
2010	906.5	75.5	46	78.8	6209.8	0.63	-1.19	0	218	218
2011	1620.9	135.1	68.1	166.1	27586.1	1.21	0.86	0	508.5	508.5
2012	834.5	69.5	40.8	84.3	7111.6	1.33	1.58	0	270.2	270.2
2013	1164	97	50.5	115.9	13438.2	1.17	1.15	0	367.4	367.4
2014	1144.8	95.4	61.1	103.5	10705.5	0.59	-1.18	0	284	284

Appendix 9: Descriptive statistics of rainfall in Tanore Upazila

Year	Annual	Mean	Median	S.D	Variance	Skewness	Kurtosis	Min	Max	Range
1976	1310.2	109.2	39.3	131.3	17245.1	0.92	-0.42	0	376.4	376.4
1977	1470.2	122.5	87.3	139.8	19546.1	1.59	2.93	0	476.8	476.8
1978	1415.8	118	72.5	133	17696.1	1.38	0.98	0	390.5	390.5
1979	1415.4	117.9	44.1	141.6	20051.9	0.93	-0.92	0	368.6	368.6
1980	1576.7	131.4	105.9	136.3	18580.6	0.4	-1.48	0	370.7	370.7
1981	1836.3	153	54.3	190.4	36242.4	1.28	1.03	0	593.1	593.1
1982	1049.5	87.5	27.1	148.7	22103.2	2.4	5.89	0	503.1	503.1
1983	1263.5	105.3	49.1	124.7	15557.5	0.91	-0.79	0	329.3	329.3
1984	1344.3	112	33.3	136.3	18566.8	0.71	-1.4	0	332.1	332.1
1985	1335.5	111.3	75.8	126.3	15957.7	0.97	-0.03	0	373.9	373.9
1986	1592.7	132.7	65.7	155.2	24090.7	0.85	-0.74	0	418.4	418.4
1987	1717.4	143.1	49.7	236.7	56017.2	2.4	6.19	0	811.6	811.6
1988	1917.3	159.8	88.7	167.7	28138.8	0.81	-1.1	0	437	437
1989	1789.4	149.1	60.6	174.2	30339	0.55	-1.6	0	416.5	416.5
1990	1472.5	122.7	88.5	148.3	21986.9	1.49	2.64	0	494.8	494.8
1991	1692.6	141	68	153.8	23653.3	0.71	-1.11	0	411.2	411.2
1992	1182.5	98.5	30	137.8	18997.8	1.58	2.12	0	434.5	434.5
1993	1269.6	105.8	77.8	106.6	11356.8	1.45	2.32	0	367.8	367.8
1994	749.5	62.5	40.5	76.5	5847	1.99	4.89	0	270.5	270.5
1995	1792.7	149.4	82	155.1	24069.9	0.75	-0.79	0	450.5	450.5
1996	1203	100.3	50.8	121.5	14762.1	1.21	0.61	0	370	370
1997	1670	139.2	45.5	170.2	28965.1	1.14	-0.13	0	480.5	480.5
1998	1943.5	162	63	217.8	47450.6	1.32	0.1	0	595.5	595.5
1999	2624.5	218.7	80.3	304.8	92898.7	1.93	4.37	0	1036	1036
2000	2387.5	199	205.8	193.9	37600.8	1.36	2.82	0	685.5	685.5
2001	1714.3	142.9	77.9	172.8	29854.9	0.9	-0.27	0	495	495
2002	2102	175.2	74.8	197.4	38979.7	0.56	-1.64	0	475	475
2003	2052.7	171.1	129.8	134.7	18151.2	0.39	-1.41	0	366.7	366.7
2004	1626.6	135.6	95.5	149.4	22321.7	0.85	-0.45	0	428.5	428.5
2005	1530.1	127.5	78	175.5	30796.2	1.74	2.2	0	538.3	538.3
2006	1431	119.3	22.4	194.7	37916.9	1.71	1.62	0	545.5	545.5
2007	582.7	48.6	0	82.8	6856.6	1.68	2.09	0	249.9	249.9
2008	815.1	67.9	14	98.4	9680.5	1.51	1.24	0	285.2	285.2
2009	1111.2	92.6	37	114.7	13164.8	1.25	1.08	0	358	358
2010	1011.1	84.3	63.5	91.5	8380.7	0.61	-1.26	0	231	231
2011	1249	104.1	55	132.1	17447.7	1.23	0.39	0	370	370
2012	1233	102.8	64	116.8	13630.6	0.88	-0.74	0	319	319
2013	1183	98.6	40.5	137	18777.5	2.01	4.58	0	468	468
2014	1507	125.6	24.5	160.9	25873.5	0.74	-1.59	0	365	365

Appendix 10: Descriptive statistics of rainfall in Shibganj Upazila

Year	Annual	Mean	Median	S.D	Variance	Skewness	Kurtosis	Min	Max	Range
1976	1123.8	93.6	13.5	128.4	16499.3	1.18	0.2	0	368.6	368.6
1977	1895.3	157.9	101.7	161.3	26009.3	0.71	-0.93	0	434.5	434.5
1978	1331.5	111	75.8	122.9	15111.9	0.84	-0.72	0	335.6	335.6
1979	1437	119.7	48.9	164.1	26928.6	1.81	3.27	0	542	542
1980	1483.5	123.6	42.6	147	21609.2	0.72	-1.03	0	398	398
1981	2110.9	175.9	156.2	164.5	27075	0.46	-1.35	2.5	446.9	444.4
1982	921.2	76.8	52.7	75.3	5666.6	0.7	-0.71	0	223.1	223.1
1983	988	82.3	42.4	90.4	8173	0.73	-1.19	0	243.2	243.2
1984	1656	138	55.7	154.6	23897.1	0.53	-1.69	0	368.9	368.9
1985	1333	111.1	58.1	131.7	17349.9	0.91	-0.63	0	349.4	349.4
1986	1424.1	118.7	79.4	136.7	18698.7	0.79	-0.95	0	345.5	345.5
1987	1459.2	121.6	33	181.3	32878.4	1.65	1.57	0	518.3	518.3
1988	2015.7	168	82	182.3	33250.8	1.02	-0.07	0	548	548
1989	1588.8	132.4	51	180.8	32690	1.25	0.17	0	510	510
1990	1463	121.9	81.5	130.8	17117.7	0.92	-0.22	0	385	385
1991	2276	189.7	103	212.9	45305.9	1.03	0.33	0	655	655
1992	1009	84.1	34	141.7	20068.6	2.5	6.78	0	490	490
1993	718	59.8	28.5	77.6	6027.6	2.04	3.89	0	262	262
1994	1070	89.2	55.5	100	9999.4	1.54	2.6	0	339	339
1995	2116	176.3	72.5	210.1	44125.7	1.09	-0.19	2	563	561
1996	1481	123.4	72	135.9	18470.4	0.74	-1.2	0	360	360
1997	1583	131.9	39	168	28226.6	1.35	0.9	7	509	502
1998	2107	175.6	135.5	177.5	31491	0.65	-0.75	0	517	517
1999	148.1	12.34	3.45	16.73	280	1.18	0.34	0	49.2	49.2
2000	2078.9	173.2	68.5	272.6	74322.6	2.36	6.16	0	943	943
2001	1570	130.8	115	135.6	18390.9	0.09	-2.27	0	298	298
2002	1416	118	78	129.6	16800.5	0.87	-0.58	0	367	367
2003	1098.7	91.6	55.5	90.3	8156.2	0.87	-0.41	0	261	261
2004	1304	108.7	49.5	127.2	16168.8	0.95	-0.32	0	368	368
2005	1649	137.4	173.1	52	29948.4	1.4	1.29	0	534	534
2006	1006	83.8	32.5	103.9	10787.8	0.91	-0.96	0	272	272
2007	1897	158.1	15	333.9	111502.3	2.99	9.52	0	1174	1174
2008	1322	110.2	35.5	171.1	29290.3	1.61	1.27	0	483	483
2009	1755	146.3	22.5	222.3	49403.5	2.06	4.74	0	749	749
2010	979	81.6	87	73.7	5431.7	0.25	-1.46	0	194	194
2011	1388	115.7	39.5	143	20455.9	0.94	-0.18	0	414	414
2012	1287	107.3	71	101	10194.2	0.57	-1.27	0	270	270
2013	1419	118.3	61.5	134.4	18056.2	0.87	-0.56	0	379	379
2014	1328	110.7	66	115.9	13422.1	0.54	-1.33	0	319	319

Appendix 11: Descriptive statistics of rainfall in Porsha Upazila

Year	Annual	Mean	Median	S.D	Variance	Skewness	Kurtosis	Min	Max	Range
1976	1245.5	103.8	38.4	142.3	20252.6	1.64	2.27	0	450.7	450.7
1977	1664.8	138.7	63.5	160.1	25639.5	1.08	0.22	0	483.6	483.6
1978	1406.2	117.2	53.8	154.5	23863.5	1.61	2.23	0	494.4	494.4
1979	1733.6	144.5	61	189.4	35878.7	1.51	1.39	0	585.8	585.8
1980	1688	140.7	99.6	151.6	22983.9	0.53	-1.32	0	402.3	402.3
1981	1655.6	138	103.2	140.4	19722.1	0.91	-0.31	0	397.9	397.9
1982	955.3	79.6	19	101.4	10273.6	1.02	-0.58	0	259.5	259.5
1983	1271.8	106	62.9	101	12215.1	0.5	-1.49	0	293.5	293.5
1984	1430	119.2	71.8	144.9	20986	1.27	0.55	0	410	410
1985	1371.4	114.3	43.8	148.2	21954	1.32	1.27	0	460.4	460.4
1986	1653.1	137.8	60.3	154.7	23933.3	0.64	-1.45	0	385.1	385.1
1987	2162.3	180.2	78.6	240.5	57837.6	1.42	1.15	0	734	734
1988	1708	142.3	99.8	164.9	27180.4	1.42	1.1	0	497.8	497.8
1989	1154.6	96.2	53.6	134.2	18002.4	1.99	4.5	0	457.1	457.1
1990	1551	129.3	74.1	153.6	23602.7	1.17	0.25	0	427.9	427.9
1991	1998.8	166.6	86.6	189.9	36064	0.92	-0.71	3.5	502.5	499
1992	1200.6	100.1	58.6	120.7	14558.8	1.55	2.05	0	404.3	404.3
1993	1420.1	118.3	99.5	108.7	11807.9	0.64	-0.88	0	305.3	305.3
1994	1120.8	93.4	66	99	9793.2	0.9	-0.17	0	298.1	298.1
1995	2144.7	178.7	68.4	204.4	41787.7	0.62	-1.5	0	505.7	505.7
1996	1285.9	107.2	24	162.6	26426.2	1.79	2.69	0	514.3	514.3
1997	1055.2	87.9	16.8	180.9	32711.6	3.02	9.6	0	639	639
1998	1826.7	152.2	79.5	164.7	27120	0.92	-0.17	0	495.9	495.9
1999	902.5	75.2	86.4	47.3	7457.4	0.72	-1.17	0	229	229
2000	1862.6	155.2	76.7	202.4	40975	1.78	2.72	0	654.2	654.2
2001	1204	100.3	52.5	115.4	13311.9	0.59	-1.39	0	299	299
2002	1890.9	157.6	124.8	172.2	29659.8	0.8	-0.48	0	503.9	503.9
2003	2038	169.8	188.8	149.7	22403.9	0.73	-0.26	0	452.5	452.5
2004	2103.4	175.3	51.3	221.8	49204.3	1.12	0.27	0	654.9	654.9
2005	1905.5	158.8	54.3	212	44948.2	1.51	1.82	0	666.5	666.5
2006	1917.1	159.8	63.7	215.6	46483.3	1.67	2.66	0	701	701
2007	1623.7	135.3	3	265	70238.9	2.14	4.38	0	844.4	844.4
2008	1005.6	83.8	6.1	144.1	20761.4	1.86	2.87	0	447.6	447.6
2009	782.9	65.2	6	89.1	7938.9	1.17	0.37	0	261.1	261.1
2010	1860.4	155	20.7	317.4	100774.1	2.87	8.79	0	1107.2	1107.2
2011	1167.8	97.3	18.1	126	15872.2	1.12	0.26	0	369.6	369.6
2012	935.4	78	4.1	166.5	27709.9	2.62	6.94	0	556.3	556.3
2013	1336.5	111.4	33.7	138.8	19265	1.05	-0.25	0	393	393
2014	852.6	71.1	23.8	97	9412.2	1.42	1	0	289.1	289.1

Appendix 12: Rainfall deviation percentage from actual rainfall in Godagari Upazila during the period of 1976-2014

Year	June	M	D	July	M	D	August	M	D	Sept	M	D	Oct	M	D
1976	100.3	247	-59	124.2	260	-52	322.2	227	42	227.1	254	-11	71.2	109	-35
1977	494.4	247	100	256.1	260	-1	114.7	227	-49	155.4	254	-39	186.1	109	71
1978	340.3	247	38	43.3	260	-83	207.4	227	-9	387	254	52	130.1	109	19
1979	157.5	247	-36	280.5	260	8	265.7	227	17	387.9	254	53	52.2	109	-52
1980	373.8	247	51	250.1	260	-4	135.9	227	-40	196.9	254	-22	257.3	109	136
1981	39.4	247	-84	406.5	260	56	248.5	227	9	321.7	254	27	0	109	-100
1982	175.2	247	-29	219.1	260	-16	118	227	-48	67.6	254	-73	17.8	109	-84
1983	139.4	247	-44	227.4	260	-13	265.6	227	17	287.1	254	13	207.1	109	90
1984	287.3	247	16	222.4	260	-14	191.6	227	-16	334.7	254	32	176.6	109	62
1985	296.5	247	20	289.7	260	11	82.4	227	-64	139.8	254	-45	102.9	109	-6
1986	272.5	247	10	311.1	260	20	238.6	227	5	386	254	52	220.3	109	102
1987	102.8	247	-58	315.2	260	21	617.2	227	172	449.7	254	77	3.6	109	-97
1988	603.6	247	144	379.9	260	46	425.3	227	87	116.2	254	-54	155.8	109	43
1989	124.6	247	-50	333.7	260	28	114.7	227	-49	424.8	254	67	81.8	109	-25
1990	231.3	247	-6	316.6	260	22	207.6	227	-9	151.5	254	-40	139.9	109	28
1991	428.6	247	74	264	260	2	189.9	227	-16	356.7	254	40	53.5	109	-51
1992	130	247	-47	315.9	260	22	219.7	227	-3	153.5	254	-40	62	109	-43
1993	206	247	-17	330.9	260	27	191.8	227	-16	444.8	254	75	194	109	78
1994	404.6	247	64	126.2	260	-51	504.3	227	122	74.7	254	-71	203.8	109	87
1995	243.2	247	-2	179.6	260	-31	203	227	-11	550.9	254	117	80.2	109	-26
1996	185.3	247	-25	152.8	260	-41	269.7	227	19	130.7	254	-49	0	109	-100
1997	94.8	247	-62	365.3	260	41	369	227	63	265.1	254	4	0	109	-100
1998	92.4	247	-63	388	260	49	345.3	227	52	165.7	254	-35	109	109	0
1999	363.9	247	47	295.8	260	14	398.4	227	76	367.5	254	45	74.8	109	-31
2000	224.2	247	-9	140	260	-46	186.5	227	-18	639.2	254	152	75.5	109	-31
2001	283	247	15	263	260	1	193	227	-15	168	254	-34	194	109	78
2002	118.7	247	-52	209.3	260	-20	297.8	227	31	171.4	254	-33	101.7	109	-7
2003	250.5	247	1	174.5	260	-33	56.2	227	-75	96.5	254	-62	181.8	109	67
2004	357.6	247	45	235.8	260	-9	158	227	-30	241.9	254	-5	201.7	109	85
2005	105.1	247	-57	525.2	260	102	139.5	227	-39	125.6	254	-51	285.6	109	162
2006	267.6	247	8	225.7	260	-13	86	227	-62	337.1	254	33	18	109	-83
2007	302.7	247	23	385.6	260	48	177.8	227	-22	312.2	254	23	97	109	-11
2008	514.9	247	108	240.6	260	-7	0	227	-100	156	254	-39	62.1	109	-43
2009	160.5	247	-35	195.5	260	-25	195.5	227	-14	250.1	254	-2	55.6	109	-49
2010	165.4	247	-33	218	260	-16	61.5	227	-73	162.3	254	-36	86.8	109	-20
2011	508.5	247	106	194.1	260	-25	356.6	227	57	207.4	254	-18	7.5	109	-93
2012	153.3	247	-38	270.2	260	4	104	227	-54	133.6	254	-47	55.6	109	-49
2013	183.1	247	-26	178	260	-32	367.4	227	62	162.2	254	-36	163.8	109	50
2014	153.2	247	-38	284	260	9	208.4	227	-8	218.4	254	-14	93.6	109	-14

Appendix 13: Rainfall deviation percentage from actual rainfall in Tanore Upazila during the period of 1976-2014

Year	June	M	D	July	M	D	Aug	M	D	Sept	M	D	Oct	M	D
1976	191.7	243	-21	271.8	284	-4	376.4	288	31	149.8	296	-49	40.6	126	-68
1977	476.8	243	96	248.2	284	-13	196	288	-32	88.9	296	-70	136.5	126	8
1978	366.4	243	51	163.8	284	-42	91.7	288	-68	390.5	296	32	52	126	-59
1979	195.1	243	-20	314.6	284	11	368.6	288	28	318.9	296	8	89.3	126	-29
1980	370.7	243	53	268.3	284	-6	173.7	288	-40	190	296	-36	258.3	126	105
1981	63.5	243	-74	593.1	284	109	298.2	288	4	308.4	296	4	0	126	-100
1982	503.1	243	107	112.3	284	-60	245.7	288	-15	24.4	296	-92	29.7	126	-76
1983	75.2	243	-69	228.2	284	-20	306	288	6	329.3	296	11	190.5	126	51
1984	238.7	243	-2	332.1	284	17	319.2	288	11	256.2	296	-13	131.5	126	4
1985	219	243	-10	373.9	284	32	126.5	288	-56	283.5	296	-4	115	126	-9
1986	176	243	-28	287.3	284	1	200	288	-31	373	296	26	418.4	126	232
1987	116.8	243	-52	237.5	284	-16	811.6	288	182	344.3	296	16	26.7	126	-79
1988	437	243	80	378.6	284	33	416.1	288	44	266.4	296	-10	127.9	126	2
1989	210.8	243	-13	364.7	284	28	281.2	288	-2	416.5	296	41	120.6	126	-4
1990	166.4	243	-32	494.8	284	74	236.3	288	-18	207.5	296	-30	135.5	126	8
1991	411.2	243	69	186	284	-35	270.5	288	-6	371.5	296	26	70.5	126	-44
1992	150.5	243	-38	434.5	284	53	265.5	288	-8	185.5	296	-37	35	126	-72
1993	146	243	-40	367.8	284	30	172	288	-40	212.3	296	-28	40.5	126	-68
1994	270.5	243	11	80.5	284	-72	101	288	-65	77.5	296	-74	25.5	126	-80
1995	245.7	243	1	330.5	284	16	316	288	10	450.5	296	52	205	126	63
1996	235	243	-3	0	284	-100	236.5	288	-18	370	296	25	75.5	126	-40
1997	165	243	-32	331	284	17	395.5	288	37	480.5	296	62	0	126	-100
1998	25.5	243	-90	595.5	284	110	520.5	288	81	420	296	42	140.5	126	12
1999	350	243	44	395	284	39	286	288	-1	1036	296	250	120.5	126	-4
2000	315	243	30	300	284	6	270	288	-6	685.5	296	132	55	126	-56
2001	375	243	54	190	284	-33	155	288	-46	291	296	-2	495	126	293
2002	345.5	243	42	450.5	284	59	421	288	46	475	296	60	125	126	-1
2003	315	243	30	366.7	284	29	352.5	288	22	150.5	296	-49	331	126	163
2004	428.5	243	76	349	284	23	268.5	288	-7	164.6	296	-44	207	126	64
2005	90.5	243	-63	538.3	284	90	152.2	288	-47	114.1	296	-61	425.5	126	238
2006	55	243	-77	0	284	-100	482	288	67	545.5	296	84	30	126	-76
2007	150.9	243	-38	249.9	284	-12	122.2	288	-58	0	296	-100	59.7	126	-53
2008	285.2	243	17	0	284	-100	112.5	288	-61	235.2	296	-21	62	126	-51
2009	59	243	-76	152.2	284	-46	358	288	24	213	296	-28	115	126	-9
2010	231	243	-5	194	284	-32	223	288	-23	135	296	-54	100	126	-21
2011	370	243	52	118	284	-58	336	288	17	192	296	-35	0	126	-100
2012	234	243	-4	276	284	-3	166	288	-42	319	296	8	88	126	-30
2013	120	243	-51	154	284	-46	468	288	63	126	296	-57	214	126	70
2014	300	243	23	338	284	19	353	288	23	365	296	23	15	126	-88

Appendix 14 : Rainfall deviation percentage from actual rainfall in Niamatpur during the period of 1976-2014

Year	June	M	D	July	M	D	August	M	D	Sept	M	D	Oct	M	D
1976	210.9	242	-13	490.1	309	59	106	247	-57	122.3	283	-57	30.5	122	-75
1977	618.9	242	156	381.3	309	23	141.4	247	-43	37.3	283	-87	96.9	122	-21
1978	445.1	242	84	232.8	309	-25	167.9	247	-32	261.3	283	-8	10.5	122	-91
1979	144.7	242	-40	588.4	309	90	287.3	247	16	99.7	283	-65	37	122	-70
1980	248.3	242	3	214.3	309	-31	291.4	247	18	273.9	283	-3	305.4	122	150
1981	36.2	242	-85	207	309	-33	200.1	247	-19	448.7	283	59	0	122	-100
1982	211.7	242	-13	267.1	309	-14	331.6	247	34	8.9	283	-97	44.5	122	-64
1983	167.5	242	-31	319.1	309	3	253.1	247	2	344.1	283	22	238.3	122	95
1984	212.9	242	-12	358.7	309	16	275.4	247	11	376.9	283	33	203.2	122	67
1985	168.1	242	-31	206.1	309	-33	137	247	-45	299.4	283	6	45.5	122	-63
1986	100.7	242	-58	223	309	-28	75.6	247	-69	387.8	283	37	352.8	122	189
1987	33.9	242	-86	591.5	309	91	651.6	247	164	420.6	283	49	19.1	122	-84
1988	341.4	242	41	246.3	309	-20	551.1	247	123	148.3	283	-48	134.8	122	10
1989	33.7	242	-86	468.8	309	52	93	247	-62	487	283	72	99.4	122	-19
1990	130	242	-46	389	309	26	224.4	247	-9	764	283	170	104.6	122	-14
1991	324.3	242	34	400.9	309	30	202.1	247	-18	353.6	283	25	162.7	122	33
1992	185.7	242	-23	347.1	309	12	194.7	247	-21	272.5	283	-4	202	122	66
1993	222	242	-8	266.8	309	-14	167.2	247	-32	199.6	283	-29	25.2	122	-79
1994	211	242	-13	172.3	309	-44	149.3	247	-40	206.3	283	-27	138	122	13
1995	146	242	-40	243.2	309	-21	342.7	247	39	625	283	121	37	122	-70
1996	347.5	242	44	320.7	309	4	258.9	247	5	37	283	-87	0	122	-100
1997	69	242	-71	283	309	-8	278	247	13	207.7	283	-27	23	122	-81
1998	203	242	-16	340.9	309	10	244.7	247	-1	258.6	283	-9	175.8	122	44
1999	208	242	-14	437	309	41	217.1	247	-12	401	283	42	80	122	-34
2000	345.7	242	43	79	309	-74	332	247	34	575.3	283	103	43.5	122	-64
2001	230	242	-5	266	309	-14	393	247	59	296	283	5	392	122	221
2002	303	242	25	393	309	27	512.5	247	107	368	283	30	25	122	-80
2003	434.7	242	80	210.3	309	-32	167	247	-32	132	283	-53	147	122	20
2004	469.2	242	94	484.7	309	57	226.3	247	-8	123	283	-57	225	122	84
2005	149.3	242	-38	434	309	40	336.8	247	36	113	283	-60	528	122	333
2006	185	242	-24	138.5	309	-55	237.3	247	-4	312	283	10	52	122	-57
2007	342.2	242	41	354.5	309	15	262.3	247	6	440	283	55	170	122	39
2008	283.5	242	17	231.5	309	-25	0	247	-100	236	283	-17	84	122	-31
2009	64.5	242	-73	293.6	309	-5	246.2	247	0	291	283	3	90	122	-26
2010	427	242	76	149	309	-52	126	247	-49	254	283	-10	114	122	-7
2011	490	242	102	215	309	-30	267	247	8	297	283	5	0	122	-100
2012	117	242	-52	329	309	6	80	247	-68	260	283	-8	101	122	-17
2013	229	242	-5	129	309	-58	291	247	18	92	283	-67	196	122	61
2014	334	242	38	329	309	6	326	247	32	316	283	12	11	122	-91

Appendix 15: Rainfall deviation percentage from actual rainfall in Nachole during the period of 1976-2014

Year	June	M	D	July	M	D	August	M	D	Sept	M	D	Oct	M	D
1976	222	232	-4	97.9	299	-67	419	259	62	309.9	271	14	45.7	117	-61
1977	496.5	232	114	375.9	299	26	291.3	259	12	231	271	-15	160.1	117	37
1978	203.7	232	-12	210.4	299	-30	75.4	259	-71	335.8	271	24	147.3	117	26
1979	151.1	232	-35	530.4	299	77	274.8	259	6	243.4	271	-10	29.7	117	-75
1980	139.7	232	-40	253.1	299	-15	432	259	67	110.5	271	-59	194.3	117	66
1981	147.2	232	-37	560.1	299	87	208.7	259	-19	307.8	271	14	0	117	-100
1982	163.6	232	-29	187.8	299	-37	290.2	259	12	26.1	271	-90	8.9	117	-92
1983	105.9	232	-54	359.8	299	20	223.4	259	-14	282.2	271	4	249.4	117	113
1984	184.9	232	-20	392.7	299	31	257.2	259	-1	245	271	-10	128.6	117	10
1985	346	232	49	237.3	299	-21	209.8	259	-19	320.2	271	18	73.9	117	-37
1986	132.2	232	-43	354.2	299	18	109.9	259	-58	474.8	271	75	386	117	230
1987	191.6	232	-17	352.1	299	18	552.5	259	113	296	271	9	7.6	117	-94
1988	404.9	232	75	282.9	299	-5	422.1	259	63	122.2	271	-55	176.4	117	51
1989	84.5	232	-64	369.3	299	24	101.1	259	-61	258.9	271	-4	68.5	117	-41
1990	178.7	232	-23	480.8	299	61	123.3	259	-52	212.7	271	-22	152.5	117	30
1991	201.2	232	-13	273.8	299	-8	276.7	259	7	294.2	271	9	90.6	117	-23
1992	152.5	232	-34	273.6	299	-8	411.6	259	59	346.8	271	28	60	117	-49
1993	194.4	232	-16	252.2	299	-16	200.2	259	-23	277.1	271	2	70	117	-40
1994	347.3	232	50	130.6	299	-56	171.3	259	-34	146.3	271	-46	150.5	117	29
1995	212.2	232	-9	263.8	299	-12	372.8	259	44	509.6	271	88	94	117	-20
1996	319.1	232	38	194.9	299	-35	324.1	259	25	93.6	271	-65	0	117	-100
1997	196.6	232	-15	162.6	299	-46	300.1	259	16	198	271	-27	11.5	117	-90
1998	167.9	232	-28	509.1	299	70	267.2	259	3	444	271	64	133.4	117	14
1999	500.1	232	116	729.7	299	144	673.7	259	160	417.3	271	54	92.6	117	-21
2000	336.8	232	45	137.3	299	-54	297	259	15	687.8	271	154	8.8	117	-92
2001	428	232	84	268	299	-10	96	259	-63	234	271	-14	305	117	161
2002	168.6	232	-27	214.4	299	-28	319.7	259	23	354	271	31	35	117	-70
2003	384.8	232	66	318.6	299	7	198.4	259	-23	167.5	271	-38	189.4	117	62
2004	313	232	35	471.6	299	58	167.4	259	-35	218.4	271	-19	550.8	117	371
2005	79.6	232	-66	370.9	299	24	219.9	259	-15	277	271	2	273.8	117	134
2006	0	232	-100	186.5	299	-38	0	259	-100	425.6	271	57	0	117	-100
2007	320.3	232	38	607.6	299	103	417.5	259	61	299.6	271	11	74.5	117	-36
2008	401.2	232	73	280.8	299	-6	0	259	-100	138.1	271	-49	24.5	117	-79
2009	15	232	-94	221.4	299	-26	396.8	259	53	237.8	271	-12	118.8	117	2
2010	157.1	232	-32	179.5	299	-40	151.3	259	-42	150.3	271	-45	26	117	-78
2011	455.5	232	96	65	299	-78	281	259	8	383.5	271	42	2	117	-98
2012	140	232	-40	127	299	-58	136.5	259	-47	187.2	271	-31	45.5	117	-61
2013	197.3	232	-15	89	299	-70	261.7	259	1	111.8	271	-59	357.3	117	205
2014	201.5	232	-13	287.5	299	-4	175	259	-32	208	271	-23	35.5	117	-70

Appendiex 16: Rainfall deviation percentage from actual rainfall in Shibganj Upazila during the period of 1976-2014

Year	June	M	D	July	M	D	August	M	D	Sept	M	D	Oct	M	D
1976	96.6	214	-55	139.2	319	-56	368.6	243	52	256.3	266	-4	27	163	-83
1977	275.7	214	29	434.5	319	36	259.9	243	7	121.9	266	-54	225.6	163	38
1978	335.6	214	57	82.5	319	-74	198.8	243	-18	304.6	266	15	69.1	163	-58
1979	84.9	214	-60	542	319	70	263.7	243	9	266.2	266	0	38.9	163	-76
1980	319.8	214	49	398	319	25	235.9	243	-3	248.2	266	-7	193	163	18
1981	185.4	214	-13	363.2	319	14	231.1	243	-5	401.8	266	51	446.9	163	174
1982	163.9	214	-23	144.7	319	-55	223.1	243	-8	143.4	266	-46	11.9	163	-93
1983	81.3	214	-62	243.2	319	-24	192.3	243	-21	160.2	266	-40	195.6	163	20
1984	242.6	214	13	336	319	5	368.9	243	52	352.5	266	33	226.3	163	39
1985	226	214	6	349.4	319	10	189.2	243	-22	330.2	266	24	110.5	163	-32
1986	168	214	-21	282	319	-12	125.8	243	-48	345.5	266	30	341.6	163	110
1987	133.4	214	-38	455.8	319	43	518.3	243	113	185.4	266	-30	2.5	163	-98
1988	409	214	91	336.5	319	5	548	243	126	190	266	-29	265	163	63
1989	92	214	-57	363	319	14	130	243	-47	510	266	92	95	163	-42
1990	235	214	10	385	319	21	160	243	-34	310	266	17	160	163	-2
1991	430	214	101	655	319	105	320	243	32	360	266	35	136	163	-17
1992	58	214	-73	490	319	54	203	243	-16	78	266	-71	97	163	-40
1993	54	214	-75	55	319	-83	165	243	-32	262	266	-2	25	163	-85
1994	339	214	58	102	319	-68	179	243	-26	161	266	-39	118	163	-28
1995	174	214	-19	272	319	-15	342	243	41	563	266	112	554	163	240
1996	262	214	22	257	319	-19	315	243	30	360	266	35	59	163	-64
1997	220	214	3	509	319	60	371	243	53	240	266	-10	15	163	-91
1998	111	214	-48	517	319	62	291	243	20	407	266	53	284	163	74
1999	27.3	214	-87	28.8	319	-91	28.6	243	-88	49.2	266	-82	6.4	163	-96
2000	329	214	54	145	319	-55	349	243	44	943	266	255	63	163	-61
2001	288	214	35	223	319	-30	253	243	4	218	266	-18	298	163	83
2002	211	214	-1	227	319	-29	309	243	27	367	266	38	90	163	-45
2003	261	214	22	236.7	319	-26	56	243	-77	122	266	-54	171	163	5
2004	256	214	20	258	319	-19	133	243	-45	170	266	-36	368	163	126
2005	157	214	-27	534	319	67	388	243	60	210	266	-21	210	163	29
2006	176	214	-18	190	319	-40	239	243	-2	0	266	-100	14	163	-91
2007	198	214	-7	1174	319	268	213	243	-12	248	266	-7	30	163	-82
2008	483	214	126	414	319	30	0	243	-100	230	266	-14	72	163	-56
2009	29	214	-86	194	319	-39	230	243	-5	334	266	26	749	163	360
2010	194	214	-9	119	319	-63	105	243	-57	191	266	-28	134	163	-18
2011	414	214	93	221	319	-31	295	243	21	206	266	-23	2	163	-99
2012	178	214	-17	270	319	-15	86	243	-65	240	266	-10	52	163	-68
2013	250	214	17	168	319	-47	379	243	56	59	266	-78	310	163	90
2014	193	214	-10	319	319	0	197	243	-19	243	266	-9	77	163	-53

Appendix 17: Rainfall deviation percentage from actual rainfall in Porsha Upazila during the period of 1976-2014

Year	June	M	D	July	M	D	August	M	D	Sept	M	D	Oct	M	D
1976	93.4	238	-61	179.3	334	-46	450.7	263	71	294.8	275	7	18.3	165	-89
1977	341.7	238	44	483.6	334	45	159.2	263	-39	82.1	275	-70	228.3	165	38
1978	494.4	238	108	219.7	334	-34	132.9	263	-49	311.5	275	13	43.7	165	-74
1979	112.8	238	-53	585.8	334	75	375.3	263	43	123.4	275	-55	352.6	165	114
1980	224	238	-6	402.3	334	20	348.2	263	32	215.7	275	-22	155.5	165	-6
1981	153.4	238	-36	397.9	334	19	378.7	263	44	239.4	275	-13	48.8	165	-70
1982	256	238	8	174.4	334	-48	259.5	263	-1	141.7	275	-48	69.3	165	-58
1983	29.8	238	-87	293.5	334	-12	174.5	263	-34	221.5	275	-19	178.8	165	8
1984	197.5	238	-17	410	334	23	136.5	263	-48	381.4	275	39	137.6	165	-17
1985	81.2	238	-66	460.4	334	38	273.3	263	4	244.3	275	-11	171.4	165	4
1986	87.9	238	-63	355.2	334	6	186.8	263	-29	385.1	275	40	338.7	165	105
1987	238	238	0	472	334	41	734	263	179	429.8	275	56	29.7	165	-82
1988	497.8	238	109	227.6	334	-32	428.3	263	63	145.3	275	-47	122	165	-26
1989	175.9	238	-26	457.1	334	37	97	263	-63	201	275	-27	80.2	165	-51
1990	138.1	238	-42	406.2	334	22	427.9	263	63	177	275	-36	96.3	165	-42
1991	502.5	238	111	364.8	334	9	260	263	-1	482.5	275	75	99.1	165	-40
1992	132.6	238	-44	404.3	334	21	195.6	263	-26	84.3	275	-69	173.3	165	5
1993	305.3	238	28	197.8	334	-41	291.5	263	11	204.7	275	-26	91.5	165	-45
1994	201.4	238	-15	207.3	334	-38	108.6	263	-59	298.1	275	8	128	165	-22
1995	300.9	238	26	299.2	334	-10	505.7	263	92	406.9	275	48	481.8	165	192
1996	294.7	238	24	514.3	334	54	250.2	263	-5	20.5	275	-93	104.2	165	-37
1997	53	238	-78	109	334	-67	160	263	-39	639	275	132	0	165	-100
1998	246.1	238	3	342.1	334	2	495.9	263	89	203.4	275	-26	309.7	165	88
1999	171.3	238	-28	229	334	-31	65.6	263	-75	188.7	275	-31	153.4	165	-7
2000	452.3	238	90	79	334	-76	191.3	263	-27	654.2	275	138	72.1	165	-56
2001	299	238	26	252	334	-25	125	263	-52	219	275	-20	95	165	-42
2002	289.5	238	22	329.2	334	-1	503.9	263	92	351.2	275	28	107.5	165	-35
2003	195.5	238	-18	256.2	334	-23	190.1	263	-28	188.4	275	-31	410	165	148
2004	290.9	238	22	654.9	334	96	355.1	263	35	218	275	-21	464.4	165	181
2005	88	238	-63	424.3	334	27	308.1	263	17	212.2	275	-23	666.5	165	304
2006	318.7	238	34	377	334	13	72.5	263	-72	701	275	155	245	165	48
2007	844.4	238	255	318	334	-5	421.3	263	60	0	275	-100	23.5	165	-86
2008	244	238	3	447.6	334	34	2	263	-99	43	275	-84	223.8	165	36
2009	10	238	-96	261.1	334	-22	170.8	263	-35	69.4	275	-75	124.1	165	-25
2010	274.7	238	15	281.9	334	-16	114.6	263	-56	1107.2	275	303	39.1	165	-76
2011	263.3	238	11	194	334	-42	369.6	263	41	157.8	275	-43	12.1	165	-93
2012	24	238	-90	556.3	334	67	248.4	263	-6	0	275	-100	0	165	-100
2013	129.3	238	-46	269.1	334	-19	157.7	263	-40	393	275	43	299.4	165	81
2014	215	238	-10	126.8	334	-62	126.7	263	-52	289.1	275	5	26.5	165	-84