A SEMINAR PAPER ON

Drought: A Threat to Ensure Food Security in Bangladesh

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ABSTRACT

This seminar paper was prepared to review the threat of drought to ensure food security in Bangladesh. This seminar paper is exclusively a review paper and all the information was collected from secondary sources like various relevant books and journals publications etc. Agriculture is the spinal column of Bangladesh. Agriculture sector is the contributor of income and employment generation in Bangladesh. Now a days, Food security is considered as human rights of the citizens. Agricultural droughts can create serious threats to food security. Drought creates a credible threat on the agriculture, biodiversity, environment and affects all form of food security components namely availability, access to food, utilization and stability. Drought occurs due to inadequate rainfall, lowering the ground water aquifers, changes in temperature and so on. Different techniques are being adopted to mitigate drought problems namely drought resistant variety, conservation of rainwater, zero tillage and so on. Taking into account the above realities this paper shows the impact of drought on agriculture and possible ways of mitigation.

TABLE OF CONTENTS

Chapter	Title	Page No.
	ABSTRACT	I
	TABLE OF CONTENTS	II
	LIST OF TABLES	III
	LIST OF FIGURES	IV
I	**INTRODUCTION**	1-3
II	**MATERIALS AND METHODS**	4
III	**REVIEW OF FINDINGS**	5-22
IV	**CONCLUSIONS**	23
	REFERENCES	24-27

LIST OF TABLES

Table No.	Title	Page No.
1	Production of rice	5
2	Area facing both agricultural and meteorological drought risks	9
3	Chronology of major drought events and its impact in Bangladesh	10
4	Trend in mean temperatures in Bangladesh	13
5	Level of differences in different climatic parameters in drought year and normal years	14
6	Drought affected areas by cropping season	16
7	Impact of drought on agriculture and crop production	16
8	Ranking of climatic variable according to their adverse effects	17
9	Development of drought tolerant crop varieties by research institute in Bangladesh	20
10	Difference in water used between AWD and Farmers Practice (FP) (modified)	20
11	Categories of adaptation practices for increasing crop productivity	21

LIST OF FIGURES

Figure No.	Title	Page No.
1	Map of Bangladesh indicating physiological drought prone area.	7
2	Drought-prone areas of Bangladesh.	8
3	Drought affected areas of Bangladesh in different years.	8
4	Season wise rainfall in Bangladesh.	11
5	Mean monthly rainfall, evapotranspiration and temperature in drought prone region.	11
6	Groundwater table in the north western region (Rajshahi and Chapai Nawabganj) in 1995 and 2009.	12
7	Variation in mean maximum temperature from 1948-2010.	13
8	Local perception about drought for T.aman rice in Barind tract.	14
9	Agriculture impact of drought according to production loss of agriculture crops (%).	17
10	Social impact of drought according to probability of migration of respondents (%).	19

CHAPTER I

INTRODUCTION

Agriculture is the spinal column of the country and is synonymous to the food security of the country. Attaining food self-sufficiency by 2013 along with ensuring food to all is adopted in the 'Vision 2021' of the Government of Bangladesh. Pressure for increased crop production is caused due to the rapid population growth which is the most important challenge. Agriculture is the single largest productive sector of the economy and it contributes about 20.83% to the total gross domestic product (GDP) of the country (Faroque *et al.*, 2013) and employ 48.4% workforce of the country. For these reasons, the government has put highest priority to the agriculture sector. Bangladesh is one of the most climate vulnerable countries in the world. Located between the Himalayas and the Bay of Bengal, the country is very prone to natural disasters. Climate change accelerated the intensity and frequency of occurrences of drought, irregular rainfall, high temperature etc. that resulted from global warming that is directly and indirectly related to crop production. Ensuring food security for all is one the major challenges that Bangladesh faces today. Despite important achievement in food grain production and food availability, food security at national, household and individual levels remains a matter of main concern for the government mainly due to drought (Kashem and Faroque, 2013).

Devastating and recurrent droughts caused by varying rainfall patterns occur frequently in many parts of Bangladesh, causing substantial damage and loss to agriculture and allied sectors. Drought impact, associated with late or early monsoon rains or even complete failure of monsoon, spreads over a large geographical area – much larger than areas affected by other natural hazards. Bangladesh faced major droughts in 1973, 1978-79, 1981-82, 1989, 1992 and 1994-95. The food grain production lost in the 1978-79 drought was probably 50 to 100 percent more than was lost in the great flood of 1974, showing that drought can be as devastating as a major flood or cyclone. Drought can affect the rice crop in three different seasons, which accounts for more than 80 percent of the total cultivated area in the country. Droughts in March and April inhibit timely land preparation and tillage, delaying planting of crops during monsoon season (Paul, 1998).

Increased climate variability means additional threats to drought-prone environments and is considered a major crop production risk factor. It forces farmers to depend on low-input and low-risk technologies, leaving them incapable to adopt new technologies that would allow them to get maximum gains during favorable seasons and less able to recover quickly after disasters. Increasing climate risks undermine development and poverty reduction efforts in

drought-prone areas. Future climate variability and change will aggravate these problems even more in drought-prone environments. Drought is the most complex and least understood of all natural disasters in Bangladesh. It is a natural disaster which causes the greatest loss in the world and has the largest impacts among all the natural disasters (Chunqiang, 2010). It is one of the major causes of crop loss worldwide, reducing average yields for most crop production by more than 50% (Islam *et al.,* 2014; Wang *et al.,* 2003). In recent years, concern has grown worldwide that droughts may be increasing in frequency, severity and duration given changing climatic conditions and documented increases in extreme climate events (Sivakumar *et al.,* 2014; Peterson *et al.,* 2013) though it's characteristics will vary from one climate regime to another (Iglesias *et al.,* 2012). It is a recurring natural hazard (Wilhite *et al.,* 2005) that can cause widespread damage to agricultural production. Additionally droughts have a multidimensional effect on human being in terms of several socio-economic parameters like human health, scarcity of labor, disease prevalence, etc. (Adger, 1999). It triggers to food insecure and elevate the poverty level through direct effects on crop production (Zimmerman *et al.,* 2003). Like other countries of the world, Bangladesh also faces the adverse impact of drought owing to its geographical position.

This study is much more important because this paper aims to provide background information for a discussion on drought from the climate change perspective which affects the food security in Bangladesh. All dimensions of food, water and natural capital security are affected by climate extremes and variability and likely to be affected by drought (Parry *et al.,* 2007). While drought is commonly presented as a gradual shift in climatic trends, its impacts will be most strongly felt by resource insecure populations through changes in the distribution, nature and magnitude of extreme events as these affect crops, disease outbreaks and soil and water quality (Field *et al.,* 2012). In Bangladesh, agriculture is one of the main economic drivers (Chowdhury *et al.,* 2013). Despite its contribution to the overall economy, this sector is challenged by multiple factors predominantly climate-related disasters like drought. Drought is a normal, recurrent climate feature (Keshavarz *et al.,* 2010) which, if badly managed can lead to a loss of crop production, food shortages and for many, starvation (Paul, 1998). Particularly over the last decade, unsustainable development and improper use of natural resources have increased vulnerability to drought in some parts of Bangladesh. Drought happens very often in many parts of Bangladesh mainly due to inadequate rainfall affecting agriculture severely. Every five to ten years Bangladesh is experienced with drought and it causes a great amount of losses to the agricultural crops and ultimately affects the food security. Following this, the paper identifies some of the causes and events of drought to

highlight the frequency and severity of drought in Bangladesh. It highlights some measures that the people of the drought prone areas can take to support their agricultural production to promote food security.

Based on the above discussion, the present study has been aimed with the following objectives-

Objectives:

1. To get an overall idea about food security ,causes and impact of drought in agriculture;
2. To highlight the possible mitigation approaches of drought for ensuring food security in Bangladesh.

CHAPTER II

MATERIALS AND METHODS

This seminar paper is exclusively a review paper. Therefore, all the information was collected from secondary sources like various relevant books and journals publications etc. The related topics have been reviewed with the help of library facilities of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Bangladesh Agricultural Research Institute (BARI) and Bangladesh Rice Research Institute (BRRI). For collecting recent information, internet browsing was also being practiced. Good suggestions, valuable information and kind consideration were taken from honorable seminar course instructors, major professor and other resource personnel to enrich this paper. After collecting all the available information, it has been compiled and arranged chronologically as per the objectives of this paper.

CHAPTER III

REVIEW OF FINDINGS

3.1 Food security

The 1996 World Food Summit defined food security as "a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious foods that meets their dietary needs and food preferences for a healthy life." Now a days, food security is considered as human rights of the citizens (Barrett, 2010).

FAO has defined four dimensions of Food security which are as follows-

3.1.1 Availability

Food is available for all in sufficient quantities and of appropriate quality, the production of food can be domestic or can be imported.

Table 1. Production of rice

Crop	Production (million metric ton)	
Rice	1972-73	2014
	9.93	> 34

(Source: Saleque *et al.,* 2015)

Rice is the staple food of the people living in Bangladesh. More production can ensure the availability of the food for the people (Table 1).

3.1.2 Access

Food is accessible by all individuals by means of having adequate resources (including inherited resources, earned resources, common resources etc.) for purchasing nutritious food.

3.1.3 Utilization

Non-food inputs in food security are important which brings physiological satisfaction and provides nutrition wellbeing. Through clean water and sanitation, proper health care along with adequate diet is important in terms of utilization of food.

3.1.4 Stability

This means that an individual should have access to enough food at all the time even in sudden shock and in seasonal food insecurity season (Ecker and Breisinger, 2012).

3.2 Food insecurity

Food security is inversely proportional to food insecurity. When any of the above factors (availability, access to food, utilization and stability) is missing, then food insecurity exists. Food insecurity is of two types-

3.2.1 Chronic food insecurity

It means persistent food insecurity that exists over a long time when people do not have enough food to meet their regular need. It is often caused by not having assets or not having enough production or not having the right resource to purchase food.

3.2.2 Transitory food insecurity

It means temporary, short-term food insecurity caused by sudden shocks. Poverty, hunger and malnutrition lead to food insecurity of any country (FAO, 2008).

Many factors affect agricultural production and ultimately to the food security. Drought is one of them.

3.3 Perception about drought

Drought is recurrent and creeping phenomenon. It is an insidious natural hazard that results from a deficiency of precipitation from expected or "normal" such that when it is extended over a season or longer period of time, the amount of precipitation is insufficient to meet the demands of human activities and the environment (Wilhite, 2005). Drought is a departure from the average or normal conditions of rainfall, sufficiently prolonged (1-2 years) as to affect the hydrological balance and adversely affect ecosystem functioning and the resident populations. In most cases, drought is temporary. A month-long drought may occur in an area that normally experiences alternating wet and dry periods.

3.4 Categories of drought

There are actually four different ways that drought can be classified (Koren *et al.,* 2004). These categories are described below:

3.4.1 Meteorological drought

When precipitation departs from the long-term normal. This drought can be classified as follows from the rainfall departure.

1. Slight drought : When rainfall is 11 to 25% less from the normal rainfall.
2. Moderate drought : When rainfall is 26 to 50% less than the normal rainfall.
3. Severe drought : When rainfall is more than 50% less than the normal rainfall.

3.4.2 Agricultural drought

When there is insufficient soil moisture to meet the needs of a particular crop at a particular time. Agricultural drought is typically evident after meteorological drought but before a hydrological drought. The agricultural drought, linked to soil moisture scarcity, occurs at different stages of crop growth, development and reproduction.

3.4.3 Hydrological drought

When deficiencies occur in surface and subsurface water supplies.

3.4.4 Socio-economic drought

When human activities are affected by reduced precipitation and related water availability. This form of drought associates human activities with elements of meteorological, agricultural and hydrological drought (Alam *et al.*, 2013).

Besides the above type of drought, there is another type of drought called physiological drought (salinity).

3.4.5 Physiological drought

Salinity is also known as physiological drought. The coastal area covers about 20% of the country and over thirty percent of the net cultivable area. Out of 2.85 million hectares of the coastal and off shore areas about 0.83 million hectares are arable lands, which cover over 30% of the total cultivable lands of Bangladesh (Figure 1).

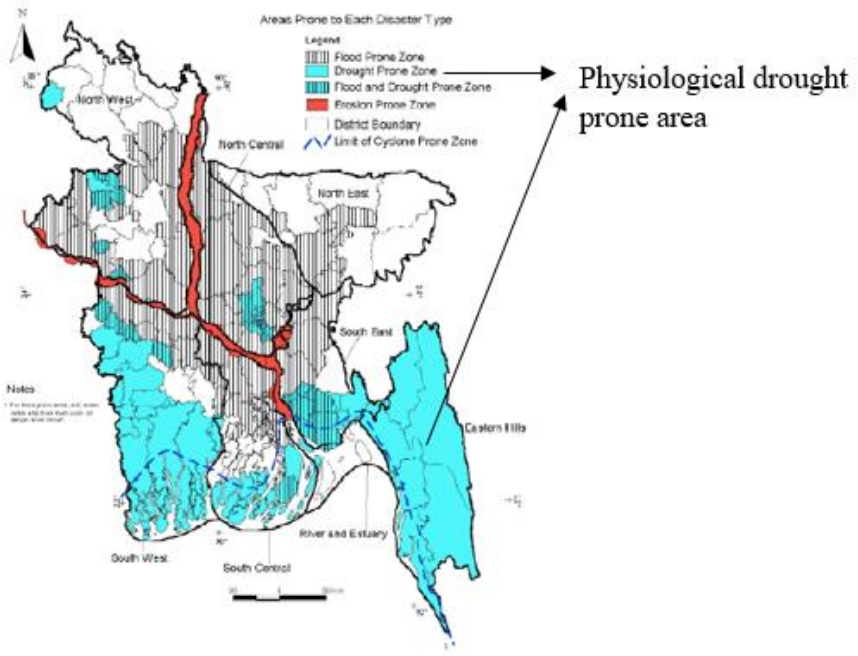

Figure 1. Map of Bangladesh indicating physiological drought prone area.

(Source: Ha and Ahmad, 2015)

3.5 Drought affected area in Bangladesh

Normally northwestern part of the country encounters more droughts than the other parts of the country. In Bangladesh, the Barind (upland of Northwestern part) has been experiencing drought conditions for the last two to three decades. This area is designated as the severe drought-prone areas (Figure 2). It covers Barind Tract, Punarbhava floodplain and Ganges

river flood plain area. This drought-prone region covers most part of the greater Dinajpur, Rangpur, Pabna, Rajshahi, Chapai Nawabganj, Bogra, Joypurhat and Naogaon district. After severely drought affected Northwestern region, Southwestern part of Bangladesh is also facing drought impacts. But the severity of drought in this region is moderate. Among South western region, mainly Jhenaidah, Jessore and Satkhira districts experiences drought during the dry season (Habiba *et al.*, 2011).

This has an enormous impact on the crop production as the production of all winter crops goes down with the arrival of droughts. Droughts also come with land degradation, low livestock population, unemployment, and malnutrition (Chowdhury, 2010).

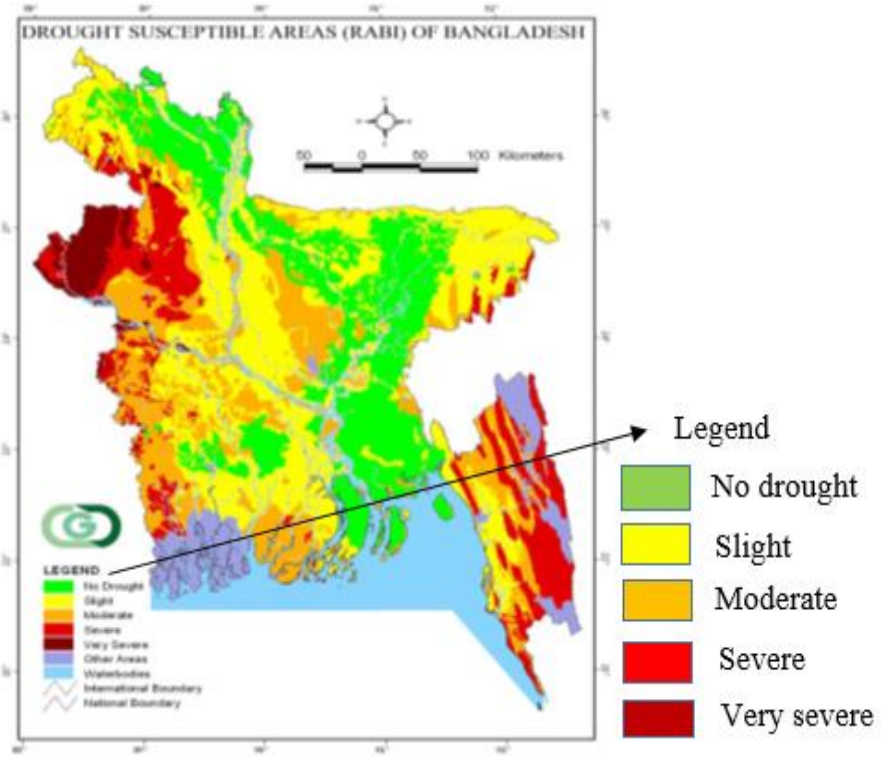

Figure 2. Drought-prone areas of Bangladesh. (Source: Delaporte and Maurel, 2016)

Bangladesh is at higher risk from droughts. Drought conditions due to deficiency in rainfall

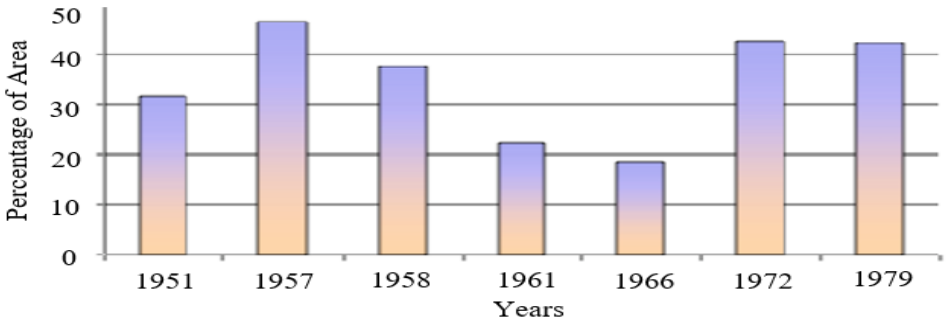

Figure 3. Drought affected areas of Bangladesh in different years.

(Source: Ha and Ahmad, 2015)

affect different parts of Bangladesh mostly during the pre-monsoon and post-monsoon periods. One study has shown (Figure 3) that from 1949 to 1979, drought conditions had never affected the entire country and total population in any drought year. The drought of 1979 was one of the most severe in recent times. The percentage of drought-affected areas was 31.63 percent in 1951, 46.54 percent in 1957, 37.47 percent in 1958, 22.39 percent in 1961, 18.42 percent in 1966, 42.48 percent in 1972, and 42.04 percent in 1979 (Figure 3) (Ha and Ahmad, 2015).

Table 2. Area facing both agricultural and meteorological drought risks

Sl. No.	Drought Risk	No. of Districts	Name of Districts	Area (km^2)	% of Area
1	No risk	2	Sirajgong, Naogaon	5437.34	16.86
2	Slight risk	4	Kurigram, Nawabgong, Bogra, Joypurhat	7322.45	22.71
3	Moderate risk	5	Rangpur, Rajshahi, Pabna, Natore, Lalmonirhat	9581.58	29.72
4	Severe risk	3	Dinajpur, Nilphamari, Gaibandha	6867.32	21.29
5	Very severe risk	2	Panchagarh, Thakurgaon	3036.31	9.42
Total		16		32245	100%

(Source: Murad and Islam, 2011)

A study reported that the percentage of areas in each district of the north-west region facing combined drought risk (Table 2). Sirajgong and Naogaon are two districts free from drought risk. Slight and moderate risk areas encompass 22.71% and 29.72% of total geo-graphical area (Table 2). Severe and very severe risk prevails in nearly 21.29% and 9.42% of the area which includes the districts that are major producers of food grains and different vegetable, (Murad and Islam, 2011).

3.6 Events of drought

Although droughts were not continuous, they did affect the low rainfall zones of the country. Droughts are associated with the late arrival or early withdrawal of monsoon rains and with intermittent dry spells. Between 1949 and 1991, droughts occurred in Bangladesh 24 times. Very severe droughts hit the country in 1951, 1957, 1958, 1961, 1972, 1975, 1979, 1981, 1982, 1984 and 1989, 1994, and 2000, 2006 and 2009. Past droughts have typically affected about 47% area of the country and 53% of the population (Selvaraju *et al.*, 2006). Every five to ten years, Bangladesh is affected by the major country-wide droughts. It causes huge loss

to the agricultural crops, livelihood, health and fisheries etc. which are directly related to food security of the country.

Table 3. Chronology of major drought events and its impact in Bangladesh

Year	Details
1874	Extremely low rainfall affected Bogra, great crop failure.
1951	Severe drought in Northwest Bangladesh substantially reduced rice production.
1973	Drought responsible for the 1974 famine in northern Bangladesh which is one of the most severe of the century.
1975	Drought affected 47 percent of the country and more than half of the total population.
1978-79	One of the most severe droughts with widespread damage to crops reducing rice production by about 2 million tons and directly affecting about 42 percent of the cultivated land and 44 percent of the population.
1981	Severe drought adversely affected crop production.
1982	Drought caused a loss of rice production of about 53000 tons while, in the same year, flood damaged about 36000 tons.
1989	Drought dried up most of the rivers in Northwest Bangladesh with dust storms in several districts, including Naogaon, Nawabganj, Nilpahamari and Thakurgaon.
1994-95	The most persistent drought in recent times which caused immense crop damage, especially to rice and jute, the main crops of Northwest Bangladesh and to bamboo clumps, a leading cash crop.
1995-96	Crops in the northwestern region affected.
2006	A reduction of Aman crop about 25-30 percent in northwestern part.

(Source: Selvaraju *et al.,* 2006)

In 2009, Bangladesh is experienced with serious agricultural drought particularly in the northwestern region.

3.7 Causes of drought

3.7.1 Inadequate Rainfall

Distribution of rainfall throughout the seasons is important. Rainfall is inadequate (time, intensity and distribution) throughout the seasons (Figure 4). A study conducted in the northwest part of Bangladesh covering two severe drought-prone districts, namely Rajshahi

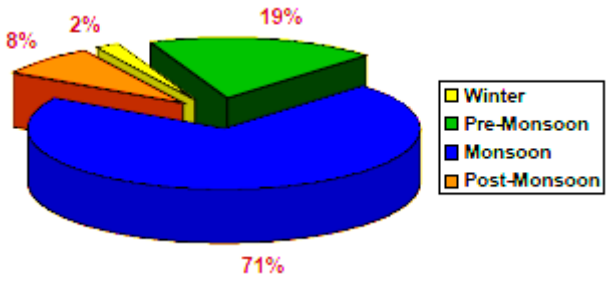

Figure 4. Season wise rainfall in Bangladesh. (Source: Hossain, 2015)

and Chapai-Nawabganj and comprises a total of 14 upazilla. Climatically, this region belongs to the dry humid zone with annual average rainfall varying from 1,400 to 1,900 mm (Shahid, 2011). Rainfall varies widely from year to year as well as from place to place. In 2000, for instance, the total annual rainfall in this area was 1,690 mm, whereas in 2010 it went down to 793 mm. On the contrary, in 2006, the annual total rainfall of Bangladesh was 2,178mm, whereas in drought-prone areas it was 1,193 mm (Habiba *et al.*, 2011). The monthly mean rainfall distribution in the study area varies. Average monthly humidity varies from 62% (in March) to 87 % (in July) with a mean annual of 78 % (Jahan *et al.*, 2010). According to Bangladesh Water Development Board (BWDB), the annual evapotranspiration of the area ranges from 370 to 1,120 mm. In the study area, it has been demonstrated that evapotranspiration exceeds more than 0.5 times during the dry season than the monsoon season, thus, accelerating agricultural drought and affecting food security.

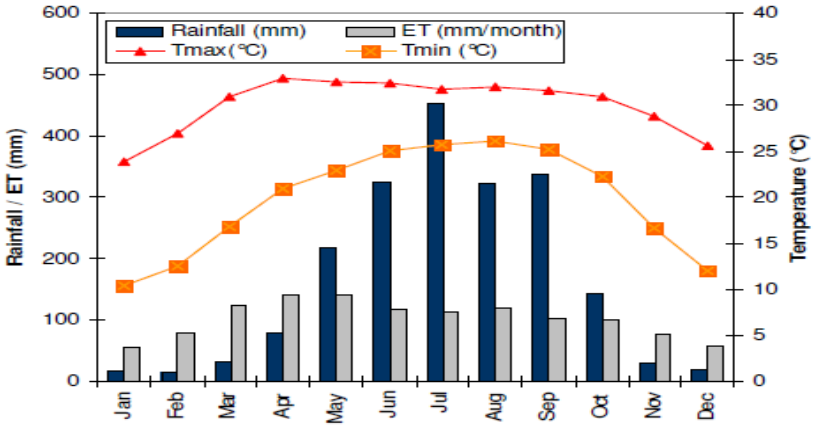

Figure 5. Mean monthly rainfall, evapotranspiration and temperature in drought prone region. (Source: Selvaraju *et al.*, 2006)

The mean monthly rainfall of the regions varies. The rainfall pattern is a uni-model that peaks in July. Rainfall exceeds the potential evapotranspiration in monsoon months (June to September) but is less than evapotranspiration in the remaining months (Figure 5). Highest maximum temperature occurs in April, and the highest minimum temperature occurs in June and July (Selvaraju *et al.*, 2006).

3.7.2 Declining of groundwater aquifers

A study revealed that about 75 % of irrigation water in northwestern region comes from groundwater (Shahid and Hazarika, 2010). However, excessive utilization of groundwater for irrigation and domestic purposes results in the depleted trend of the groundwater table (Habiba *et al.,* 2012). This causes great threat to the irrigated agricultural system because of overdrawn aquifers, lowered water tables and reduced stream flow.

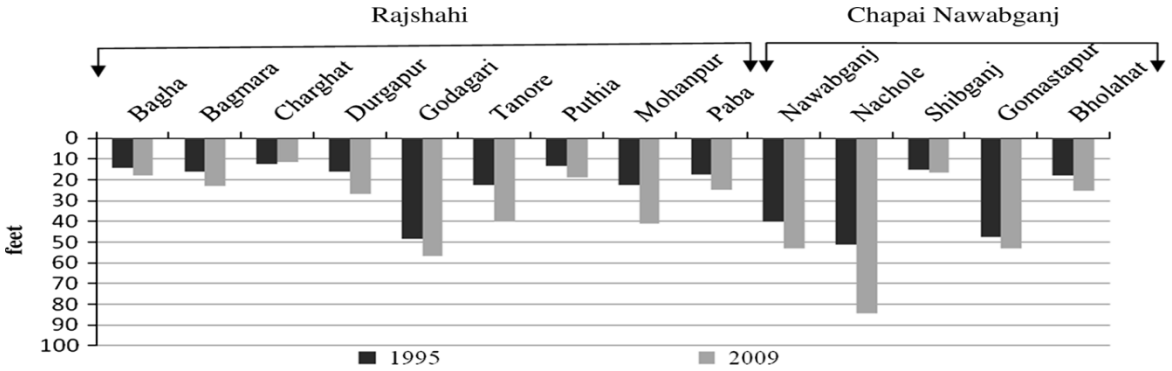

Figure 6. Groundwater table in the north western region (Rajshahi and Chapai Nawabganj) in 1995 and 2009. (Source: Jahan *et al.,* 2010)

Ground water table has gone down more in Nachole, Chapai Nawabganj in 2009 compared to 2005. It has lowered in 2009 compared to 2005 in all cases (Figure 6).

3.7.3 Deforestation and Hydrological Cycle

Vegetation is one of the most important stabilizers of climatic factors- temperature, precipitation and also carbon sequestration. Therefore, deforestation destabilizes climatic factors as it is being cutting and clearing for fuel, farms, plantations and settlements. The intensity of deforestation in Bangladesh is increasing with the growing population. For example, in northern Bangladesh, the percentage of vegetation coverage in the densely populated is lower than in the sparsely populated areas. Deforestation causes the damage of habitat, loss of biodiversity and river bank erosion which brings drought. It can also cause extreme temperatures and low precipitation (Nelson, 2009). Literature revealed that average temperature is increasing day by day due to the decreasing vegetation coverage and increasing greenhouse gases.

3.7.4 Farakka Barrage

The ‘Farakka barrage’ of India across the Ganges has created a serious problem in Bangladesh. The overflow of the Ganges water causes severe floods which inundate Bangladesh and the underflow causes extreme drought which brings in famine. They both are damaging the economic base of Bangladesh and affecting the ecological balance of the country (Afroz & Rahman, 2013).

3.7.5 Temperature change

Extreme temperature impacts adversely on crops and soil characteristics. High temperature is also a key factor in the evolution of new pests and/or decreasing of croplands. The evolution of new kinds of bacteria, algae and virus borne diseases would increase as a result. Crop production would also decrease, causing economic losses in the affected regions and whole of the country. The global temperature increase by 2°C predictions by 2100 would impact rural poverty and urban food insecurity (Vermeulen *et al.,* 2012). Climatic impacts adversely affect food production, patterns of crop productivity, fishery and livestock system, food distribution and market access (Nelson, 2009; Liverman and Kapadia, 2010). Rice and wheat production is likely to decrease 28 % and 68 % respectively due to a 1–2 °C increase in temperature (Hasan *et al.,* 2013).

Table 4. Trend in mean temperatures in Bangladesh

Season	Trend in mean temperature (^{o} C for data period of century)	
	1948-2010	1980-2010
Winter (Dec-Feb)	+1.2	+1.2
Pre-monsoon (Mar-May)	+0.7	+3.2
Monsoon (Jun-Sep)	+1.2	+2.7
Post-monsoon (Oct-Nov)	+2.0	+1.5
Annual (Jan-Dec)	+1.2	+2.4

(Source: Mondal *et al.,* 2012)

Annual (Jan-Dec), pre-monsoon (Mar-May) and monsoon (Jun-Sep) mean temperatures have increased during 1980-2010 compared to 1948-2010 (Table 4).

The variation of annual mean maximum temperatures for all-Bangladesh is presented in figure 7.

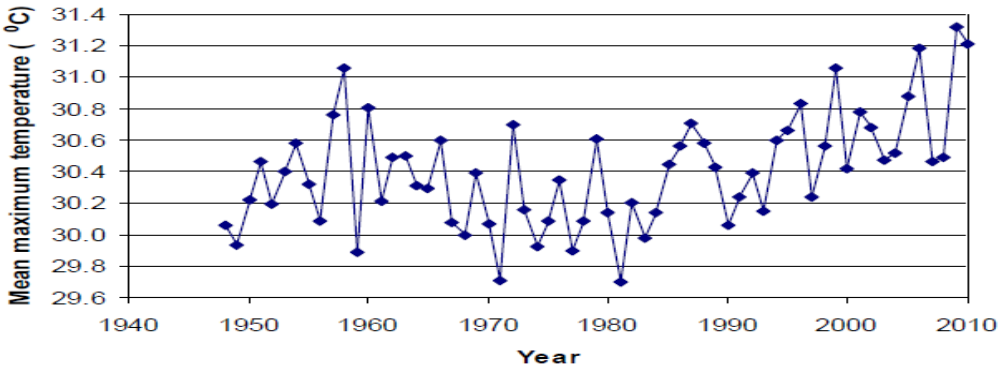

Figure 7. Variation in mean maximum temperature from 1948-2010.

(Source: Mondal *et al.,* 2012)

The maximum temperature has started rising since 1970s or 1980s. The rising trend is 0.82 ^{0}C per century since 1948 and 2.84 ^{0}C per century since 1980. So the recent trend since 1980 is much higher than the historical trend since 1948 (Figure 7). Due to increasing trend of mean maximum temperature, drought has become a serious problem for agriculture and ultimately a threat to food security (Source: Mondal *et al.*, 2012)

Another study revealed that temperature, rainfall, sunshine hours and solar radiation is changed over time. Those phenomena are given in the following table (Table 5).

Table 5. Level of differences in different climatic parameters in drought year and normal years

Years	Average maximum temperature(in ^{0}C)	Total rainfall (mm)	Monthly average sunshine hours	Solar radiation(gm-cal/cm^2/day)
Normal year (3 years average)	32.04	1699.15	83.67	4323.5
Drought year (1994)	33.51	1163.32	89.22	4481.0

(Source: Dey *et al.*, 2012)

Average maximum temperature has increased in drought year compared to normal year whereas total rainfall has decreased in drought year (Table 5). So production of food crop is greatly affected.

3.8 Intensity of drought

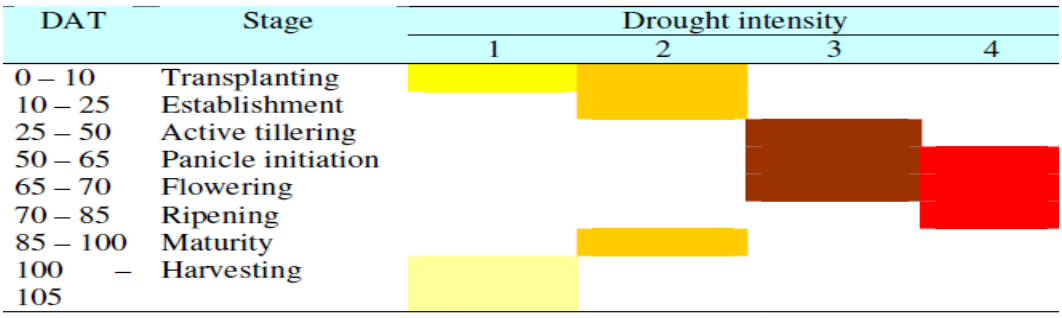

Figure 8. Local perception about drought for T.aman rice in Barind tract.

(DAT= Days after transplanting, 1-slight drought; 2-mild drought; 3-moderate drought; 4-severe drought) (Source: Selvaraju *et al.*, 2006)

Local populations understood that rainfall distribution is more important than seasonal rainfall totals. Lack of sufficient water for timely transplanting led to late harvest of T.aman

and had a cascading effect on subsequent crops. With regard to transplanted aman (T.aman) rice, it was perceived that transplanting and establishment stages were affected by mild drought, the active tillering stage was affected by moderate drought, and the panicle initiation, flowering and ripening stages were affected by severe drought (Figure 8). Generally it was perceived that severe drought during flowering and ripening stages reduced the grain yield up to 70 percent. They also perceived the maturity stage was affected by mild to moderate drought (Figure 8). Farmers are very much concerned about drought at various stages of crop growth during T.aman. The problem ranking the farmers gave to T.aman crop was considered most informed because 100 percent of the farmers grew this crop in all their available land, indicating that T.aman, a crop often affected by drought, is an essential part of the agricultural system in the rainfed Barind Tract (Selvaraju *et al.,* 2006).

3.9 Impacts of drought

3.9.1 In terms of agriculture

Though agriculture is the prime sector of Bangladesh, it is severally affected by different natural hazards for instance drought. Historical data revealed that, every five to ten years, Bangladesh is affected by the extreme drought events. Nevertheless, local droughts occur regularly and affect crop production. The end results of drought usually first appear on agriculture and then impacts on food production, water resources and farmer's life and livelihood (Habiba *et al.,* 2012). Ultimately it affects the food security of the country. Mainly, inadequate pre-monsoon rainfall, a delay in the onset of the rainy season or an early departure of the monsoon leads to droughts in Bangladesh (Shafie *et al.,* 2009). Monsoon failure often brings famine to the affected regions and as a result crop production reduces drastically. Every year 3 to 4 million hectares of lands are affected by droughts of different magnitudes. Agricultural activities in Northwestern regions of Bangladesh are particularly exposed to droughts almost three cropping season.

During the kharif season, it causes significant destruction to the T. aman crop is approximately 2.32 million ha every year. In the Rabi season, about 1.2 million ha of agricultural land faces droughts of different magnitudes. Pre-monsoon drought is called Rabi and Pre-Kharif drought since it affects both Rabi and Pre-Kharif crops. The commonly affected major crops include HYV Boro, Aus, wheat, pulses, sugarcane, and potatoes. Significant damages can occur where irrigation opportunities are limited. Post-monsoon drought is also known as Kharif drought as it affects Kharif crops. Aman rice is the most common Kharif crop that is affected by post-monsoon drought as its reproductive stage is

severely constrained by shortage of available moisture. Table 6 represents drought prone areas by cropping seasons.

Table 6. Drought affected areas by cropping season

Crop season	Area under various drought severity class (in million ha)				
	Very severe	Severe	Moderate	Slight	Unaffected
Pre-kharif	0.403	1.15	4.76	4.09	2.09
Kharif	0.344	0.74	3.17	2.90	0.68
Rabi	0.446	1.71	2.95	4.21	3.17

(Source: Ahmed and Roy, 2007)

In kharif season, normally aman rice is affected due to drought. As a result, a substantial amount of yield loss is occurred (Dey *et al.,* 2012). Droughts adversely affect the crop production, causes annual damages of 2.32 million hectares crop production (Habiba *et al.,* 2011). Scarcity of water limits crop production while irrigation coverage is only 56% (Cell, 2006). In Bangladesh, rice faces the highest loss due to drought because rice production is very much dependent on water availability. During drought period rice does not get enough water which causes production loss. Additionally drought also affects the production of other major crops (Table 8).

Table 7. Impact of drought on agriculture and crop production

Crops	(%) Yield Reduction			
	Slight	Moderate	Severe	Very Severe
T. Aman	0-20	20-35	35-45	45-100
B. Aus	0-10	10-30	30-40	40-100
Wheat	0-40	40-50	50-59	59-100
Mustard	0-30	30-40	40-50	50-100
Potato	0-60	60-70	70-80	70-100

(T. Aman= Tranplanted Aman, B. Aus= Broadcast Aus)

(Source: Ahmed, 2006)

Moreover, Another study conducted (Habiba *et al.,* 2012) in northwestern region of Bangladesh revealed that about 53.33% production of rice was reduced significantly whereas the production of potato, jute, onion and bean were decreased 13.33%, 26.66%, 6.66% and 4% respectively due to drought (Figure 9).

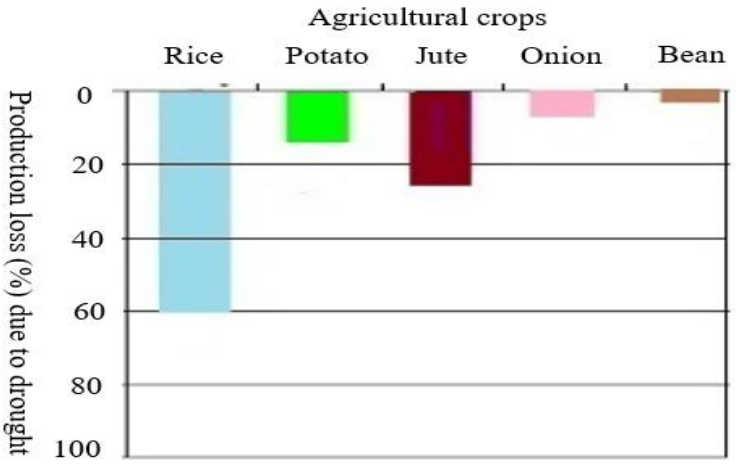

Figure 9. Agriculture impact of drought according to production loss of agriculture crops (%).

(Source: Habiba *et al*., 2012)

Drought frequently occurs in Bangladesh and causes huge destruction to the crops.

3.9.2 In Terms of Fisheries

The frequency of extreme droughts has an adverse effect on fish habitat and populations, and the incidence of diseases is expected to rise. Drought causes drying up of surface water bodies like canals, ponds, beels and rivers etc. It also hinders fishing activities and causes difficulties for the fishing dependent livelihood. It is reported by Haque (2007) that seasonal variations of rainfall and temperature have diverse implications on fishing, hatchery operations, fish production and livelihoods of a wide range of people directly and indirectly involved with fisheries and aquaculture. Furthermore, drought causes loss of biodiversity and extinction of some fish species. Drought affects brood stock rearing, fish fecundity, hatching and growth rate of fish.

Table 8. Ranking of climatic variable according to their adverse effects

Hatchery operations	Flood	Drought	Cyclones	Total (n=30)
Brood stock rearing	11(37%)	8(27%)	2(7%)	30 (100%)
Fish fecundity	10 (33%)	9 (30%)	1 (3%)	30 (100%)
Hatching rate of fish	11 (37%)	8 (27%)	1 (3%)	30 (100%)
Growth rate of fish	10 (33%)	7 (23%)	1 (3%)	30 (100%)

(Source: Billah, 2013)

Drought adversely affects different hatchery operations more than cyclones. Drought greatly affects fish fecundity (30%) (Table 8).

3.9.3 In Terms of Livestock

Livestock are affected by air temperature, humidity, wind speed, and thermal radiation, which influence their growth, milk production, reproduction, health, and wellbeing. Moreover, due

to lack of grazing facilities and shortage of food that makes unfavorable environment for the livestock. Sometimes, cattle and poultry suffer from heat stroke, even affected by different diseases. Drought also diminishes the reproductive capacity of cattle and poultry. Thus, it causes economic loss for the livestock dependent livelihood in drought affected areas (Dey *et al.,* 2012). Ultimately it brings a threat to food security in the country.

3.9.4 In Terms of Environment

Drought causes the environmental degradation in various ways. It dries out the natural water bodies and thus causes loss of wild and cultural stocks. It reduces water levels in reservoirs, lakes, and ponds, increases salt concentration, water temperature, affects air and water quality and degrades landscape quality and causes soil erosion. On the contrary, drought has substantial effect on ground water aquifer. Surface water as well as ground water is the main source of fresh water in drought prone area. Not only excessive use of groundwater for irrigation purposes but also domestic uses cause depletion of groundwater level during the dry season in Northwest Bangladesh (Habiba *et al.* 2011). This causes a great threat to the irrigated agricultural system and also causes draw down of ground water level and leads to environmental problems such as heavy metal contamination, arsenic and salinity. Besides ground water aquifer, drought also acts as a catalyst of land degradation that causes reduction of soil moisture and water retention capacity. It enhances the drying out of topsoil and effective loss of soil structure and aggregation. Moreover, drought declines soil organic matter contents, reduces microbial activity. On the other hand, it causes loss of biodiversity by hampering the microbial activities, extinction of some species and damage to plant and animal species, increase incidence of the diseases by bringing pathogen and parasites (Shaw *et al.,* 2013).

3.9.5 Social Impact

Livelihood pattern becomes change in the drought prone area. It was noticed that the probability of migration rate increases more during drought period than the normal period due to monga. The result was shown that about 84% drought victims migrated from drought prone area for better livelihoods and the government assistance during 1994 severe drought while 65% of other household migrated for different incidents except drought. About 59 % drought victims leaved the area in 2006 drought whereas only 40 % victims migrated from drought affected area in recent years. About 26% past drought victims migrated from the area with no drought period while 18% of other household migrated for different unpleasant incident of the area (Figure 10). The Intergovernmental Panel on Climate Change (IPCC) assessment narrates that droughts will affect 8 million people by 2050 (Huq, 2011). However,

their migration decision did not change even after they have received cash assistance and information assistance about how to cope with the droughts (Andrijasevic & Walters, 2010). The result is reliable with the finding of (Motamed and Devisti, 2012) who stated that drought has social impact.

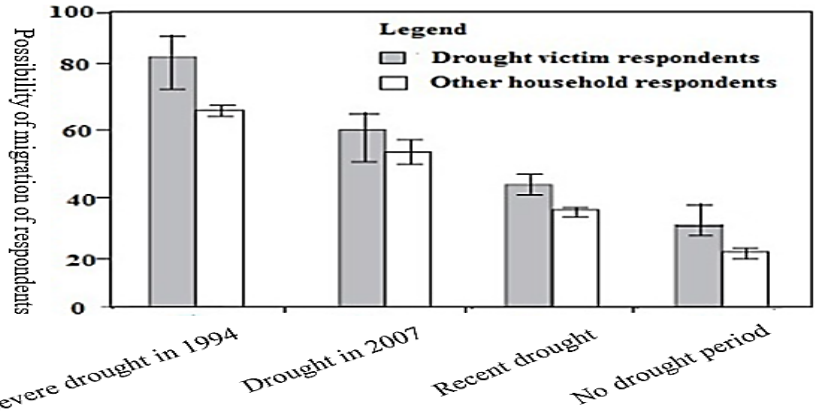

Figure 10. Social impact of drought according to probability of migration of respondents (%). (Source: Huq, 2011)

All the above factors make foods insecure and ultimately affect food security.

3.10 Drought adaptation and mitigation approaches

Mitigation techniques are to be adopted for reducing drought impacts on agriculture for ensuring food security. The country is trying to develop coping mechanism against natural hazard like drought through support of the government. Some mitigation approaches are as follows-

3.10.1 Use of drought resistant crop varieties

Researchers of different institutions under National Agricultural Research Systems (NARS) are engaged to innovate technologies that will be resilient to climate change and ensure expected crop production. Research and developments of stress (drought, high temperature) tolerant rice and wheat varieties can ensure food security by an increase in yield of up to 20%. Bangladesh Rice Research Institute (BRRI) has released drought tolerant BRRI dhan42/43, and Salt-cold-drought tolerant BRRI dhan56/57 using gene-marker technology. Seeds of BRRI dhan varieties are multiplied by the Bangladesh Agricultural Development Corporation (BADC) and disseminated by the Department of Agriculture Extension (DAE) to the farmers for cultivation in the drought prone districts. Innovation of short duration varieties like BR 33 by BRRI and BINA 7 by the Bangladesh Institute of Nuclear Agriculture (BINA) is successfully cultivated to avert so called monga situation in the northern Bangladesh. Bangladesh Agriculture Research Institute (BARI) is working with heat tolerant wheat and tomato varieties (Selvaraju *et al.,* 2006).

Table 9. Development of drought tolerant crop varieties by research institute in Bangladesh

Name of drought tolerant crop	Developed technology (Variety)
Rice	BRRI dhan42/43, BRRI dhan48, BRRI dhan56, BRRI dhan57
Pulse crop	BARI chola5, BARI mungbean lines BMX-01007
Barley	BARI barley6

(Source: Shaw *et al.,* 2013)

Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) has developed some drought tolerant variety namely BU chola1, BU dhan1, BU soybean1 etc.

3.10.2 Irrigation and improved irrigation efficiency

Success of climate change adaptation depends on availability of fresh water in drought-prone areas. Irrigation is crucial in the context of climate change. In the comparatively dry Rajshahi and Rangpur division (Barind region), Barind Multipurpose Development Authority (BMDA) ensures irrigation for rice where 100 hour free electricity bill for irrigation of last year's aman season were provided to the farmers from the Ministry of Agriculture (MoA) in 2009. A 20% rebate in the electricity bills for irrigation throughout the country to encourage irrigated cropping has also been provided by the government. Besides, Introduction of 'Alternate Wetting and Drying (AWD)' irrigation technique by the Department of Agricultural Extension (DAE) has been found to be promising in increasing water use efficiency for crop production.

Table 10. Difference in water used between AWD and Farmers Practice (FP) (modified)

N-P-K-S-Zn (kg/ha)	Amount of water(mm)		Yield (kg/ha)		Water productivity (kg/m^3)	
	AWD	FP	AWD	FP	AWD	FP
Kurigram						
100-24-42-10-3.5(BRRI)	742	1017	6393	5193	0.86	0.51
188-16-40-9.0 (FP)			5626	4627	0.76	0.46
Pirgonj, Rangpur						
100-24-42-10-3.5(BRRI)	780	1032	5698	4998	0.73	0.49
105-17-25-0(FP)			4817	4516	0.62	0.44

(AWD= Alternate Wetting and Drying) (Source**:** Maniruzzaman and Biswas, 2014)

AWD is a water saving method. This method is advantageous over FP (Farmers Practice) method (Table 10).

3.10.3 Increased crop productivity and food security

Table 11. Categories of adaptation practices for increasing crop productivity

Sl. No	Categories	Adaptation practice	Experts' comments
1.	Agronomic management	Seedbed method for T. Aman rice	The practice would be viable under climate change scenarios of the future as rainfall is expected to show higher variability.
		Manures and composting	Available water hyacinth can be applied in the pit surrounding mango plants and other raw materials can also be used.
		Strengthening field bunds (Ail lifting)	The practice of ail lifting is highly useful in non-irrigated areas and is cost effective.
2.	Water harvesting	Re-excavation of traditional ponds	Careful evaluation needs to be done in consultation with department of fisheries.
		Canals, Mini-ponds	Excavating new canals and mini-ponds in non-irrigated areas.
3.	Water resources exploitation	Shallow and deep tube wells	Possibility of extending the deep tube well scheme for non-irrigated areas may be explored.
4.	Water use efficiency	Direct sown rice (drum seeder)	It is a useful technique for kharif II season to reduce the water requirement.
		Drought resistant rice varieties	These varieties are highly useful for the Barind region.
5.	Crop intensification	1.Green manure – T.Aman 2.T. Aus– Chini atap 3. T. aman – Chickpea	These practice can increase the cropping intensity and improves the nutritional security and soil fertility.
6.	Alternate enterprise	Mango and jujube (*Ziziphus jujuba* Mill) cultivation	These are promising crops to manage drought in Barind areas because the crops can be cultivated successfully with little irrigation.

(Source: Selvaraju *et al.*, 2006)

Bangladesh is highly sensitive to climate variability and change impacts on the agriculture sector. The key risks from climate change to agriculture and allied sectors in northwestern Bangladesh are related to increased drought frequencies (kharif II) and inadequate availability of water for irrigation (rabi). Agriculture depends on freshwater resources and, thus, depends on the success of adaptations in that sector. Moreover, the agriculture sector has the difficult task of meeting the ever increasing demand for food.

The agriculture sector must have increased productivity if agriculture is to remain a source of employment and a key element of economic development. Crops need to be diversified and thus, less vulnerable to climate change. Adaptation practices related to new cropping systems involving drought resistant crops will benefit the sector as a whole. In fact, with successful adaptation, the production of major crops would not be threatened by climate change. The agronomic management practices suggested (Table 11) would improve the productivity of crops under drought conditions and ensure food security (Selvaraju *et al.,* 2006).

3.10.4 Rainwater harvesting and management

There is high rainfall variability in the drought-prone areas, with different types of seasonal droughts (initial, mid and terminal) posing major threats to rice production. Yet, often, high intensity rainfall is wasted due to non-availability of proper storage structures. Rainwater harvesting and recycling are essential for managing seasonal droughts through supplemental irrigation. Thus primary adaptation options need to be concentrated on rainwater harvesting, recycling and conservation. The feasible adaptation options at community level are excavation and re-excavation of traditional ponds and canals, water control structures and miniponds (Selvaraju *et al.,* 2006).

3.10.5 Zero tillage

Zero or minimum tillage is practiced to conserve the soil moisture. A minimum soil disturbance is done to reduce moisture through evaporation. It appears to benefit adaptation to climate change rather than mitigation. Conserving soil and water resources are important measures for adapting agricultural systems to climate change (Luo *et al.,* 2010).

All the above discussed drought adaptation and mitigation approaches will play a vital role in minimizing the threat of drought to ensure food security in Bangladesh.

CHAPTER IV

CONCLUSIONS

On the basis of the findings of this review paper the following conclusions can be drawn.

1. Drought is a continuous threat to agriculture and ultimately to food security. It is occurred due to inadequate rainfall, lowering the groundwater level and so on. It remains to be the most important threat to food production and food and nutritional security in Bangladesh. Its effects are inter-temporal and long-lasting.

2. For ensuring food security, various techniques should be adopted to mitigate drought problems namely drought resistant variety, rainwater harvesting and management, improved irrigation efficiency, alternate wetting and drying, zero tillage etc.

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