Study on Agricultural Cropping Pattern Change in a Water Stress Area of North-west Region of Bangladesh a Case Study in Sapahar Upazilla under Naogaon District

by

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A thesis submitted to BRAC Institute of Governance and Development (BIGD) in partial fulfillment of the requirements for the degree of Master of Art in Governance and Development (MAGD)

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Declaration

I do hereby declare that the dissertation entitled "**Study on agricultural cropping pattern change in a water stress area of north-west region of Bangladesh, a case study in Sapahar upazilla under Naogaon district**." submitted to BRAC Institute of Governance and Development (BIGD), BRAC University in partial fulfillment of the requirements for the Degree of Masters of Arts in **Governance and Development** is exclusively my own and original work. No part of it in any form, had been submitted to any other University or Institute for any degree, diploma or for other similar purposes.

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Abstract

This study examines the effect of drought on cropping pattern of sample farms in the North-west Regions of Bangladesh. A strong drought can cause greater than 40% damage to broadcast aus rice. During the kharif season, it causes significant destruction to the transplant aman rice crop in approximately 2.32 million ha every year. Past droughts have naturally affected about 53% of the population and 47% of the country. Cropping systems in a region are determined by soil and climatic conditions. Changes in cropping patterns are likely to impact on the availability of water resources due to differences in crop water requirements. The objective of this study was to identify impact of drought on cropping pattern under water stress condition in North-west region of Bangladesh. Farmers from a total of 100 selected farms were interviewed for farm level data in September to December 2016 time periods. Change of cropping system over the study period (2006-2015) in Shapahar upazila . Meanwhile, it is evident that the cropping pattern was dominated by grain crops (rice and wheat, between the 2006 and 2015, with rice constituting the largest area, followed by wheat. Although a major grain crop, rice occupied maximum areas in wet season, whereas wheat and mango orchard can be cultivated in dry areas. Although the area of grain crops showed a downward trend over the study period, the share of grain crops was still more than 0·50 of total crop area sown. Around 51% farmers responded that due to the cropping pattern change and technological advancement, the production is increasing. On the other side, 39% farmers said that production is increasing due to the improved irrigation facility but climatic variation creating significant obstacles in this process and hampering the production in a big extent. Changing the cropping pattern has significant effects on regional crop productivity: in this way, this new crop has increased the total crop production without increasing significantly the regional water consumption. The results of this case study indicate that regional agricultural water can be used effectively by properly planning crop areas and patterns under irrigation water limitations. Crop production is influenced by inadequate rainfall, high temperature, severe drought, river erosion, and tropical storms. All of which are likely to increase as a result of climate change. Most fields remain fallow during winter and Kharif-I season after harvest of Transplant Aman rice due to moisture stress. The area under cash crops (mango orchard, wheat, water melon and vegetable) increased phenomenally over the study period. It was found that mango orchard performed better, with an average gross margin of marginal, small, medium and large farmers at Sapahar upazila under Naogaon district. Despite this higher production performance, the costs increase was < 5% for other crops. In addition, the benefit-cost ratios of all other crops were higher for better production than rice. It must also be noted that both less water required crops and mango orchard cultivation was profitable compared to rice cultivation. The highest gross return and gross margin were found from mango orchard in all the (marginal, small, medium and large) farmers group and the lowest gross return and gross margin were found from rice cultivation at sapahar upazilla in Naogoan district. This demonstrates that cash crops are turning into a prevailing crop type and mirrors an inclination toward expansion of pay by farmers, who are subbing them for water-intensive crops like rice and sub-par (low financial return) ones like wheat and mango orchard. To cope with the adverse effects of droughts, the farmers have been adapting strategies like increase irrigation facilitates, and cultivating drought tolerant crops, less water required crops like wheat, jujebe and mango orchard. In any case, there is a need to cultivate a feasible sustainable cropping pattern that is multifunctional, which can guarantee food security, improve normal asset utilize and give steady and exceptional return to farmers.

Key Words: Cropping Systems, drought stress, crop productivity

Agricultural Cropping Pattern Change in a Water Stressed Area of North-west Region of Bangladesh: A Case Study of Sapahar Upazilla Under Naogaon District

Background of the Study

The 21st century faces multiple challenges like climate change, population growth, food shortage, poverty, hunger, accelerated land cover change and environmental degradation (Neamatollahi et al. 2017). Due to the inadequate food supply, about 1 billion people stay hungry every day in the world and the figure will increase to 2 billion by 2050. This scenario enforces the increasing momentum in agricultural production with more than 70 percent increase for the developing countries of Asia and Africa in coming decades (Neamatollahi et al. 2017). In this regard, improved cropping pattern, better management practices are essential to enhance agriculture productivity. Due to the rapid change in population and urbanization, land and water resources are becoming very limited. Subsequently, crop optimization has received extensive attention in recent years and improved cropping pattern have been developed to determine the optimal use of the available resources for maximizing the net benefits subjected to some constraints (Osama et al. 2017). Land and water are the key factors for sustainable agricultural development of a nation.

Growing populations and food consumption, coupled with competition between different water use sectors, increase the pressure on water resources (Karimov et al. 2012). Increased food supply cannot be achieved by expanding the area of cultivated land, since that is already a scarce natural resource around the world. Furthermore, it cannot come from any significant expansion of irrigated area because of competition for water by industrial and domestic water demands (Harwood 1998). Water scarcity is a major constraint of agricultural production in arid areas, where rainfall is limited (Umetsu et al. 2007). Moreover, farmers are under pressure to reduce the use of irrigation (thereby releasing water to other sectors and the ecological environment) and use water more efficiently (Perry 2011). Meanwhile, irrigation water availability is highly vulnerable to climate change and irrigation allocation limitation (IPCC 1995; Singh et al. 2005). In the face of future water scarcity, possible means for the agricultural sector to adapt are via changes in cropping patterns and adjustments according to available water resources (Boustani & Mohammadi 2010). Adjustment of cropping patterns according to irrigation water availability, such as reducing the area of water-intensive crops or changing crop types to ones with more efficient water use, provides a potential means of alleviating irrigation water scarcity (Wang et al. 2011).

The cropping pattern reflects the proportion of land area under different crops at a particular moment. A change to this pattern implies modification of that proportion, which largely depends on the facilities available to raise crops in a given agro-climatic condition.

Drought is a recurrent phenomenon in Bangladesh, afflicting the country at least as frequently as major floods and cyclones (Paul, 1998). Different studies have been carried out on the impact of droughts on agriculture (Saleh et al., 2000; Mazid et al., 2005), food production (Ericksen et al.,1993), land degradation (Karimand Iqbal, 2001; Government of Bangladesh, 2005), economy and society (Paul, 1998). But none of these studies highlighted the need for drought risk reduction in Bangladesh. Furthermore, no study has identified the geographic distribution of human vulnerability to drought (Shahid and Behrawan, 2008). According to the fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC,2007), Bangladesh will experience severe floods and droughts in the coming decades due to the effect of climate change. Farmers of the north western region of Bangladesh perceive drought to have been occurring more frequently in recent decades. Although Bangladesh has achieved remarkable success in disaster management related to floods and tropical cyclones through early warning and post disaster management, little has been done regarding drought. Thus, it is important not only to study the impact of drought but also to reflect on the socio-economic, institutional and physical aspects of a given area. Based on these, adaptation action can be undertaken at the local level for improving drought management policy. In this regard, this study attempts to find out a suitable cropping pattern under water stress condition in north west region of Bangladesh.

Rationale of the Study

Bangladesh is predominantly an agro-based country with one of the highest human population densities worldwide and limited land area. Agriculture is the most important sector in our target research area in North-west region. Bangladesh is one of the countries with the lowest agricultural productivity in the world. The yields of cereals and most of the non-cereal crops are lower as compared to other countries. Improvement of cropping pattern through inclusion of less water requirement crops at drought prone areas increasing cropping intensity as well as reduced food insecurity (Mishra and Hossain, 2005; Rahman *et. al.*, 2005).

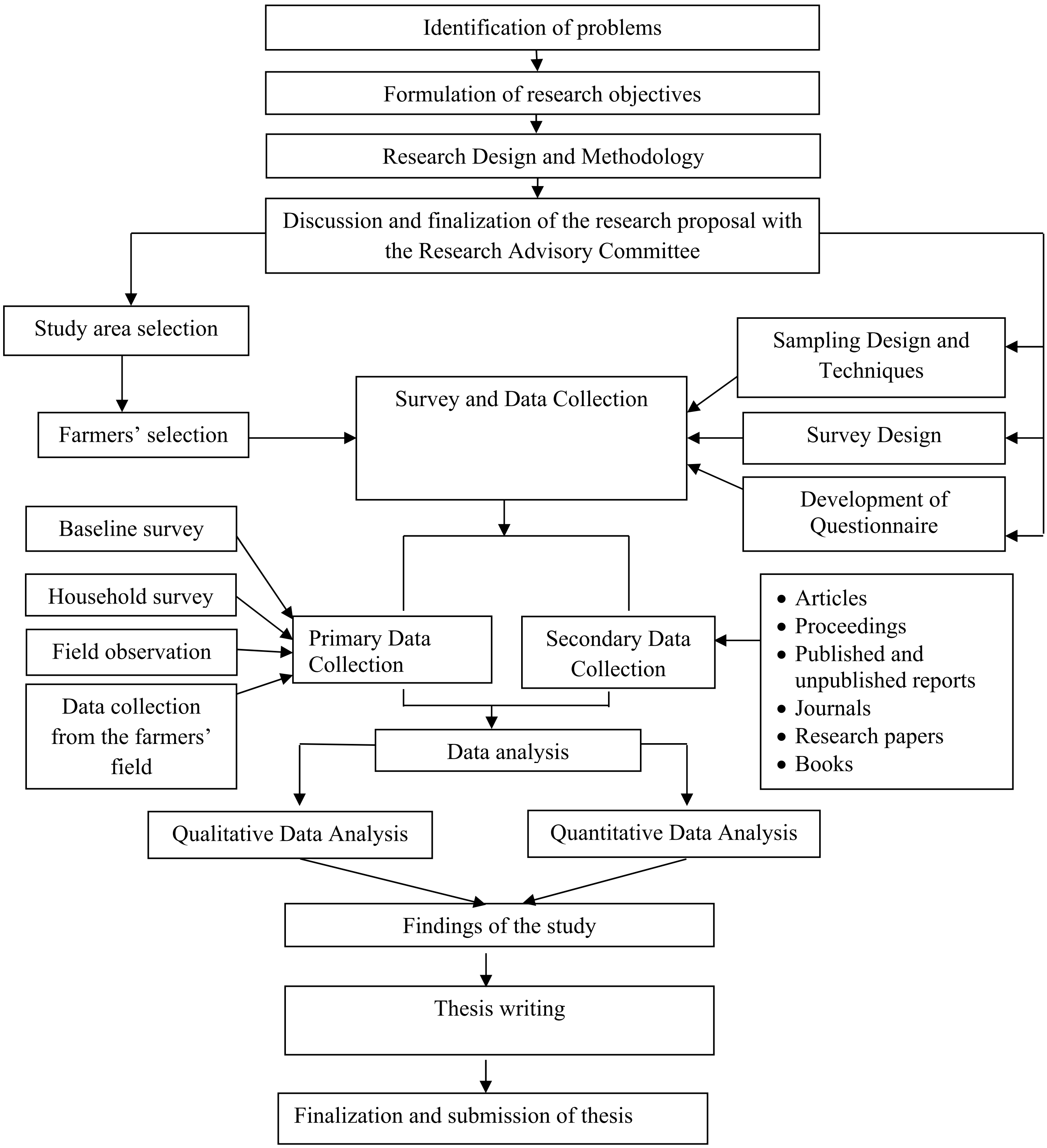
Water scarcity is a major concern for agricultural production in north-west region of Bangladesh where the amount of rainfall is limited. How will the agricultural sector, or farmers adapt with the changes in future water scarcity in face of global warming? One way is to change cropping patterns and make adjustment for available water resources. Another way might be to change farming practices by adjusting cultivation period, applying appropriate crop rotations and/or developing and adopting new varieties that are resilient to future climate variability. Drought is being considered as the main cause which hampers the estimated agricultural production, here in Bangladesh over the last few decades. As a consequence, severity of moisture stress, particularly in the north-western districts, will increase leading to drought conditions. An earlier estimate suggests that the area severely affected by drought in Rabi season could increase from 4000 km2 to 12000 km 2 under severe climate change scenario (Huq et al. 1996). As a result of climate change, every year Bangladesh experiences a dry period for seven months, from November to May, when rainfall is normally low. Apart from this, inadequate pre-monsoon showers, a delay in the onset of the rainy season or an early departure of the monsoon may create droughts in Bangladesh (Shafie et al. 2009). Adding together, ADB states that lower precipitation during the dry season under climate change has the potential to increase drought risk in Bangladesh (ADB, 2005). It is a recurrent phenomenon in some parts of the country, but the north-west region is mostly a drought-prone area because of high rainfall variability receiving much lower rainfall compared to the rest of the country thus this area is relatively dry. The average annual rainfall in this part is 1329 mm whereas in the north-east part the average annual rainfall is 4338 mm (Shahid and Behrawan, 2008). Nevertheless, drought can hit both drought-prone and non-drought prone areas of Bangladesh and it is being reported more in Rajshahi, Chapai Nawabganj, Naogaon, Rangpur, Bogura, Pabna, Dinajpur and Kustia Districts of Bangladesh because of the characteristics of moisture retention capacity and infiltration rate (Paul, 1995).

Northwestern regions of Bangladesh are particularly exposed to droughts. A strong drought can cause greater than 40% damage to broadcast Aus. During the kharif season, it causes significant destruction to the Aman crop in approximately 2.32 million ha every year. In the rabi season, about 1.2 million ha of agricultural land face droughts of different magnitudes. Apart from the agricultural loss, droughts have important effect on livestock population, land degradation, health and employment. Between 1960 and 1991, drought events occurred 19 times in Bangladesh. Very strong droughts hit the country in 1961, 1975, 1981, 1982, 1984, 1989, 1994, and 2000. Past droughts have naturally affected about 53% of the population and 47% of the country. Cropping systems in a region are determined by soil and climatic conditions. Nevertheless, potential productivity and monetary benefits act as guiding principles in the selection of a particular cropping system. These decisions with respect to choice of crops and cropping systems are further constrained by several other forces, related to infrastructure facilities, socioeconomic factors, technological developments and water resources (Iikhmove 1998). Changes in cropping patterns are likely to impact on the availability of water resources due to differences in crop water requirements (Fasakhodi et al. 2010). Different crops have different water use characteristics. Categories and quantities of crops planted in a region could influence the total amount of water use for crop production. Therefore, regional cropping pattern adjustment offers the potential to relieve pressure on local water resources and reduce conflict over the limited water resources (Huang et al. 2012). Analysis of the impact of changing the cropping pattern on water resource consumption can assist policy decisions at the micro-level and regional planning for improvement of regional water productivity.

Objectives

1) To identify impact of drought on cropping pattern under water stressed condition in North west region of Bangladesh
2) To find out the suitable crops and cropping pattern against drought for increasing farmers income and profitability of north -west region of Bangladesh.

Figure-1 : Research Design



Scope and Limitations of the Study

This study will cover only Sapahar sub-district under Nagoan district. This study will try to cover all the issues related to crop production under drought/ stress condition. After applying these technologies in the study area farmers will be benefited and it will be a great scope for the small holder farmers to increase their income as well improve their livelihood.

One of the major limitations of the work was the study covers only one out of 46 sub-districts in the drought prone areas and only one out of 5 districts in the drought prone zone, such that the results may not apply to all districts of the drought prone areas or other part of the countries.

Thesis Plan (Breakdown of Chapters)

The paper is structured as follows: following this background of the study & rational of the study (introduction), a literature review is provided first, on the theories adopted during study, and so on the causes and impacts of drought in Bangladesh with the research design of the study. Next, within the methodology section, first described the study areas and data collection technique as well as methods that have been reviewed for this purpose. Besides, however data were collected and analyzed is also stated. In the results section, all the parameters and variables are presented. The outline of chapters or organization of the dissertation is as follows:

Chapter 1 : Introduction

Chapter 2 : Causes and Impacts of Drought in Bangladesh

Chapter 3 : Methodology of the Study

Chapter 4 : Results and Discussion

Chapter 5 : Findings and Conclusion

References

Chapter 2: Causes and Impacts of Drought in Bangladesh

Impacts of Drought in Bangladesh

Every five years, Bangladesh is affected by the major country-wide droughts. However, local droughts occur regularly and affect crop production. The agricultural drought, linked to soil moisture scarcity, occurs at different stages of crop growth, development and reproduction. Monsoon failure often brings famine to the affected regions and as a result crop production reduces drastically.

Northwestern regions of Bangladesh are particularly exposed to droughts. A strong drought can cause greater than 40% damage to broadcast Aus. During the kharif season, it causes significant destruction to the Aman crop in approximately 2.32 million ha every year. In the rabi season, about 1.2 million ha of agricultural land face droughts of different magnitudes. Apart from the agricultural loss, droughts have important effect on livestock population, land degradation, health and employment. Between 1960 and 1991, drought events occurred 19 times in Bangladesh. Very strong droughts hit the country in 1961, 1975, 1981, 1982, 1984, 1989, 1994, and 2000. Past droughts have naturally affected about 53% of the population and 47% of the country (Habiba et al. 2011).

The associated crop production decline, lower employment opportunities and losses of assets contributed to raise household food insecurity. Consumption of food fell, along with household capability to meet food requirements on a sustainable way. Vegetables and several other pulses varieties are in short supply throughout the drought.

Droughts cause major problem in household health because its subsequent impact of decreasing food consumption leads to significant increases in illnesses. It also causes an increase in chronic energy deficiency among the agricultural workers.

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).

Suitable Cropping Pattern

Cropping system signifies the sequence of crops grown over a specific piece of cultivated land and to increase the benefits from the available physical resources. Therefore, the basic approach is an efficient cropping is to increase production and economic returns. A flexible cropping system helps in capturing economic opportunities and environmental realities and in ensuring balanced farm growth at regional level. Hence, selection of component crops needs to be suitably planned for efficient utilization of resource base and to increase overall productivity. Bangladesh is facing challenges to ensure food security due to decreasing agricultural land for high population pressure and increased food demand under drought condition. To overcome this situation, it is not possible to horizontal expansion but only we can increase vertical expansion. In north-western part of Bangladesh, the most dominant cropping pattern is T. aman (wet season rice) - boro (dry season rice). Other cropping patterns such as potato- boro rice- T. aman rice, vegetables- Fallow- T. aman rice and wheat- mungbean- T.aman rice are also practice by the farmer needs intensification for increasing system productivity and increase income of the Bangladeshi farmers. There is an ample scope of substantial improvement of the productivity of the double rice cropping sequence with the inclusion of short duration variety of the different crops including oilseeds, pulses, vegetables, rainfed rice and also high value crops such as water melon, sweet gourd, mango orchard, potato and most of the less water required crops. Hence, the diversification of cropping system is necessary to get higher yield and return, to maintain soil health, sustain environment and meet daily requirement of human. This information will also help to improving the productivity of existing rice based cropping system through crop intensification in Bangladesh as well as to minimize the drought impact.

Causes of Drought in Bangladesh

Causes of drought are related to non-availability of surface water resources and climate variability. The direct cause of a shortage of rainfall may be because of one or more factors including large-scale downward air movement within the atmosphere or absence of available moisture in the atmosphere which suppresses rainfall. Variations in such factors involve variations in global, regional and local climate and weather. While it may be potential to indicate the direct cause of a drought event in a particular location, but it frequently is not possible to recognize an underlying cause.

Short-term episodes of drought can be related to global oceanic and atmospheric circulation features. For instance, the ENSO (El Nino/southern oscillation) phenomenon, which results from warm surface water development of the Pacific coast of the South America, influences the levels of rainfall in various areas of the earth, such as monsoon rainfall in Bangladesh. The link between rainfall and sea surface temperature has been recommended as a potential cause of long, dry regimes.

Rising levels of CO_2 and other GHGs have been recommended as causes of variations of rainfall that are characterized as climate change. There are strong evidences that climate change will change the rainfall pattern and consequently more frequent droughts are happened. Among the local-level reasons are human-induced alterations resulting from vegetation loss because of deforestation and over exploitation of resources (Habiba et al. 2011).

Erratic Rainfall

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

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.

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.

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).

Review of Literature

Major constraints in crop production

Bray *et al.* (2000) stated environmental stress as the primary cause of crop losses worldwide, reducing average yields for most major crops by more than 50%. he also mentioned that the tropical vegetable production environment is a mixture of conditions that varies with season and region. Climatic changes would influence the severity of environmental stress imposed on vegetable crops. Moreover, increasing temperatures, reduced irrigation water availability, flooding, and salinity would become major limiting factors in sustaining and increasing vegetable productivity. Extreme climatic conditions would also negatively impact soil fertility and increase soil erosion. Thus, additional fertilizer application or improved nutrient use efficiency of crops will be needed to maintain productivity or harness the potential for enhanced crop growth due to increased atmospheric CO_2.

Bray (2002) mentioned that the response of plants to environmental stresses depends on the plant developmental stage and the length and severity of the stress. Measures to adapt to these climate change-induced stresses are critical for sustainable tropical or sub-tropical vegetable production.

Shin (2001) reported that there are different causes of the low productivity at saline and non-saline areas. Vegetables in much of Asia and the Pacific region are grown by small-scale farmers who are unorganized and scattered in different locations, and this also applied to Bangladesh. Concentration on production is important because low production can affect all the players in agribusiness sector.

Siskos *et al.* (2001) illustrated that external factors such as weather and susceptibility to diseases and pests have significant effects on the output and quality of agricultural produceat the production level .

Acquah and Masanzu (1997) described low production as also a result of limited access to inputs such as irrigation, seeds, fertilizers, and credit, as well as of poor cultural practices, poor soil, and low levels of management skills. In addition, a low level of production may ultimately hamper the agro-industry supply chain and finally farmers will be adversely affected.

Anik et al. (2012). stated that Bangladesh is highly dependent on irrigation for agriculture especially for summer and winter. This scenario is much more delicate in North- Western part of the country. In the North-Western part of the country experiencing droughts annually, are mainly results of adverse climate change impact such as decreasing rainfall, huge temperature increase and other so on. The situation is very critical both water for domestic use and for agriculture, which comes mostly from ground water via deep tube well and shallow tube wells. Climate change impact resulting drought and decreasing ground water level has become a main concern to present agricultural activities in drought prone areas, in northern part. In northern part, drought is the main concern for agricultural production as well food security. The reason of this production disparity is due to massive climate change impact on North-Western region. Availability of both surface water and ground water is therefore very critical for the habitation of these areas

Low Productivity in North-west Region of Bangladesh

It is obviously true that agricultural productivity has been increased through technological development and by substitution of fertilizer, concentrates and energy for labour and land. In other words, efficiency can be increased by proper use of farm inputs in the agricultural field. So, output growth is not only determined by technological innovations but also by the efficiency with which available technologies are used. In the developing countries (like Bangladesh) where most of the farmers are less educated or illiterate, they do not know what to produce, what technology and inputs to use, how much and when to look after their crops etc. Low productivity of crop production and low income of the farmers at drought prone region of Bangladesh due to lack of technical knowledge, drought, weed infestation and infestation of insect & diseases.

According to NDMC (2006), Drought takes place in Bangladesh more frequently than the past because of climate change and it appears in this country in every 5 years. Each year 0.45 million ha of land is affected by very severe drought during the rabi season while 0.40 and 0.34 million ha are affected during the pre-kharif and kharif seasons, respectively.

Tanner et al. (2007) mentioned that about 2.7 million ha of land in Bangladesh are vulnerable to annual drought.

Shahid and Behrawan (2008) stated that drought as a recurrent phenomenon in some parts of the country, but the north-west region is mostly drought-prone area because of high rainfall variability.

According to Brammer (1987), drought of different intensities occurs in Bangladesh that has a significant impact on agriculture and agricultural products. For instance, the consecutive drought of 1978 and 1979 directly affected 42 % of cultivated land and reduced rice production by an estimation of 2 million ton.

Likewise Rahman and Biswas (1995) mentioned the drought of 1994–1995 led to a decrease in rice and wheat production of 3.5 × 10 6 tons. On the other hand, drought in 1997 caused a reduction of around 1 million ton of food grain, of which about 0.6 million ton were transplanted Aman rice.

Rahman *et al.* (2008) studied the data from 2006 and indicated that drought caused 25 %–30 % crop reduction in the northwestern part of Bangladesh.

According to Banglapedia (2006), apart from rice crop, drought affects other crops, such as jute, wheat, corn, potatoes, sugarcane, different types of pulses and oilseeds, and vegetables and cause significant damage in production where irrigation is limited.

Drought

According to FAO (2007) report, the drought condition in North-Western Bangladesh in the recent decades had led to a shortfall of rice production of 3.5 million tons in the 1990s. A severe drought can cause more than 40 % damage to broadcast Aus rice. Each year, during the Kharif season, drought causes significant damage to the Transplant Aman rice crop in about 2.32 million ha. In the Rabi season, 1.2 million ha of cropland are facing droughts of various magnitudes. Apart from loss to agriculture, droughts have significant effect on land degradation, livestock population, employment and health.

Boyer and Westgate (2004) mentioned water shortage as one of the most important factors limiting crop yield worldwide. In the tropical and sub-tropical regions, unequal distribution of precipitation, high evaporation, and low rainwater use efficiency always constrain agricultural production and sustainable development

Turner (2004)stated that low rainwater use efficiency severely limits crop yields and as an extreme, total crop failure.

Gutezeit (2004) reported that soil water deficit during the seedling stage caused fruit yield decline of broccoli (*Brassica oleracea*). Turner (2011) mentioned those issues to have become more serious with the global climate change and its significant impacts on agriculture.

Xiao and Wang (2003) narrated these issues aiming to alleviate many management strategies had been tested to improve rainwater use efficiency in semiarid regions over the past decades, like rainwater harvesting (Mzirai and Tumbo, 2010), mulching including plastic, crop straw, gravel-sand cover (Wang et al., 2011a; Sarolia and Bhardwaj, 2012), drip or supplement irrigation (Wang et al., 2011b; Anita and Giovanni, 2012).

As stated by MOEF, (2009), agricultural production is influenced by seasonal characteristics and climatic variables in Bangladesh such as temperature, rainfall, humidity, day length. Furthermore, it is hindered by various types of climatic disasters like flood, cyclone and drought. Flood and cyclone are the most common disasters in Bangladesh. Drought particularly is the most complex and the least understood among all climatic disasters. It should not be viewed because of its insidious and creeping nature, but more because its effect is much more significant than flood and cyclone. Thus, the end results of drought usually first appear on agriculture and then impacts on food production, water resources and farmer's life and livelihood.

Irrigation

Gan *et al.* (2009) mentioned scarce and unpredictable precipitation and low water availability for irrigation purpose are the major factors limiting agricultural productivity. Turner and Meyer (2011) depicted this issue to become more serious as global climate change has significant impacts on agricultural systems.

Agricultural water use efficiency (WUE) is defined as crop yield per unit of water use. It is still very low at farmers' level.

Deng *et al.* (2006) stated poor irrigation management practices to be the primary causes for low WUE.

According to Lohmar *et al.* (2003) lack of investment in infrastructure development is the primary causes for low WUE. Innovative approaches of water-saving technology need to be adopted to increase crop productivity in Bangladesh. However, increasing crop productivity in Bangladesh still requires innovative approaches to water saving in agriculture. Morton (2007) mentioned that rising temperature, altered rainfall patterns and more frequent extreme events would increasingly affect crop production, often in those places that are already most vulnerable.

Weed infestation

Akobundu (1980) mentioned that weeds reduce crop productivity by interfering with crop growth. For example, uncontrolled weed reduce yield by about 40% in maize and 84% in upland rice, 31–70% in groundnut (Lagoke et al., 1981), and 73–78% in cayenne pepper (*Capsicum annuum* 'Cayenne') in Nigeria (Awodoyin and Ogunyemi, 2005).

Akobundu and Ekeleme (2001) reported that uncontrolled *Imperata cylinderica* (L.) Raeuschel resulted in 92% reduction in maize grain yield. Weeds reduce yields by competing for space, light, water and nutrients, weakening crop stand and reduce harvest efficiency (Abbasi et al., 2013).

Adigun (2000) reported that unrestricted weed growth throughout the crop life cycle resulted in 92 to 95% reduction in tomato fruit yield. The minimum weed-free period in cucurbit crops has been estimated as the first 4 to 6 weeks after planting (Noble, 2009). Stall (2009) reported that weed growth reduced cucurbit yield and interfere with harvest, promote disease, or propagate them as well as host of insect.

Qasem (2003) mentioned weed interference with crop plants severely reduce crop growth and lower yield and quality.

Dimson (2001) stated that many workers denied any alternative (e.g. adding more water and/or fertilizers) to weed control if crop yield losses are to be avoided or minimized. Weed competition early in the season may lead to irrecoverable growth and yield losses of cole crops and add appreciably to the cost of farm operations, while for optimum yield, crops must be kept weed-free for almost the entire growing season.

However, Dimson (2001) also pointed that , yield loss of crops planted for seed production may reach up to100% if broadleaf weeds are not controlled and was less severe for grassy weeds.

Farooq *et al.* (2011) mentioned weed control as one of the biggest challenges in agricultural ecosystems. In some cases, weeds produce allelopathic chemicals and release these chemicals into the soil. These allelochemicals are toxic to crops leading to a reduction in crop productivity. Weeds appear before, with or after the crop emergence.

Zoschke and Quadranti (2002) stated that weeds compete with crops for water, light, nutrient, and space, and uncontrolled weeds can stunt crop growth and reduce crop yield.

Orkwor (1990) revealed that weed competition is a major constraint to economic crop production including vegetables and he found 80% yield loss of okra [*Abelmoschusesculentus* (L.) Moench] in uncontrolled weed growth.

According to Labrada (1994) and Gupta (1998), weeds must be controlled within four weeks after planting to realize the potential yield in cabbage. Weeds can reduce maize grain yield by 35–70% when not properly controlled (Mohammadi, 2007).

Abouziena et al. (2007) stated some findings indicating that high soil fertility levels stimulate crop growth compared with weed growth, whereas Berger et al. (2007) mentioned that high nutrient levels encourage weed growth and increase crop yield loss.

Insects and diseases

Insect pests pose a serious threat for economic production of vegetables. A number of viral diseases can infect cucurbit crops, including cucumber mosaic virus, papaya ringspot virus, squash mosaic virus, watermelon mosaic virus, and zucchini yellow mosaic virus. These can cause significant yield losses and fruit quality defects.

Gilbert et al. (2009) mentioned that, interest in sustainable agricultural practices has grown with the aim of reducing production costs and potential environmental impacts of pesticidesin recent years .

According to IPM-CRSP (2004) cucurbits occupy 66% of the land under vegetable production in Bangladesh and contribute 11% of total vegetable production in the country including cucumber (*Cucumis sativus*), squash (*Cucurbita argyrosperma*), watermelon (*Citrullus lanatus*), pumpkin (*Cucurbita moschata*) and muskmelon (*Melothria scabra*).

stated that more plant diseases are caused by fungi and fungal-like organisms compared with any other group of plant pest and over 8,000 species are reported to cause disease. Jenkins (2005) defined nematodes (eel worms) as small, non-segmented worms and can cause a significant reduction in vegetable yield.
Lancaster (2006) narrated Bacterial diseases occur when bacteria enter inside the plant either through natural leaf openings or from damage caused by insects, other pathogens, or mechanical means.

The use of herbicides and pesticides can be detrimental to the complex relationships between plants, pests, and predators. Because pesticides, even organic varieties, make no distinction between helpful and hurtful insects, at the end their regular use can have many negative impacts, including the suppression of the soil food web and pollution of waterways. Instead, encouraging the presence of predatory warriors that will defend and protect crops from common pests is not only an environmentally sound management strategy, it also encourages biodiversity and plant pollination.

Synthetic pesticides cannot differentiate between beneficial and harmful insects and can have many negative impacts at the end of their regular use, including the suppression of the soil food web and pollution of water bodies. It is important to develop alternative and non-toxic methods of pest management to minimize the development of pesticide resistance and its adverse effect on human health and the environment.

Increasing Crop Productivity through Drought Management

Mulching

Mulch is a layer of material applied to the surface of an area of soil. Its purpose is any or all the following:

- ✓ to conserve moisture
- ✓ to improve the fertility and health of the soil
- ✓ to reduce weed growth
- ✓ to enhance the aesthetic value of the area

Kornecki et al. (2005) stated that the main purpose of mulching is to reduce evaporation and water erosion, while Wang et al. (2003) mentioned mulch as to maintain soil temperature, and Johnson and Fennimore (2005) described that mulch suppress weeds.

According to Muller (1991) film mulch is beneficial to soil and the micro-environment. Such type of mulching affects the plant microclimate directly in many ways: (i) it reduces the amount of water loss due to evaporation (Muller, 1991) , (ii) it redistributes moisture in the soil and thus alleviates water stress to some extent (Li et al., 2004), (iii) it keeps the topsoil warmer after sowing (Wang et al., 2003), (iv) it reduces the bulk density of soil (Anikwe et al., 2007), (v) it increases microbial biomass (Agüero et al., 2008), (vi) it decreases the leaching loss of fertilizers around the root zone (Haraguchi et al., 2004), (vii) it reduces the root zone salinity (Dong et al., 2008), and (viii) it increases nutrient availability.

Muhammad et al. (2009) mentioned indirect effects of mulching include lowering the population of pathogens, increasing arbuscular mycorrhizal fungi and spore density in the rhizosphere of spring wheat (Liu et al., 2011), and inhibiting most annual and perennial weeds (Cohen et al., 2008).

Li et al. (1999) illustrated that mulching also directly and indirectly affects the plant by increasing the rate of photosynthesis and thus the rate at which soluble sugars are transformed and reducing physical damage to roots and thus leading to greater root biomass (Li et al., 2004). As a result, mulching increases crop yields both quantitatively and qualitatively (Luis Ibarra-Jiménez et al., 2011), and enhances WUE (Zhou et al., 2009).

Management of Drought

Rahman (1995) described 60–70% reduced crop yield in Bangladesh in the drought affected districts. Drought of unpredictable intensity and duration results in low and unstable crop productivity in this region. Kouwenhoven et al. (2002) mentioned that proper field management practices such as mulching and rotation being suggested to improve crop growth and productivity through enhancing water and nutrient uptake.

Apart from irrigation facilities, electricity often creates a problem in this area. Sometimes there is no supply of electricity for a long time and farmers cannot get irrigation water from BMDA, which also affects their crop field during the drought season. However, the supply of fuel is sufficient for farmers to operate a shallow tube well for providing water for their crop fields. Besides, other related development schemes such as infrastructure development and construction of water reservoirs and dams have a positive impact on physical conditions in this area. Moreover, households are trying to adapt to drought risk by using different drought-tolerant crops and jujube and mango cultivations on their land.

Siddique et al. (2012) and Turner (2004) mentioned that inefficient use of scarce water, coupled with drought and heat stress during the cropping season, threatens agricultural sustainability in dryland environments.

Again, Turner (2011) stated that new technologies have been developed to drastically increase the precipitation use efficiency (PUE) in rain-fed farming systems reliant on precipitation to tackle the drought problem. These new technologies include mulching (Gosar et al., 2010), crop residue retention (Wang et al., 2011b), rainwater harvesting (Li et al., 2006), no-till farming systems (Gan et al., 2008), strategic supplemental irrigation (Guo et al., 2001), in-site microcatchments (Jia et al., 2006), and the use of terraces in agro-ecosystems (Liu et al., 2009).

Water Use Efficiency (WUE)

In case of deficit irrigation, there is a need to adopt appropriate technology to conserve the water in the soil profile and its best possible utilization for plant growth. Mulching (organic and inorganic) is an appropriate approach to enhance efficiency level of irrigation besides improving crop yield (Sarkar et al., 2007). Reduction in evaporation from crop field through polyethylene mulch enhances both productivity and WUE (Lie et al., 2004). By creating a barrier between soil surface and adjacent atmosphere, mulching minimizes the evaporation loss from soil surface and thus utilizes the conserved water for higher transpiration (Moitra et al., 1996) and improves yield and WUE of tomato (Agele et al., 2002). Organic (plant materials) and synthetic mulches (plastic of different colors like white, black, red, green, yellow and transparent) are widely used in vegetable production for their efficacy to conserve soil moisture by altering water distribution between soil evaporation and plant transpiration (Raeini and Barathakur, 1997). Thus, the conserved water can be used more effectively by the crops towards transpiration (Sarkar et al., 2007).

Under plastic mulch condition withholding of irrigation for 1–2 weeks after transplanting of tomato crop enhanced the fruit yield by 8–15% with 20% less expense of irrigation water (Ngouajio et al., 2007). Adoption of surface and sub-surface drip irrigation system along with plastic mulch, saved irrigation water by 15–51% and 7–29%, respectively, with 11–80% more tomato fruit yield compared with the conventional irrigation system (Zotarelli et al., 2009). Higher tomato fruit yield under mulches might be partly due to low weed population, causing a reduction in competition for nutrient and water (Shrivastava et al., 1994) and partly for a better water availability due to moisture conservation by mulching. The highest leaf area index and photosynthetically active radiation interception in tomato crop under black polyethylene mulch recorded the maximum fruit yield (Patel et al., 2000). Increase in soil temperature and efficient utilization of water and nutrients resulting from the use of the black polyethylene mulch might be an important reason for the highest yield (Lamont, 1996).

Power et al (2008) studied the effect of different mulches on soil moisture conservation and crop yield using sugarcane trash mulch, wheat straw mulch, black plastic mulch and transparent plastic mulch to combat draught. Result showed that per cent increased in soil moisture conservation over control was maximum in sugarcane trash mulch (13.56%) followed by black plastic mulch (12.34%), transparent plastic mulch (10.74%) and wheat straw mulch (7.04%). As a result of better moisture conservation and higher crop yield the transparent plastic mulch gave the higher water use efficiency (WUE) of 37.03 kg/ha-cm, which was 83.68 % more than that of control.

Weed Management

Cover crops and mulches are a suitable choice for sustainable agriculture because they improve weed control and crop performance. Liebman and Davis (2000) mentioned cover crops to be extremely suitable for use in sustainable cropping systems based on low external inputs, especially where an IPM is required (Nyiraneza and Snapp, 2007), such as in organic farming systems (den Hollander et al., 2007).

Ohno et al. (2000) described the use of cover crops and mulches for concerning weed control by reducing the germination and the development of the weed seeds through allelopathic (Kruidhof et al., 2008) and mechanical effects, and the competition between the cover crops and the weeds for limited resources such as light, water and nutrients (Kruidhof et al., 2008).

Zibilske and Makus (2009) mentioned that the choice of the most suitable mulch is dependent on the environment of the cultivation and the farmers' preferences.

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-

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)

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.

Diversification and Intensification of rice-based cropping system

Intensification means addition of crop components in an existing cropping system of the region. It is a way of intensifying cropping sequence to an economically viable level. Sequence in cropping is a unique age old practice in Bangladesh Agriculture.

Gunasena (2006) suggested multiple cropping to increase food production potential to over 30 t/ha with an increase of the increasing intensity by 400-500 per cent. Crop diversification can be approached for increasing income, employment and land use efficiency. It may be horizontal crop diversification - by broadening of base of the system, simply by adding more crops to the existing cropping system by utilizing multiple cropping techniques coupled with efficient management practices. Hence, Diversification and intensification of rice-based systems to increase productivity per unit resource is very pertinent. The importance of highly intensive crop sequence is also well recognized to meet the growing demand of ever-increasing population. An intensification of cropping sequence is essentially depending on the need of the area.

Increased crop productivity and food security

Selvaraju *et al.* (2006) suggested agronomic management practices to improve the productivity of crops under drought conditions and ensure food security. 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 sector. In fact, with successful adaptation, the production of major crops would not be threatened by climate change.

Rainwater harvesting and management

Selvaraju *et al.* (2006) pointed that excavation and re-excavation of traditional ponds and canals, water control structures and miniponds to be the The feasible adaptation options at community level are excavation and re-excavation of traditional ponds and canals, water control structures and miniponds. 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.

Zero tillage

Luo et al. (2010) stated that conserving soil and water resources are importan measures for adapting agricultural systems to climate change. Zero or minimum tillage is practiced conserving 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. All the above discussed drought adaptation and mitigation approaches would play a vital role in minimizing the threat of drought to ensure food security in Bangladesh.

Adaptation option by using different technologies, crops and cropping pattern

Cropping system signifies the sequence of crops grown over a specific piece of cultivated land and to increase the benefits from the available physical resources. Therefore, the basic approach is an efficient cropping is to increase production and economic returns. A flexible cropping system helps in capturing economic opportunities and environmental realities and in ensuring balanced farm growth at regional level. Hence, selection of component crops needs to be suitably planned for efficient utilization of resource base and to increase overall productivity. Bangladesh is facing challenges to ensure food security due to decreasing agricultural land for high population pressure and increased food demand.

Introduction of the high yielding drought tolerant crops, orchard and water efficient crops could produce sustainable yield in the north western regions. New weather conditions will be particularly characterized by a rise in temperature and less precipitation, whereas extreme events such as droughts and cyclones are also going to occur more frequently. When the rice fields are converted into mango orchard, total rice production decreases because of decreased rice field areas. Farmers couldn’t produce two rice crops during the year, as one vegetation cycle was remained fallow due to the severe drought. Thus increasing drought will have an impact on agricultural production.

Crop production is adversely influenced by erratic rainfall, temperature extremes, increased drought, floods, river erosion, and tropical storms. All of which are likely to increase because of climate change. Most fields remain fallow during winter and Kharif-I season after harvest of T.Aman due to moisture stress. Growing crops with less water (wheat), mulching (potato), orchard (mango) and pit based crop (water melon) are promising adaptation options.

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. Most fields remain fallow during winter and Kharif-I season after harvest of T.Aman at northwest region of Bangladesh due to moisture stress. Growing crops with less water (wheat), mulching (potato), orchard (mango) and pit based crop (water melon) are promising adaptation options.

Chapter-3: Materials and Method

The study topic was initially conceptualized, and then the objectives were chosen, followed by the study area. The research was carried out in Sapahar, Shironti, Goala, and Tilna Unions of Sapahar Upazila.

Study Area

Between 25°01 and 25°13 north latitudes, and 88°26 and 88°38 east latitudes, is the study area. The Sapahar Upazila, which covers 244.49 square kilometres (BBS, 2001), is bordered on the north and west by West Bengal, India, Porsha Upazila on the south, and Patnitala Upazila on the east. Punarbhaba is the main river, while Jaboi Beel is a prominent feature. The Barind and Teesta Floodplain Physiographies make up most of the study region. 74.6 percent of the Upazila is covered by the Barind area (CEGIS & FAO, 2006). It is mostly made up of valleys and large flat terraces. The floodplain is normally 1 to 2 meters higher than the Barind area, which has older deposits. Normally, a valley separates the trace areas, which aids in the natural drainage of water. During the monsoon season, high terrace and valley areas are flood-free, but lower places are inundated. Highland and Beel areas make up the majority of the Teesta floodplain (15.4 percent). The study area's general topography spans from 15 to 50 meters (CEGIS & FAO, 2006). In comparison to the rest of the floodplains, the Barind area is mostly high. The flood plain soil on the western side of the study area is a depressed area that is swamped by average year flooding caused by riverbank spills.

The study area's principal soils are Clay-Clayey loam and Loam Clay-Clayey loam-Loam soil (98%) predominates, with a tiny amount of Sandy loam (2%) soils (CEGIS & FAO, 2006). Clay to Loam characterizes the top and subsoil, whereas Clay soil dominates the substratum. The internal drainage feature of the soil is often inadequately drained, i.e., water seeps from the soils at a slower rate, and water does not normally stay on the surface for more than 15 days, although it is sopping wet during the rainy season. During the months of mid-September to October, surface water drains away, and land is prepared for Rabi crop.

The average yearly temperature is approximately 25°C, with minimum and maximum temperatures ranging from 16°C to 35°C. The months of April and May experience the highest temperatures, while January has the lowest. Temperatures of the concerned areas have been reported as high as 44°C and as low as 4°C (CEGIS & FAO, 2006). Temperature trends demonstrate that peak temperatures have been rising in the recent decades.

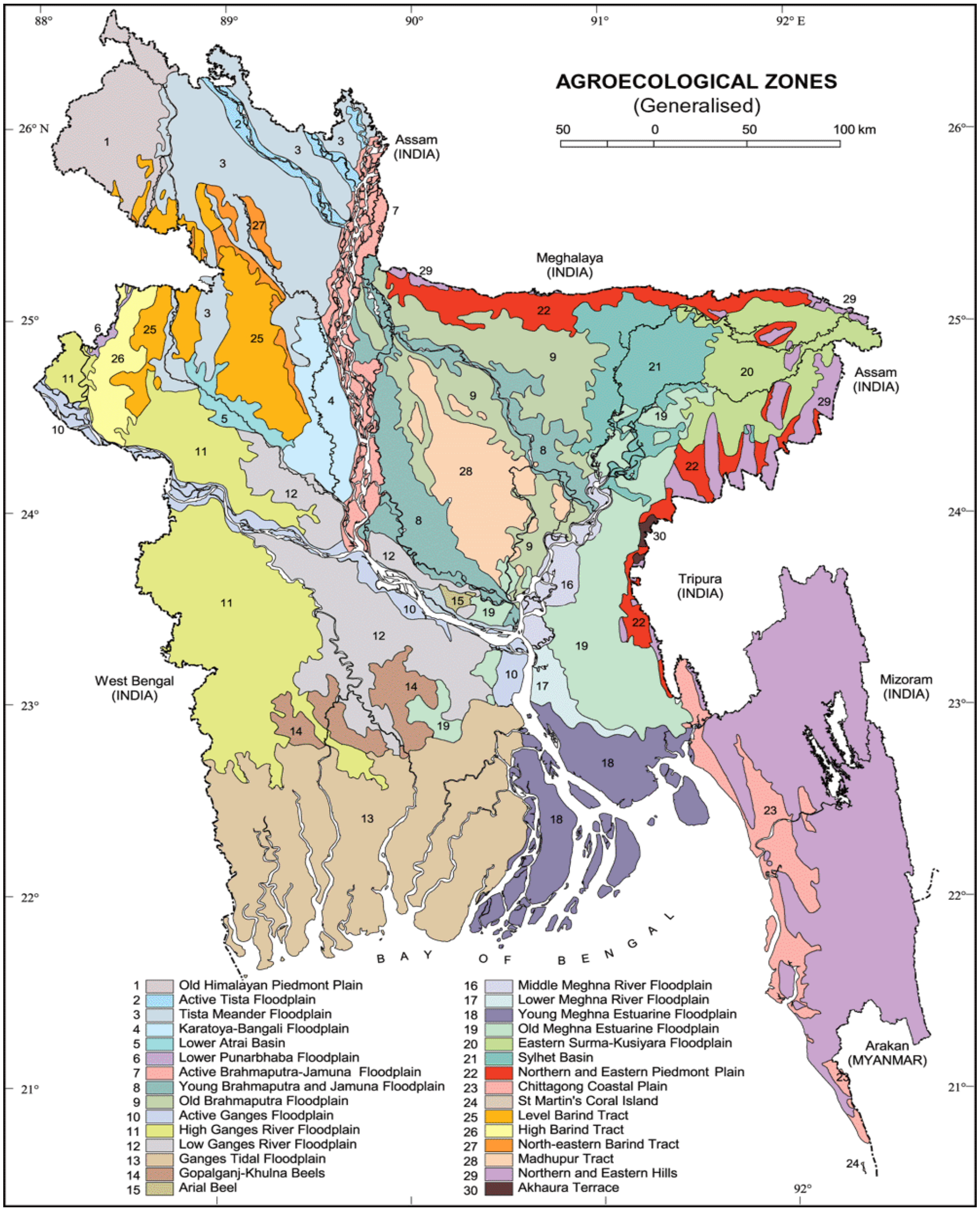


Fig.1. Agro ecological Zones of Bangladesh

Fig.2. Naogaon district map of Bangladesh

Fig.3. Sapahar Upazila under Naogaon district of Bangladesh

Crop seasons

The country grows a wide variety of crops. Crop cultivation depends on climate. Some crops are grown during all seasons, and some are grown in a particular season. Three types of crop seasons exist in the country (*Kharif-1*, *Kharif-2* and *Rabi*)

Kharif-1**:** End of spring (Mid-March) to first half of monsoon (Mid-July) is *kharif-1* season (Table 3.1). The major crops rice (Aus), vegetable (summer vegetable) and jute are usually planted at the end of spring and are harvested in first half of monsoon. In the first half of this season irrigation is needed.

Kharif-2**:** Crops are planted in monsoon (Mid-July) and are harvested in first half of winter (Mid-November). Rice (Transplant aman) and vegetable (summer vegetable) are the major crops in this season for which no need of irrigation water.

***Rabi*:** Rice (Boro), wheat, maize, potato, vegetable (winter vegetable) and pulse are major crops in this season usually are planted in winter (Mid-November) and are harvested in spring (Mid-March) which depends on irrigation.

Table 1. describes time duration of all major crops of the year according to crop seasons (*kharif-1*, *kharif-2* and *rabi*). Due to suitable temperature and occasional rainfall, large number crops are grown in *rabi* season. On the other hand, due to heavy rainfall in *kharif-2* and drought in *kharif-1* season limited numbers of crops are grown in these two seasons.

	Rabi			*Kharif-1*				*Kharif-2*				*Rabi*
	January	February	March	April	May	June	July	August	September	October	November	December
Rice1(Aus)				←	—	—	—	→				
Rice2 (Transplant aman)									←	—	→	
Rice3 (Boro)		—	—	—	→							←
Vegetable1 (Summer)					←	—	—	→				
Vegetable2 (Summer)								←	—	—	→	
Vegetable3 (Winter)	—	—	→									←
Jute				←	—	—	—	→				
Wheat	—	—	—	→								←
Maize	—	—	—	—	→							←
Potato	—	—	→									←
Pulse	—	—	—	—	→							←

Survey and Case study method were applied to conduct this study. The main purpose the study was to explore the agricultural impact or the rural community due to drought from the selected area. Primary data was used in conducting this study. To collect primary data 4 case studies were conducted with 100 questionnaire survey among the selected area.

Data collection Techniques and Tools

Data were collected for this research work was from 100 respondents in Sapahar in Naogoan district. For this research work semi structured questionnaire was used. Some of data were collected from agriculture extension office in Sapahar upazila.

Household Survey

Household survey was conducted to gather more information about the crops, cropping pattern and agricultural diversification.

Observation

Participatory, Non- Participatory observation was applied during research to study the location, and concerning crop pattern. Interview with key informants. Some knowledgeable person such as elderly persons, teachers were selected as key information's to carryout research.. Guideline were prepared for key informants interview.

Data collection methods

Both primary and secondary data were collected to complete the present study. To prepare the report data were collected by different methods. These methods can be divided in two categories.

Primary data collection methods: Primary mainly indicates the raw data which is obtained from variety of sources. Primary data were collected from field observation, reconnaissance survey, questionnaire survey and key informants interviews during the September-December, 2016. Secondary data were collected from different sources. Before questionnaire survey, Reconnaissance Survey of the study site was done to assess the prevailing conditions at the site and issues to include in the study. Then a well-defined semi-structured questionnaire was prepared according to the objectives of the research and systematic random sampling technique has been applied as sampling procedure. Based on the Kothari, 2006 formula, 100 household is drawn as sample size from the total 1000 household which is 10% of the total household at 95% confidence level. Meteorological data are collected through different organizations including BMD, BMDA, DAE of Naogaon etc. The collected data has been analyzed through some statistical software (SPSS, MS Excel etc.). Data of rainfall, temperature, relative humidity and ground water level were processed according to the seasonal variation to evaluate the climate variability accurately as much as possible.

Secondary data collection methods: The data which have been collected before by some agencies are called secondary data.

Data concerning population, socio-economics, areas, production, input and yield of demonstration fields will be collected from Statistical Year Book of Bangladesh (BBS), Bangladesh Agricultural Research Institute (BARI), Bangladesh Institute of Development Studies (BIDS), Bangladesh Agricultural University (BAU), Population Census, Regional Agricultural Office and Bangladesh Agricultural Research Council (BARC). In addition, periodicals, books, journals, reports, official records, and other published research reports are the sources to obtain generate farm data.

Trend of Temperature An overall increase in temperature is observed in the study area over the period of 1990-2011. However, the pattern of temperature trend is irregular.

Trend of Rainfall The study area is one of the most water scarce areas in Bangladesh as the total rainfall is very lower than the other parts of the country. Though the temperature trend in the study area showing a gradual increasing trend whereas the rainfall pattern decreasing gradually. In the last 10 years, the total rainfall of the study area is decreasing alarmingly and currently it's around 1000 mm-1100 mm in year which is very lower than the average rainfall (1600 mm) of the country (Banglapedia, 2006).

Existing cropping pattern data

Sapahar Upazila experience high temperature with limited soil moisture storage along with low rainfall. Moreover, no river/water bodies are present here. Vegetation is also scanty compared to other parts of the country. These situations make the area draught prone along with poor crop productivity. Monsoon T. aman rice is the major crop and backbone of the rural economy. High Barind Tract area is an acutely vegetable deficit area due to drought and other socioeconomic factors. In Shapahar upazila last 5 years rice, wheat, chickpea, potato and mustard production after transplant aman rice increasing. Now a day the farmer of this upazila goes to make a mango garden and is increasing tremendously. Major cropping patterns of this areas Boro−Fallow−T. Aman, Boro−Fallow−Fallow, Wheat−Fallow−T. Aman, Mustard−Boro−T. Aman, Boro−Aus−T. Aman and Fallow−Fallow−T. Aman (Rashid et al. 2017)

Processing, Analysis and Presentation of Data

After collection of the data, each interview schedule was verified for the sake of consistency and completeness. Editing was done before putting the data in the computer. Summarization, careful scrutiny and necessary summary tables have been made from the data. Tabular techniques have been used for analysis, interpretation and presentation of data to fulfill the objectives of the base line survey. A statistical method SPSS (Statistical Package for Social Science) was used to analyze the data in order to produce descriptive statistics (Ferdous et al. 2016).

Chapter 4: Results and Discussion

Socio-economic profile of the farmers

Socio-economic profile of the sample farmers is necessary to have an idea about the present situation of farm activities possible development opportunities and potentials for the adoption of new and improved technologies. Therefore, information regarding sample farmers age, education, household size, farm size etc was recorded for the study.

Table 2. Number, average age and educational level of different categories of farmers
Source: Researcher's own survey, 2016

Farmer category	Age (year)	Educational level (%)				
		Illiterate	PSC	J.S.C	S.S.C	HSC &Above
Marginal (0.021–0.2 ha)	43	0	10	30	60	0
Small (0.21–1 ha)	46	0	23	19	30	28
Medium (1–3 ha)	47	0	25	25	25	25
Large (above 3 ha)	44	0	0	0	0	100

Family and Farm Size of the farmers

Based on farm category, sample farmers were grouped into four categories viz. marginal, small medium and large. The farmer those who have less than 0.2 hectare of cultivable land are belongs to marginal, cultivable land is 0.2 to 0.6 hectare grouped as small farmer, the farmer who possesses 0.6 to 1.0 hectare of cultivable land are categorized as medium farmer, those who are cultivating more than 1.0 hectare of land are large farmer (Ferdous et al. 2016). Out of 99 farmers average farm size ranged from 0.18 to 0.71 hectare of land whose family size was recorded as 5.7 for marginal, the small farm size belonged to 5.8 number whereas large family size (6.7) was accounted in medium farm size owned farmer (Table 3).

Table 3. Average family size and farm size of the sample farmers

Farm Categories	**Family size (no.)**	**Number of Effective family member**	**Number of sample farmers**
Marginal (0.021–0.2 ha)	5.70	1	10
Small (0.21–1 ha)	5.80	1	64
Medium (1–3 ha)	6.70	1	20
Large (above 3 ha)	8.33	1	3

Source: Researcher's own survey, 2016

Crop cultivation under different group of farmers

It was observed that the areas under different crops of marginal, small, medium and large farmers were increased from 2006 to 2015 (table 4-7).

In contrast, the area of mango orchard increased by 10–20% compared with rice during the same period. Despite higher production of water melon, mango compared with rice, the area under mango increase and the growth rate was positive. On the other hand, the area under rice slightly increased (Table 4).

Farmers are using less land for paddy cultivation in Boro than in Aman season. They are now practicing mango orchard cultivation in the high land instead of paddy because mango orchard required less irrigation, profitable and less risky of drought. High temperature and increased drought reduce the yield of Boro rice. Yield reduction of vegetables, pulses and oil seeds is due to late planting owing to late harvest of T.Aman rice and seasonal drought.

Table 4. Area (ha) under different crops of marginal farmers in the year 2006 to 2015

↓ Year	Crop→	Paddy	Wheat	Mustard	Water melon	Mango orchard	Vegetable
2015	Area	0.11	0.06	0.04	0.01	0.05	0.02
	STDEV*	9.59	5.57	4.93	3.47	7.30	2.54
2014	Area	0.14	0.09	0.05	0.01	0.05	0.01
	STDEV*	35.46	21.82	15.34	2.27	7.30	2.84
2013	Area	0.14	0.07	0.06	0.01	0.05	0.02
	STDEV*	35.46	17.75	18.75	2.11	7.30	3.02
2012	Area	0.11	0.06	0.04	0.01	0.05	0.01
	STDEV*	9.15	10.18	5.71	3.96	7.12	3.15
2011	Area	0.11	0.06	0.05	0.01	0.05	0.01
	STDEV*	9.15	6.38	5.64	2.11	7.12	2.66
2010	Area	0.11	0.06	0.04	0.01	0.04	0.01
	STDEV*	8.82	6.28	4.48	2.51	6.83	2.66
2009	Area	0.11	0.06	0.04	0.01	0.05	0.01
	STDEV*	9.11	6.22	4.38	2.15	10.07	2.76
2008	Area	0.11	0.06	0.04	0.01	0.04	0.01
	STDEV*	9.07	5.62	5.21	2.51	6.17	2.67
2007	Area	0.11	0.06	0.05	0.01	0.03	0.01
	STDEV*	9.07	6.09	5.95	2.11	7.48	2.67
2006	Area	0.11	0.06	0.04	0.01	0.03	0.02
	STDEV*	9.07	6.06	5.57	2.07	7.89	2.53

* Standard deviation

Table 5. Area (ha) under different crops of Small farmers in the year 2006 to 2015

↓ Year	Crop→	Paddy	Wheat	Mustard	W.mealon	Mango Orch	Vegetable
2015	Area	0.43	0.25	0.13	0.05	0.11	0.01
	STDEV*	31.58	18.05	17.53	18.02	28.01	3.58
2014	Area	0.38	0.20	0.18	0.07	0.11	0.01
	STDEV*	54.98	29.80	28.26	12.02	28.01	3.28
2013	Area	0.41	0.20	0.20	0.00	0.11	0.01
	STDEV*	56.13	28.07	28.07	0.00	28.01	3.49
2012	Area	0.41	0.23	0.18	0.00	0.11	0.01
	STDEV*	57.69	32.59	25.10	0.00	28.01	3.34
2011	Area	0.41	0.23	0.16	0.07	0.11	0.01
	STDEV*	62.60	34.59	31.60	32.29	28.01	3.35
2010	Area	0.39	0.22	0.17	0.05	0.01	0.01
	STDEV*	59.90	33.65	26.25	29.49	6.50	3.37
2009	Area	0.37	0.21	0.16	0.07	0.01	0.01
	STDEV*	58.40	33.37	25.03	31.83	5.16	2.97
2008	Area	0.36	0.20	0.16	0.10	0.01	0.01
	STDEV*	59.66	32.96	26.70	44.27	7.32	2.98
2007	Area	0.32	0.19	0.14	0.07	0.02	0.01
	STDEV*	60.28	34.44	25.83	26.72	8.48	2.53
2006	Area	0.32	0.19	0.13	0.05	0.02	0.05
	STDEV*	60.88	36.46	24.43	22.41	7.41	5.04

* Standard deviation

Table 6. Area (ha) under different crops of Medium farmers in the year 2006 to 2015

↓ Year	Crop→	Paddy	Wheat	Mustard	W.mealon	Mango Orch	Vegetable
2015	Area	0.04	0.08	0.03	0.15	0.27	0.29
	STDEV*	20.14	41.04	17.53	63.01	14.26	35.81
2014	Area	1.18	0.05	0.77	0.44	0.22	0.11
	STDEV*	47.17	9.01	60.33	34.47	43.35	40.43
2013	Area	0.02	0.00	0.47	0.24	0.15	0.08
	STDEV*	3.57	3.98	64.68	35.39	31.91	36.05
2012	Area	0.02	0.02	0.52	0.26	0.28	0.06
	STDEV*	3.57	3.98	65.18	32.53	34.08	28.97
2011	Area	0.02	0.01	0.56	0.32	0.25	0.00
	STDEV*	4.00	2.92	67.13	37.93	29.20	0.00
2010	Area	0.01	0.01	0.60	0.33	0.27	0.02
	STDEV*	2.83	2.13	77.34	42.73	34.61	12.21
2009	Area	0.01	0.01	0.53	0.30	0.23	0.05
	STDEV*	2.40	2.92	63.00	35.39	27.61	25.13
2008	Area	0.00	0.01	0.48	0.27	0.21	0.08
	STDEV*	2.10	2.31	54.60	31.20	23.40	25.13
2007	Area	0.03	0.01	0.45	0.25	0.20	0.07
	STDEV*	20.24	2.54	52.00	28.73	23.27	29.57
2006	Area	0.02	0.01	0.39	0.22	0.17	0.09
	STDEV*	10.09	2.20	52.59	30.05	22.54	32.94

* Standard deviation

Table 7. Area (ha) under different crops of large farmers in the year 2006 to 2015

↓ Year	Crop→	Paddy	Wheat	Mustard	Water melon	Mango Orchard	Vegetable
2015	Area	1.66	0.79	0.62	0.60	0.89	0.18
	STDEV*	154.28	24.35	13.16	23.52	107.78	47.65
2014	Area	1.70	0.82	0.62	0.48	0.88	0.16
	STDEV*	144.91	17.55	13.16	15.14	107.78	51.38
2013	Area	1.70	0.58	0.62	0.64	0.85	0.16
	STDEV*	144.91	68.15	13.16	51.80	107.78	51.38
2012	Area	1.79	0.65	0.55	0.47	0.83	0.18
	STDEV*	181.82	41.00	36.30	18.03	107.78	25.00
2011	Area	1.70	0.82	0.62	0.30	0.83	0.16
	STDEV*	144.91	17.55	13.16	27.54	107.78	51.38
2010	Area	1.70	0.82	0.62	0.31	0.73	0.16
	STDEV*	144.91	17.55	13.16	22.55	107.78	51.38
2009	Area	1.70	0.82	0.62	0.25	0.83	0.16
	STDEV*	144.91	17.55	13.16	32.97	107.78	51.38
2008	Area	1.70	0.82	0.62	0.13	0.83	0.16
	STDEV*	144.91	17.55	13.16	57.74	107.78	51.38
2007	Area	1.56	0.78	0.50	0.24	0.38	0.16
	STDEV*	108.28	6.80	37.95	36.06	58.82	51.38
2006	Area	1.70	0.82	0.62	0.13	0.19	0.16
	STDEV*	144.91	17.55	13.16	57.74	41.63	51.38

* Standard deviation

During winter when the land becomes dry, they cultivate some vegetables like red amaranth, bottle gourd, etc. Farmers of this village depend entirely on chemical fertilizers and insecticides and it is difficult for them to get access to these agricultural inputs in the rural areas. The farmers also shared their observation that the productivity of land is decreasing day by day due to excessive use of chemical fertilizers. Therefore, they need training on bio fertilizer and Integrated Pest Management (IPM). They have requested for more outreach and training from the Department of Agricultural Extension (DAE) at the union level.

Crop production is adversely influenced by erratic rainfall, temperature extremes, increased drought, floods, river erosion, and tropical storms. All of which are likely to increase as a result of climate change. Moreover, households are trying to adapt to drought risk by using different drought-tolerant crops and jujube and mango cultivations on their land.

Table 8. Sowing and harvesting time of major crops of Naogaon District

Sowing/Planting time Range		Harvesting time Range
T.Aman	20 July to 30 August	October to November
Wheat	15 November to 15 December	April
Mustard	November	January to February
watermelon		
Mango	July	June (Planting after 4/5 years)
Vegetables*	Rabi, Kharif	Rabi, Kharif

Source: Researcher's own survey, 2016

When the rice fields are converted into mango orchard, total rice production decreases because of decreased rice field areas. Farmers couldn't produce two rice crops during the year, as one vegetation cycle was remained fallow due to the severe drought. Thus increasing drought will have an impact on agricultural production. The drought weather decreases the longevity of the houses. People are going to other places for work and earn money. Drought weather makes the life difficult. The cultivable lands lose its fertility day by day. Its fertility because of crop diminishing at quick rate people migrate different places in search of livelihood. Those who are remaining there are facing the problem of cultivation and other purposes.

Economics of major cultivated crops in Naogaon district under different farm families from 2006-2015

It was found that mango orchard performed better, with an average gross margin of marginal, small, medium and large farmers at Sapahar upazila under Naogaon district. Despite this higher production performance, the costs increase was < 5% for other crops. In addition, the benefit-cost ratios of all other crops were higher for better production than rice. It must also be noted that both less water required crops and mango orchard cultivation was profitable compared to rice cultivation. The highest gross return and gross margin were found from mango orchard in all the (marginal, small, medium and large) farmers group and the lowest gross return and gross margin were found from rice cultivation at Sapahar upazilla in Naogoan district (Table- 9,10,11,12)

Table 9. Cost and return of major cultivated crops of marginal farmers in Naogaon District

Crops	Total Variable cost (Tk. ha^{-1})	Gross Return (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})
T.aman rice	61638	127317	65680
Wheat	35927	91694	55767
Mustard	22155	50897	28742
Watermelon	90887	178097	87209
Vegetables	103852	232030	128178
Mango	56987	223476	166489

Source: Researcher's own survey, 2016

Table 10. Cost and return of major cultivated crops of small farmers inNaogaon District

Crops	Total Variable cost (Tk. ha^{-1})	Gross Return (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})
T.aman rice	62192	106625	44433

Wheat	40985	128573	87587
Watermelon	117688	251997	69189
Mustard	23790	49342	25165
Vegetables	67523	186166	84488
Mango	57550	205275	147725

Source: Researcher's own survey, 2016

Table 11. Cost and return of major cultivated crops of medium farmers in Naogaon District

Crops	Total Variable cost (Tk. ha^{-1})	Gross Return (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})
T.aman rice	62446	105312	42866
Wheat	46182	96644	50462
Watermelon	128573	272573	129600
Mustard	26613	49924	27844
Vegetables	75918	182844	83165
Mango	55663	255530	199867

Source: Researcher's own survey, 2016

Table 12. Cost and return of major cultivated crops of large farmers in Naogaon District

Crops	Total Variable cost (Tk. ha^{-1})	Gross Return (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})
T.aman rice	64494	101420	36925
Wheat	39919	95745	55826
Watermelon	112273	261970	49899

Mustard	22954	52394	29440
Vegetables	79838	204586	124747
Mango	59798	187121	127323

Source: Researcher's own survey, 2016

Determinants of Adaptation Measures

Implementation of different adaptive measures depends on several factors covering demographic, social, and economic characteristics, which are responsible for farmers' capacity building to cope with drought by undertaking an adaptive strategy. Table 13 shows the factors/determinants, which have been tested to estimate their correlation with the implementation of different adaptation measures. The significance of the relationship between the variables has been determined based on their corresponding p-values. The findings show that the age of the farmers has a significant correlation with a highest number of adaptation measures followed by high density of mango and received training on crop production technology. Many cases education facilitates the farmers to implement adaptation measures in easiest way as some adaptation strategies, i.e., crop diversification, alternative crop cultivation, intercropping, etc. requires enough space for implementation. It is understandable that farmers with formal education can easily access to updated information and can understand training, circulation, instructions, etc. provided by government and NGOs regarding disaster management. Moreover, farm size can take the challenge of implementing a new strategy as well as crop diversification. They require to purchase and/or rent water pump, seeds, fertilizer, etc. that completely depend on the availability of capital. Without capital, farmers cannot implement adaptive measures independently even though they have satisfied other influencing factors. Most of the adaptation measures are related to agricultural activities that makes farmers dependent on irrigation accessibility. Therefore, according to the findings, availability of irrigation facility strongly determines the farmers' capability of implementing adaptation measures. Another two important determinants are experience on crop production and food affords ability status of agricultural land as both have significant correlations with exactly five numbers of measures. Similarly, farmers with own agricultural land can implement adaptive strategies more independently than those of tenant farmers as their decision making ability is not absolute rather controlled by landlords.

Most fields remain fallow during winter and Kharif-I season after harvest of T.Aman due to moisture stress. Growing crops with less water (wheat), mulching (potato), orchard (mango) and pit based crop (water melon) are promising adaptation options. Moreover, households are trying to adapt to drought risk by using different drought-tolerant crops and jujube and mango cultivations on their land.

Table13: Chi-square test statistics between adaptation measures and determinants

Adaptation Measures	% of sample farmers	*P* values of Chi-square test						
		Age	Education	Farm ownership	Family size	Experience	Food Affordability	Irrigation Accessibility
Organic fertilizer	77	0.34	0.10	0.08	0.24	0.001*	0.01*	0.30
High density Mango	44	0.02*	0.10	0.24	0.07	0.02*	0.07	0.01*
Cultivation of traditional T.Aman	86	0.07	0.13	0.62	0.08	0.12	0.09	0.06
Water Withdrawal using shallow pump from Khari	26	0.91	0.001*	0.09	0.08	0.02*	0.03*	0.06
Water Withdrawal using Deep Pump	62	0.12	0.07	0.06	0.09	0.08	0.002*	0.05*
Crop Diversification	69	0.15	0.003*	0.11	0.05*	0.09	0.12	0.14
Short duration Aman cultivation	9	0.12	0.14	0.09	0.14	0.04*	0.12	0.11
High value crop cultivation (Like Mango, Vegetables, etc)	56	0.08	0.003*	0.12	0.11	0.15	0.18	0.001*
Received training on crop production technology	42	0.001*	0.07	0.09	0.15	0.16	0.05*	0.12
Irrigation by Pond Water	12	0.19	0.17	0.16	0.09	0.11	0.14	0.08

Note: *Statistically significant considering α = 0.05

Problems faced by the farmers in the study areas

The farmers with more years of schooling were found more technically efficient in crop production. This finding also confirmed the results of Bozoglu and Ceyhan (2007), Asadullah and Rahman (2009), Kulekci (2010), and Okoye et al. (2016). Asadullah and Rahman (2009) reported that education has a significant influence on improving technical efficiency in Bangladeshi crop farming. Education increases the ability to perceive, interpret, and respond to new events and enhances managerial skills of farmers which in turn help use agricultural inputs more efficiently (Bozoglu and Ceyhan, 2007). It is also encouraging to note that diverse sources of information and skills improvement through education and training have a positive influence on agricultural farming (Rahman and Hasan, 2008; Kulekci, 2010).

A higher extension access of farmers resulted in more efficiency in crop production. Similar results were reported by Parikh et al. (1995), Bozoglu and Ceyhan (2007),Kulekci (2010),and Mango et al. (2015). The farmers who maintained contact with extension workers would receive the right advice at the right time making them more efficient. Thus, provision of better extension services in the form of farmer training programs should be promoted to increase the crop production.

There is a need for optimal utilization of land resources, which could increase efficiency by reorganizing existing resources for crop production. The cultivated land has to be shifted from existing land utilization to optimum land utilization by the solution of the low water required crop production and resource constraints.

The optimal allocation under current resource conditions, prices, and yield will result in an increased area allocated to water melon, mango orchard in Sapahar upazila of Naogaon district.

Table 14. Problems faced by the farmers in the study areas

Problems	% farmers	Solution(s)
Lack of knowledge about drought tolerant crop variety/technology	90	Demonstration, Training, Field day
Lack of quality seeds	70	Education, Information/ Training
Lack of cash money for buying inputs	65	Easy credit system
Lack of irrigation facilities	85	Institutional improvement for developing irrigation facility
Lack of credit facility	55	Easy credit system
Lack of marketing facility	75	Need improvement of marketing channel, Value chain knowledge
Lack of training facility	80	Conduct training
High price of inputs	60	Increase subsidy in agricultural inputs
Infestation of insect/pests/weeds	70	Increase knowledge by training

Steps for development of adaptation option menus

An adaptation option menu provides viable options for managing climate risks. It synthesizes adaptation practices that could catalyze long-term adaptation processes. As shown in Figure 3, there are four major steps for developing the tool.

■ Identify improved adaptation options that are locally available and based on new research.
■ Analyse adaptation options based on their constraints and opportunities.
■ Validate and prioritize adaptation options against a set of key criteria.
■ Consolidate the most suitable options into an adaptation options menu.

Through efforts to determine the viability of adaptation options, it is actually possible to create a menu of adaptation options for the development planning process with the potential to be integrated into the existing institutional agenda. The adaptation option menu also provides input and acts as a catalyst for field-level demonstrations of viable adaptation options with potential to improve the capacity of rural livelihoods to adapt to climate change.

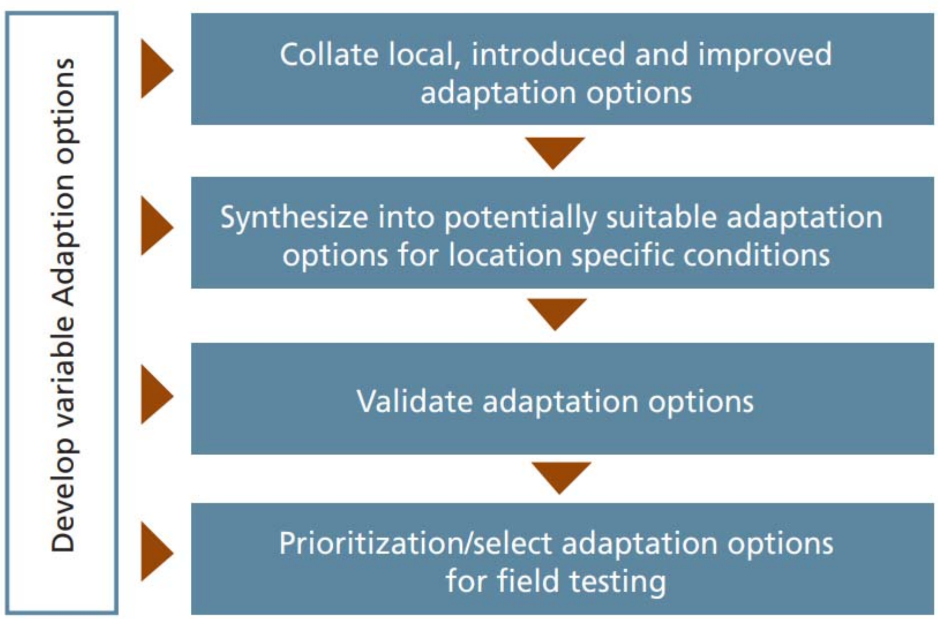


Figure-4 Selvaraju Ramamasy, 2007

Cropping Patterns practiced by the farmers

Cropping Pattern:

Sapahar Upazila experience high temperature with limited soil moisture storage along with low rainfall. Moreover, no river/water bodies are present here. Also vegetation is scanty compared to other parts of the country. These situations make the area draught prone along with poor crop productivity. Monsoon T. aman rice is the major crop and backbone of the rural economy. High Barind Tract area is an acutely vegetable deficit area due to drought and other socioeconomic factors. In Shapahar upazila last 5 years i) homestead vegetable production like tomato. brinjal, ladies finger increasing ii) chickpea, potato, mustard and wheat production after transplant aman rice increasing. The relationship between climate change, particularly that of drought is that it caused low production and less diversification of vegetables and field crops, which ultimately render low intake of food. Now a days the farmer of this upazila goes to make a mango garden and is increasing tremendously.

Table 15. Major cropping patterns practiced by the farmers at study area under Sapahar upazila, Nagoan

Major Cropping Pattern	Area (ha)
Boro−Fallow−T. Aman	3000
Boro−Fallow−Fallow	2500
Wheat−Fallow−T. Aman	7500
Mustard−Boro−T. Aman	1000
Boro−Aus−T. Aman	1000
Fallow−Fallow−T. Aman	2500

Source: Rashid et al. (2017)

Major Reasons for production Loss at Sapahar upazilla in Naogaon district

In the study area, farmers (81%) responded that due to the climatic variation the production has been hampered and as well as total production is decreasing day by day. They also identified the major reasons responsible for the adverse impact of the production. Among the different reasons for production loss, majority of farmers responded that erratic rainfall and temperature increase are very harmful for them followed by prolonged dry season. Along with these reasons they argued that short winter season and winter intensity increase is also responsible for the lower production. Moreover, farmers identified ground water table depletion; excessive fogging, lower rainfall in winter etc. are also responsible for hampering the crop production.

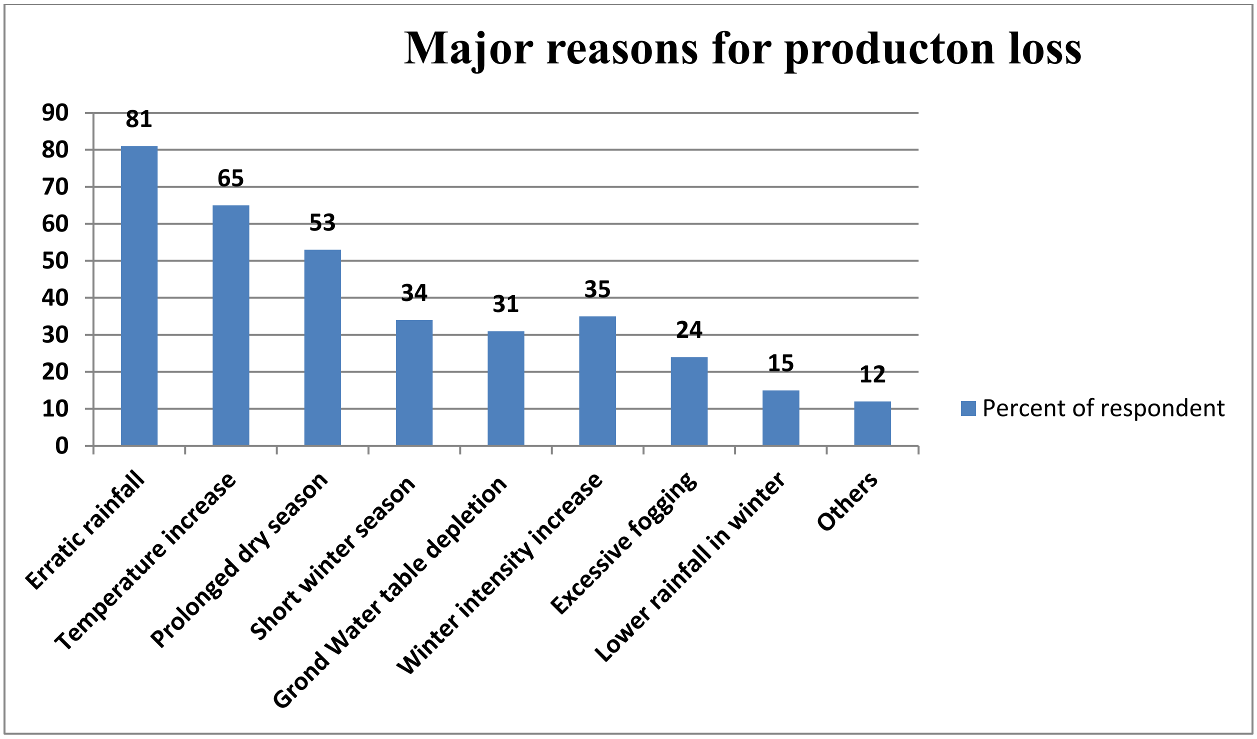


Figure 5: Farmers perception on the production loss (Source: Researcher's own survey, 2016)

Farmer's perception on the production trend Sapahar upazilla in Naogaon district

Agricultural yield mainly depends on various factors, among them climate and technological advancement are the most influential. Technological advancement including High Yield Varieties, Pesticides, fertilizer, advanced agricultural tools, irrigation facilities etc. increase the production. Climate also plays a very important role in the crop production. If the favorable climatic condition is not provided to the crops, then the production will be hampered. So, the climatic variation will adversely affect the yielding capacity of the agriculture. In the study area, farmers (87%) stated that the overall production of the crops is increasing. However, around 51% farmers responded that due to the technological advancement and more agriculture input, the production is increasing. On the other side, 36% farmers said that production is increasing but climatic variation creating considerable obstacles in this process and hampering the production in a large extent. Besides, 7% farmers said that the production was decreasing while 6% farmers argued that it's remained same.

Table 16. Farmers perception on the adaptive measures for crop production

Adaptive Measures	No. of Respondent (%)
Cropping pattern change	51
Improved irrigation facility	39
Short duration species selection	38
Setup shallow tube well in pond	27
Change of transplantation time	24
Little pond digging to conserve rain water	23
Interlinked with little khal	16

Source: Researcher's own survey, 2016

Table 17. Farmers` perception on seasonal changes of climatic parameters compared to 10 years ago

Parameter	Location	Kharif-1	Kharif-2	Rabi
Temperature	Sapahar Upazila	+	+	0
Rainfall	Sapahar Upazila	-	+	-
Flood	Sapahar Upazila	0	0	0
Drought	Sapahar Upazila	+	0	-
Fog	Sapahar Upazila	0	0	+

+ = Positive opinion, - = Negative opinion, 0 = no opinion

Source: Researcher's own survey, 2016

Existing adaptation measure

Bangladesh is already vulnerable to many climate change related extreme events. It is expected that climate change will bring changes in characteristics of extreme events and gradual changes phenomenon of the physical and natural systems. Due to higher level of dependency on natural resource base, overall impacts of climate change on Bangladesh would be significant.

In the study area, local farmers adopted some feasible options to cope with the climatic variability by using their indigenous knowledge considering their economic capacity. However, these options are very few in compare to the problem. Local farmers responded that they have changed their plantation time due to the seasonal variability. They are now transplanted *aman* and *boro* rice before June and January, respectively to ensure the rainfall. Moreover, farmers changed their cropping patter and more interested to selected water scarcity tolerant species especially wheat. Apart from this they are also converting their agricultural land into the mango garden as its not required supplementary irrigation. Local farmers are selecting different short duration and drought tolerant crop species to overcome the adverse climatic condition including short duration *boro* rice varieties-BRRI dhan36, short duration rice varieties during *kharif* season-BRRI dhan39, BRRI dhan33, drought tolerant rice varieties during kharif season-BRRI dhan42, BRRI dhan43 and low water requirement and short duration wheat varieties. For ensure the irrigation facilities, they are digging little pond, just besides their agricultural land and conserve the rainwater. For the irrigation, the farmers of this area also set shallow tube well in the pond to reach in the water level for supply. Through the help of some organization, local farmers interlinked the little *khals* to water supply. For ensure the sustainable irrigation facility, local people using different tools to assess how much irrigation is required. They were also using some local knowledge for water efficiency like set up some pot which supplies water in drop.

Farmer manages their irrigation system in the water stress by maintaining these policies;

1. Different season for various crop farmers used the improved water and irrigation supply systems to achieve maximum command area.
2. Farmer now trying to understand the value of water as an economic, social and environment good, including for nature.
3. Now farmer take training from various organizations for adoption of appropriate water and irrigation technologies that favor efficient water.

4. Farmers are aware in this upazila about water scarcity and high Barind areas.
5. Farmer reserve water in small water body like pond or khari because droughts are difficult to predict or unpredictable in these areas.
6. For control water loss they have changes in water allocation and delivery system.
7. Present farmer practicing new cultivation process which strengthening erosion control and soil and conservation.
8. Now farmer controlling groundwater withdrawals and favoring aquifers recharge.
9. They are trying to minimize water wastes; and managed the water quality.

Climatic extreme events and their impacts on drought-prone areas of Bangladesh

Summary of the work changes in extreme climate during the 21st century and its projected impacts on drought-prone areas of Bangladesh are given below-

Higher maximum temperature, more heat waves and hot days

- Increased incidence of illness among children, elderly, the poor
- Increased crop diseases and pest
- Increased threat of damage to both dry season and monsoon crops
- Increased energy demand and decreased energy supply reliability
- Increased heat stress and diseases in livestock

Increased summer drying and drought condition

- Decreased water resources (quality and quantity)
- Decreased crop yields
- Decreased groundwater resources because of over exploitation
- Declining surface water resources in ponds, tanks, rivers, etc.

Increased peak wind intensities and nor'westers throughout the summers

- Increased threat to human life
- Increased threat of wind-related damage
- Risk of different infectious disease epidemics

Higher minimum temperature, cold waves, and fewer cold days

- Decreased risk of destruction to many crops
- Decreased human mortality related with cold
- Increased activity of several diseases vectors and pest
- Increased risk to some crops such as chickpea and wheat

More intensive precipitation

- Increased soil erosion
- Increased local flood event
- Increased pressure on relief
- Increased loss of nutrients and topsoil

Increased monsoon precipitation variability

- Extended dry season and drought
- Frequent dry spells throughout the monsoon season

Increased frequency of events such as whirlwinds and hailstorms

- Increased risk of damage to irrigated summer crops (boro)
- Wind-related damage
- Damage to different fruit trees such as jack fruit and mango.

Adaptation to Drought in Bangladesh

Anthropogenic factors and climatic conditions mutually reinforce the chronic livelihoods vulnerability of drought-prone areas in Bangladesh. Droughts strike regularly, however it is the limited local capabilities and capacities and the lack of entrance to different forms of assets which make livelihoods of people vulnerable.

To reduce increasing vulnerability to affected people, successful local adaptation should be taken and it requires multiple pathways with interrelated, well planned short and long-term measures, including:

- adjustment of existing agricultural practices – such as introduction of drought-tolerant crop varieties, adjustment of cropping patterns, better storage of fodder and seeds, dry seedbeds, alternative crop cultivation, cash crops such as jujube (Ziziphus jujuba) and mango;

- ***Rainwater harvesting and management***

  physical adaptive measures – for example, excavation, re-excavation of miniponds, canals, storage facilities for preserving rainwater;()
- strengthening local initiatives – such as self-help programs, awareness raising and capacity building for local people;
- adjusting socio-economic actions – such as market facilitation, livelihood diversification, integration of indigenous knowledge, small-scale cottage industries;
- strengthening formal institutional capacities – such as local financial institutions and disaster management committees;
- formulating strategy to catalyze development of adaptive livelihood opportunities;
- supporting better research activities– such as invention of new drought-tolerant crop varieties or improved existing crops varieties, and other adaptive and conducive technologies.
- Zero tillage management crop cultivation
- Increase crop diversification
- creating advocacy and awareness on climate change.

For long-term sustainability of any type of intervention, the linkages between mainstream development and climate change adaptation need to be ensured, an enabling organizational environment must be established as well as coordination among local people, stack holders and related organization must be needed. The fundamental requirement of long-term livelihood adaptation is communication and field operations activities, coordination of agency planning, and the activities of government agencies and departments, GO agencies, NGOs and farmers.

Chapter-5: Findings and Conclusion

Introduction of the high yielding drought tolerant and water efficient crops could produce sustainable yield in the northwestern regions. The existing cropping pattern is Fallow-T. Aman (Local)-Fallow and Fallow-T. Aman (Local) - Boro (HYV). Non-rice Rabi crops hold a poor position in the agriculture of Shapahar. Climate change poses significant challenges to agricultural sector (crop production) and therefore to livelihoods and the country's overall economic development. Crop production is adversely influenced by erratic rainfall, temperature extremes, increased drought, floods, river erosion, and tropical storms. All of which are likely to increase because of climate change. Most fields remain fallow during winter and Kharif-I season after harvest of T.Aman due to moisture stress. Growing crops with less water (wheat), mulching (potato), orchard (mango) and pit-based crop (water melon) are promising adaptation options.

It was found that mango orchard performed better, with an average gross margin of marginal, small, medium and large farmers at Sapahar upazila under Naogaon district. Despite this higher production performance, the costs increase was < 5% for other crops. In addition, the benefit-cost ratios of all other crops were higher for better production than rice. It must also be noted that both less water required crops and mango orchard cultivation was profitable compared to rice cultivation. The highest gross return and gross margin were found from mango orchard in all the (marginal, small, medium and large) farmers group and the lowest gross return and gross margin were found from rice cultivation at Sapahar upazilla in Naogoan district.

Climate variability and change devastate the predominant income source of the locals. Currently, farmers of Sapahar (study area) can apply two main coping mechanisms to counter these developments: digging canals (khals) for freshwater reservation and cultivating drought-resistant crops. Drought resistant crops like wheat and other suitable water efficient crops could be tried to grow for feed as well as food. However, sectoral cooperation and coordination is required for the success. A balance is to be maintained among the quality & quantity of food produced, maintaining sustainability of the environment and natural resources. To address the impact of climate change and its adaptation, the following things should be considered as the major focus:
1. A specific agricultural development plan based on drought ecosystem and economy should be introduced to create awareness in the community as well as national and international level.

2. Enhanced capacity building for government and non-government authorities, as well as restructuring existing institutional frameworks to make them more capable of responding to the challenges imposed by climate change, are essential and would facilitate the effective implementation of activities. In addition, coordination and communication among the respective governmental agencies has to be improved.

3. Many farmers are currently using their traditional knowledge to cope with changes in climatic patterns. In order to achieve more efficient results regarding adaptation and benefit sharing, these local measures should be combined with advanced, scientifically tested techniques, however. Thus, the information about new technologies and farming practices needs to be disseminated on a wider scale, for instance through farmer training programmes.

4. Suggested innovative farming practices should be promoted for large scale adoption in vulnerable areas for increasing production, income generation and livelihood improvement of the people living in those areas. More innovative farming practices/technologies should be developed tested and adopted through on-farm trials and location-specific production programs involving farmers, researchers, and extension personnel.

6. Improvement in the crop-based weather and flood forecasting systems, early warning system, improving drainage, cultivating adaptive crops, developing technology for floating bed agriculture, rice and fish culture and organized fisheries, etc. are some of the options for water logged areas.

While it is evident that the farmers in the study area experienced adverse effects of drought on their agricultural production, the results regarding their existing coping strategies are not satisfactory. To cope with the adverse effects of droughts, the farmers have been adapting strategies like increase irrigation facilitates, and cultivating drought tolerant crops, less water required crops like jujebe and mango orchard. While these coping strategies are of specific importance to minimizing drought effects, the extent of their uptake and, consequently, their impact, is being limited by other socio-economic factors such as low income, the level of education, age, access to extension, and logistics.

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