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CASE STUDY

Climate variability and change: adaptation to drought in Bangladesh

A resource book and training guide

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Climate variability and change: adaptation to drought in Bangladesh

A resource book and training guide

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Contents

Acronyms

ADPC	Asian Disaster Preparedness Center
BARI	Bangladesh Agricultural Research Institute
BRRI	Bangladesh Rice Research Institute
CDMP	Comprehensive Disaster Management Programme
CDP	Coastal Development Partnership
CSO	civil society organization
DAE	Department of Agricultural Extension
DMC	Disaster Management Committee
DoF	Department of Fisheries
DoL	Department of Livestock
DRR	Directorate of Relief and Rehabilitation
ENSO	El Niño/southern oscillation
FAO	Food and Agriculture Organization of UN
GCM	general circulation model
GDP	gross domestic product
HYV	high-yielding variety
IPCC	Intergovernmental Panel on Climate Change
LU	learning unit
MoEF	Ministry of Environment and Forests
MoFDM	Ministry of Food and Disaster Management
NGO	non-governmental organization
NTIWG	National-level Technical Implementation Working Groups
OECD	Organization for Economic Co-Operation and Development
SRI	system of rice intensification
SWC	Storm Warning Centre
UNDP	United Nations Development Programme
UNFCC	United Nations Framework Convention on Climate Change
UTIWG	*Upazilla* Technical Implementation Working Groups

Bangla terms/crops

aus	a rice crop coinciding with late dry and early monsoon season
Barind	undulating uplands with red/yellow clay soils of Northwest Bangladesh
bhiga	equals one third of an acre
boro	dry season rice, grown from December to April
chini atap	*local fine rice variety*
jujubi	*zuzuphus mauritania* fruit tree commonly known as *ber*
khari	traditional irrigation canals
kharif I	season typically from March to June
kharif II	season typically from July to October
monga	seasonal famine condition
pre-kharif	a season before *kharif II* typically from March to June
rabi	dry season, typically from November to February
t.aman	transplanted *aman* rice typically from July to October
t.aus	transplated *aus* rice, typically grown from March – June/July
upazilla	subdistrict

Preface

In Bangladesh where agriculture is the largest sector of the economy, agricultural production is under pressure from increasing demands for food. A large percentage of the population is already vulnerable to a range of natural hazards with increasing climate variability and climate change expected to aggravate the situation further by causing more frequent and intense droughts and increasing temperatures. General Circulation Model (GCM) data project an average temperature increase in Bangladesh of 1.0°C by 2030 and 1.4°C by 2050.

Within this context, FAO and the Asian Disaster Preparedness Center (ADPC) are guiding an assessment of livelihood adaptation to climate variability and change in the drought-prone areas of Northwest Bangladesh. The project, implemented under the Comprehensive Disaster Management Programme (CDMP) and in close collaboration with the Department of Agricultural Extension (DAE), is specifically designed to characterize livelihood systems, profile vulnerable groups, assess past and current climate impacts, and increase understanding of local perceptions of climate impacts, coping capacities and existing adaptation strategies.

The initiative has guided development of a good practice menu of adaptation options that is being evaluated and field tested in partnership with local communities. As part of this initiative, a series of capacity-building and training activities on "climate change impacts and adaptation to drought" has been undertaken for national and local-level technical working group members, disaster managers and community representatives. The working group members are drawn from key research and extension organizations in Bangladesh including the DAE, Directorate of Relief and Rehabilitation (DRR), Department of Livestock (DoL), Department of Fisheries (DoF), Bangladesh Rice Research Institute (BRRI) and Bangladesh Agricultural Research Institute (BARI).

This resource book, *Climate variability and change: Adaptation to drought in Bangladesh*, has been prepared as a reference and training guide for building the capacity of agricultural extension workers and development professionals to deal with climate change impacts and adaptation, specifically targeting drought-prone areas of Bangladesh. It also presents suggestions for a three-day training course that would be readily adaptable for any areas of Bangladesh affected by climate-related risks. The information presented on climate change adaptation would enable participants to prepare, demonstrate and implement location-specific adaptation practices and, thus, to improve the adaptive capacity of rural livelihoods to climate change in agriculture and allied sectors.

Contents: Based on an initial needs assessment and feedback from the national and local-level technical working group members, the manual is presented as a series of modules containing background information as well as suggestions for application of the information. Technical definitions are drawn from the "*Climate Change 2001 Synthesis Report*" of the Intergovernmental Panel on Climate Change (IPCC).

In the background sections, Module 1 describes the basics of climate variability and change in Bangladesh; Module 2 identifies types of droughts, their underlying causes and their impacts in Bangladesh; and Module 3 builds on this to describe the impact of climate variability and change in drought-prone areas of Bangladesh. In the application sections, Module 4 introduces participatory tools and methods for undertaking community-level climate risk assessment in the agriculture sector.[1] Module 5 offers guidance for developing agricultural adaptation options to manage climate variability and change in drought-prone areas. Module 6 identifies the existing weather and climate forecast products available in Bangladesh and explains their utility for improving the adaptive capacity of rural livelihoods to reduce the impact of climate variability and change.

Who benefits from this training guide: This guide can serve as background resource material for training programmes on climate change impact and adaptation in the agriculture sector. Though designed and tested by project-based technical working group members representing extension, research and development organizations, it also can be used by other training facilitators or self-learners. However, it is strongly recommended that training participants and self-learners already have some basic knowledge of climate science and agriculture in Bangladesh.

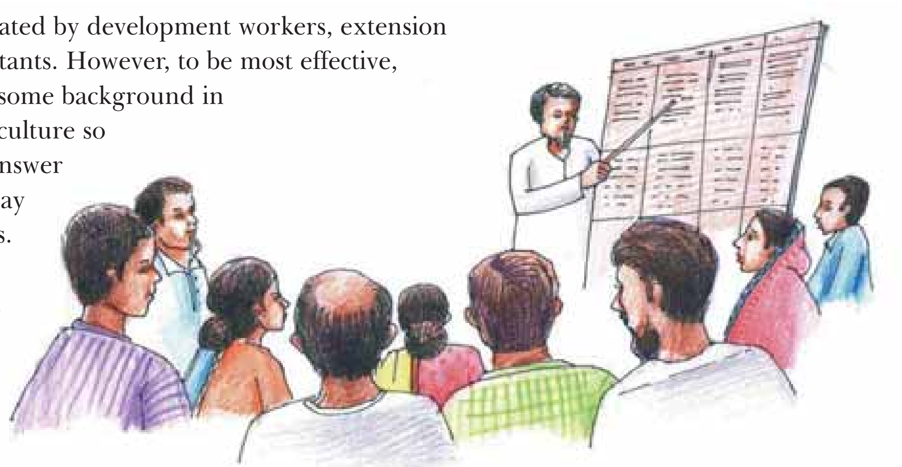
How to use this book: The training programme suggested here is designed to be flexible so base information can be tailored to participants' needs. This flexible training strategy is highly recommended over a step-by-step prescribed approach. The overall format of each module consists of sections on:

- setting goals and learning objectives,
- defining and highlighting key words and terminology,
- presenting principles and background information on individual topics, and

Each module also contains suggested training activities with LUs and exercises based on that module's content. The exercises expose the participants to new concepts and skills, current risk management practices and future adaptation practices. The training activities include suggestions for supplementary handouts as well as guidance for preparing:

- interactive lectures
- review sessions
- individual exercises
- group exercises and presentations

The training can be facilitated by development workers, extension officers or national consultants. However, to be most effective, they should already have some background in both climatology and agriculture so they will be prepared to answer technical questions that may arise from the participants. Training facilitators and participants are requested to follow the training strategy to ensure that they capture the key aspects of the module.



[1] For additional guidelines on risk assessment in a cross-sectoral and multi-hazard perspective see: *A facilitator's guidebook for conducting community risk assessment* by Directorate of Relief and Rehabilitation (DRR), Ministry of Food and Disaster Management (MoFDM), Bangladesh.

MODULE 1

Understanding climate variability and climate change

The purpose of this module is to familiarize participants with climate variability and climate change in Bangladesh. At the end of this module, participants should be able to:

1. define and distinguish between climate variability and climate change,
2. understand the enhanced greenhouse effect and its consequences on climate,
3. understand climate change scenarios for Bangladesh, and
4. analyse climate change uncertainties in drought-prone areas.

Atmosphere is the blanket of air that surrounds the earth, moving both horizontally and vertically and thus causing variations in weather and climate. It absorbs energy from the sun, recycles water and other chemicals, and works with electrical and magnetic forces to provide a moderate climate. The atmosphere also protects the earth from high-energy radiation.

Weather is the current atmospheric condition in a given place. This includes variables such as temperature, rainfall, wind or humidity. Anyone looking outside can see if it is raining, windy, sunny or cloudy and can find out how hot it is by checking a thermometer or just feeling it. Weather is what is happening now, or is likely to happen tomorrow or in the very near future.

Climate is "average" weather for a given place or a region. It defines typical weather conditions for a given area based on long-term averages. For example, on average, Bangladesh is expected to be sunny in May, rainy in July and cold in January but there may be annual deviations.

The Bangladesh Meteorological Department (BMD) averages data such as maximum and minimum temperatures and precipitation rates over the course of 30 years (or longer) to determine an area's average weather. However, some scientists think that it takes more than "average" weather to represent an area's climatic characteristics accurately. Thus, climate becomes the sum of all statistical weather information that helps describe a place or region.

Although an area's climate is always changing, the changes do not usually occur on a time scale that is immediately obvious to us. We can observe how weather changes from day to day but subtle climate changes are not as readily detectable. Weather and climate take similar elements into account, the most important of which are: air temperature and humidity, type and amount of cloudiness and precipitation, air pressure, and wind speed and direction.

Box 1.1: Weather and Climate
Climate is what you expect and weather is what you get

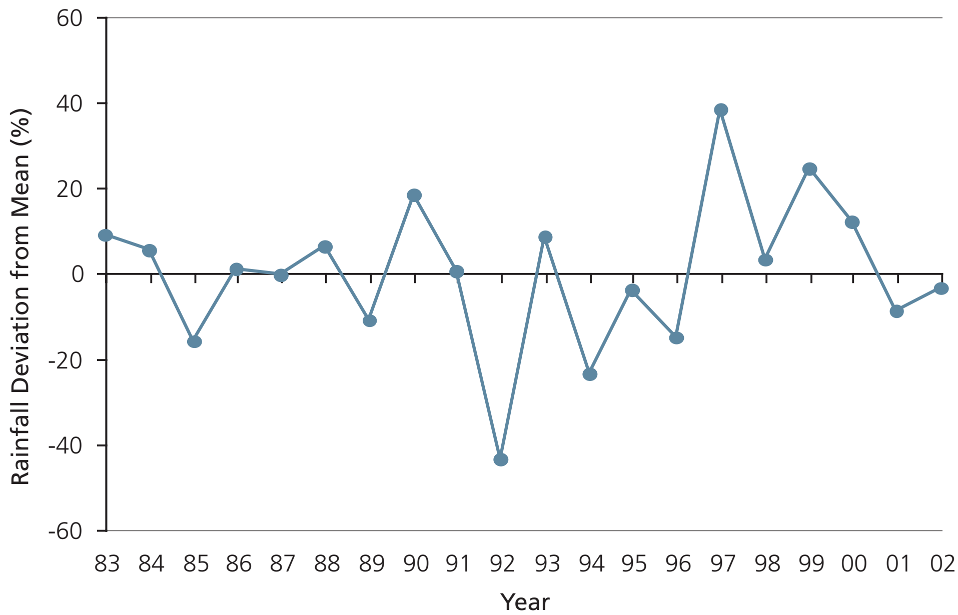
Weather is the day-to-day state of the atmosphere and its short-term (from hours to a few weeks) variations such as temperature, humidity, precipitation, cloudiness, visibility or wind.

Climate is statistical information, a synthesis of weather variation focusing on a specific area for a specified interval. Climate is usually based on the weather in one locality averaged for at least 30 years.

A change in one weather element can produce changes in regional climate. For example, if the average regional temperature increases significantly, it can affect the amount of cloudiness as well as the type and amount of precipitation that occur. If these changes occur over long periods, the average climate values for these elements will also be affected.

Climate variability refers to the climatic parameter of a region varying from its long-term mean. Every year in a specific time period, the climate of a location is different. Some years have below average rainfall, some have average or above average rainfall. For example, the average annual rainfall of Rajshahi in northwestern Bangladesh is 1 494 mm. We are not assured of getting this amount every year. The actual rainfall varying from the mean represents drought and flood conditions. Fig. 1.1 displays the year-to-year variability of Rajshahi rainfall for the period from 1983 to 2002 in terms of the percent departure from the mean.

Fig.1.1. Annual rainfall deviation (%) from the mean (1 494 mm) for Rajshahi, Bangladesh



These changes result from atmospheric and oceanic circulation, caused mostly by differential heating of the sun on earth. The atmosphere and ocean circulate in three dimensions and each acts on the other. The atmosphere moves faster than the ocean, but the ocean stores a large amount of heat and releases it slowly over long periods. Thus, the ocean acts as a memory in this circulation. These atmosphere-ocean circulations cause climate to vary in season-to-season or year-to-year time periods.

Climate change is attributed to both natural variability and human activities. Variation in climate parameters is

Box 1.2: Climate variability and climate change

Climate variability refers to variations in the mean state and other climate statistics (standard deviations, the occurrence of extremes, etc.) on all temporal and spatial scales beyond those of individual weather events. Variability may result from natural internal processes within the climate system (internal variability) or from variations in natural or anthropogenic external forces (external variability).

Climate change refers to any change in climate over time, whether due to natural variability or anthropogenic forces.

generally attributed to natural causes. However, because of changes in the earth's climate since the pre-industrial era, some of these changes are now considered attributable to human activities.

Enhanced greenhouse effect is considered the result of human activities that have increased atmospheric concentrations of greenhouse gases and aerosols since the pre-industrial era. The atmospheric concentrations of key greenhouse gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and ozone (O_3). They reached their highest recorded levels in the 1990s, primarily due to the combustion of fossil fuels, agriculture, and land-use changes.

The increase in surface temperature in the northern hemisphere during the twentieth century is considered greater than for any century in the last 1000 years. Statistics show the global mean surface temperature increased by 0.6±0.2°C (Fig.1.2), the number of hot days in a year increased in many places and the number of cold days decreased in nearly all land areas (IPCC, 2001).

Box 1.3: Enhanced greenhouse effect

Greenhouse gases are a natural part of the atmosphere that, through a natural process called the **greenhouse effect**, trap the sun's warmth and maintain the earth's surface temperature at the level necessary to support life (approximately 15°C). The earth's climate has been alternating between hot and cold periods for at least the past million years. Records from polar ice cores show oscillating periods of glacial (ice ages) and interglacial (warm) periods. The earth is currently in an interglacial period. However, the observed warming since the 1970s cannot be explained by natural causes alone. During the past 200 years, human activities such as fossil fuel-burning and land clearing have caused an increase in greenhouse gases in the atmosphere – called the **enhanced greenhouse effect** – trapping more heat and raising the earth's surface temperature.

Fig.1.2. Variations of the Earths surface temperature for the past 140 years (1860 – 2000) (IPCC, 2001)

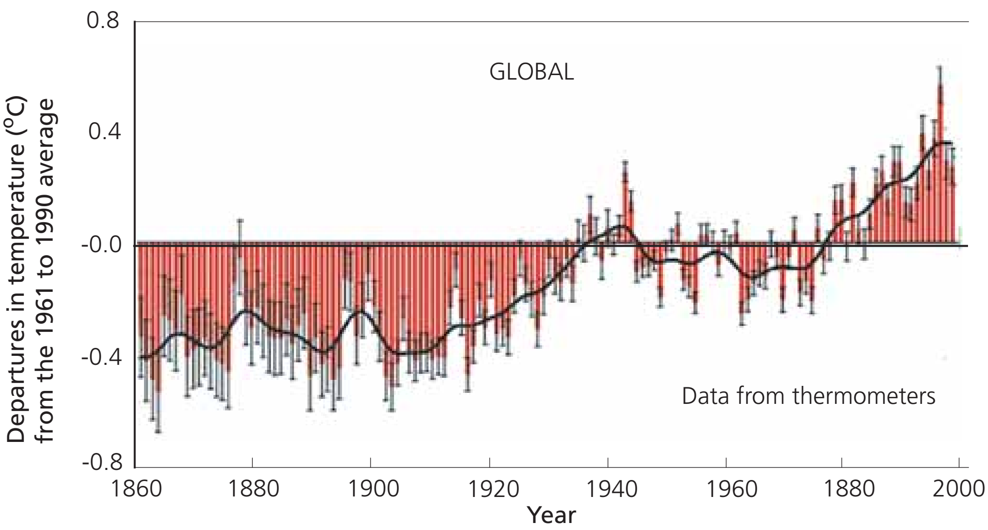
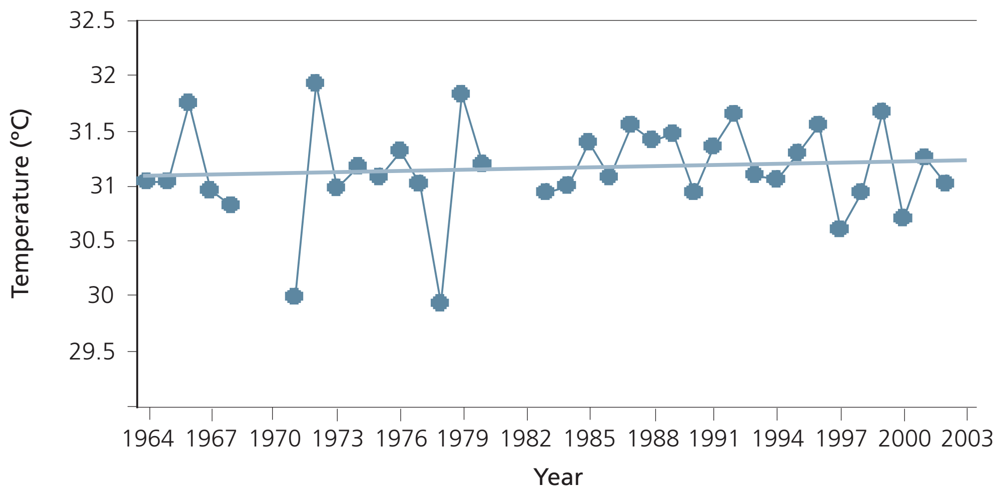


Fig. 1.3 displays the year-to-year variation of average temperature for the period from 1964 to 2003 in Northwest Bangladesh. It shows a slight increase in temperature. The year-to-year change in temperature was substantially larger than the long-term average, with fluctuations up to plus or minus 1°C.

Fig.1.3. Annual average maximum temperature variations (1964-2003) in Northwest (Barind tract) Bangladesh

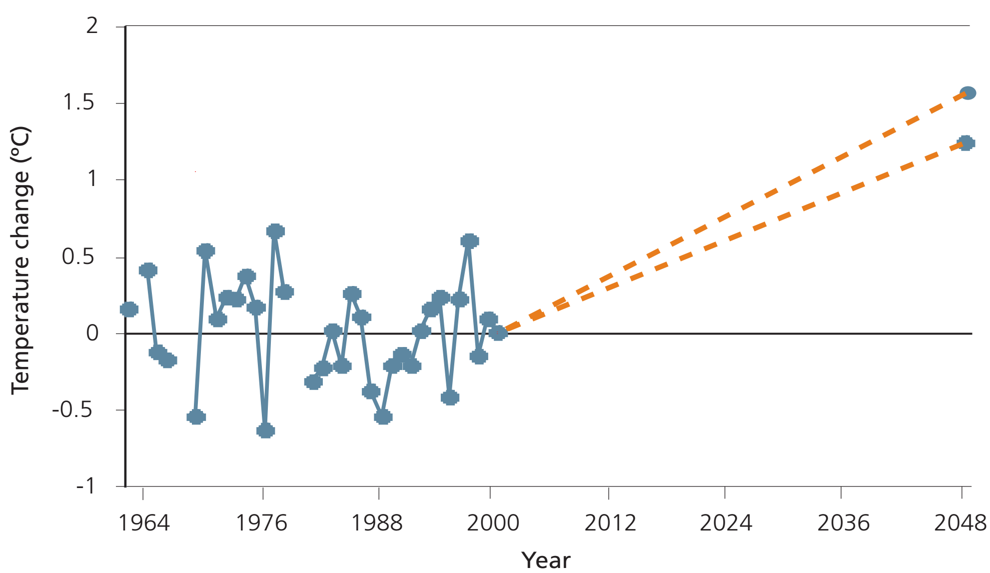


Carbon dioxide concentrations, globally averaged surface temperature and sea level are projected to rise in the future. Climate model projections show that the average surface temperature would increase with a range of 1.4 to 5.8°C between 1990 and 2100. This is about two to ten times larger than the observed warming during the twentieth century. Similarly, the average global precipitation is projected to increase during the twenty-first century but at regional levels, there will be both increases and decreases ranging from 5 percent to 20 percent.

The climate of Bangladesh should also change throughout this century because the atmosphere already has elevated levels of greenhouse gases. Bangladesh's drought-prone areas are warmer and drier than 50 years ago and current projections suggest that Bangladesh will become hotter, its nights will be warmer and it will face frequent droughts due to increased rainfall variations.

Fig.1.4. Annual average maximum temperature variations (1964-2003) and temperature projected to 2050 for *Barind* tract of Bangladesh

(the linear line is just to show the future anticipated temperature)



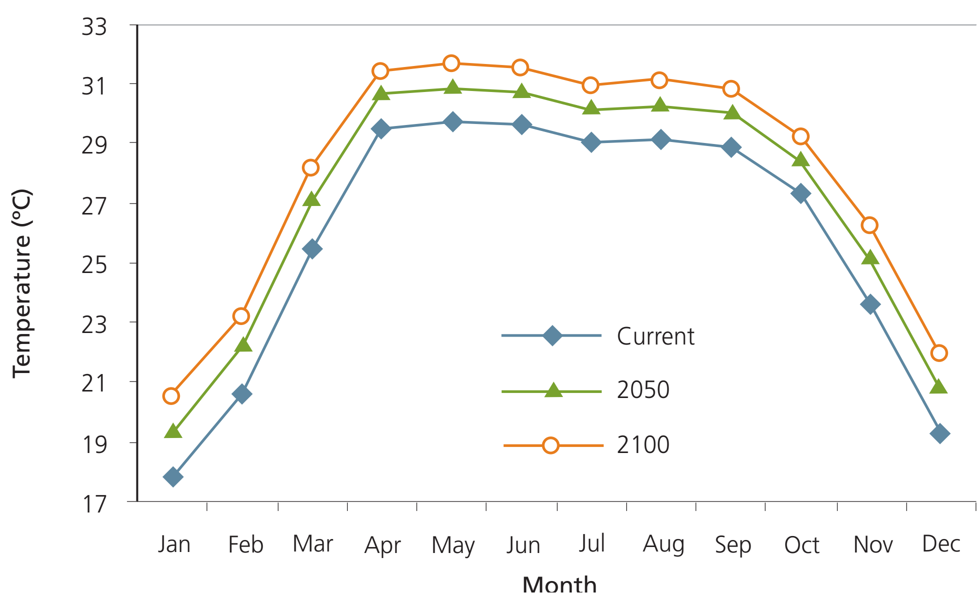
GCM analysis indicates that the average temperature of Bangladesh will increase by 1.4°C (±0.16) by 2050. Fig. 1.4 shows the average temperature variations from 1964 to 2003 and projects the temperature for Bangladesh until 2050. The two doted lines, representing the lower and upper bounds of the 2050 projection, indicate a possible temperature change if global warming gas emissions are continued. The GCM data projects more warming for winter than for summer months (Fig.1.5). Based on the above projections, Bangladesh is likely to face more hot days and heat waves, longer dry spells and higher drought risk.

Almost 80 percent of rainfall in Bangladesh comes during monsoon season (June-September). The remaining 20 percent covers eight months, including the winter months in which the high-yielding rice boro is grown. Future climate change projections show increased rainfall during monsoon season and declining rainfall in winter months (Table 1.1). Though monsoon season rainfall is projected to increase, the rainfall *variability* may increase significantly causing more intense rainfall and/or longer dry spells. Most of the climate models estimate that precipitation will increase during the summer monsoon.

Table 1.1. Estimates of temperature and precipitation changes for Bangladesh

Year	Temperature change (°C) mean (standard deviation)			Precipitation change (%) mean (standard deviation)		
	Annual	DJF	JJA	Annual	DJF	JJA
Baseline average				2278 mm	33.7 mm	1343.7 mm
2030	1.0 (0.11)	1.0 (0.18)	0.8 (0.16)	+3.8 (2.30)	-1.2 (12.56)	+4.7 (3.17)
2050	1.4 (0.16)	1.6 (0.26)	1.1 (0.23)	+5.6 (3.33)	-1.7 (18.15)	+6.8 (4.58)
2100	2.4 (0.28)	2.7 (0.46)	1.9 (0.40)	+9.7 (5.80)	-3.0 (31.60)	+11.8 (7.97)

Fig.1.5. Monthly mean temperature for current period (1964 – 2003) and projected for 2050 and 2100 in drought-prone areas of Bangladesh



Based on the above scenarios, the magnitude of these climate changes may appear very small. But, if added to existing climate extremes such as droughts, these changes could increase the severity substantially. Thus, it is quite possible that there could be a significant increase in the intensity and frequency of droughts in Bangladesh.

Box 1.4: Extreme weather

Small changes in average conditions can have big influence on extremes such as droughts. For example, the northwestern region of Bangladesh would have additional hot days in any given year. These changes are already noticeable, and the trend is expected to continue.

Climate change projections are developed from a range of computer-based models and scenarios of future greenhouse gas emissions. Both present uncertainties because it is hard to predict global greenhouse gas emission rates that far into the future. Box 1.5 provides the confidence level of these changes in climate parameters.

Box 1.5: Climate change uncertainties in drought-prone areas

There is more confidence in temperature projections than rainfall projections because there is a direct relationship between atmospheric greenhouse gas concentrations and temperatures.

Very high confidence
- High temperature in winter and changes in extreme temperature
- Declining soil moisture during dry season
- Increased drought and water scarcity during dry season

High confidence
- More monsoon rainfall variability
- Intermittent dry spells
- Increasing potential evapotranspiration

Medium to high confidence
- Increased risk of extreme rainfall events during monsoon season
- Change in onset of rainfall and seasonality

Moderate confidence
- Change in stream flow
- Declining surface water resources
- Increased terminal (end-season) drought during monsoon season

Low confidence
- Abrupt change in average monsoon season rainfall
- Floods in the *Barind* areas during monsoon season

Training strategy

This training module requires 4-5 hours and should be delivered in at least one session on the morning of the first day. It consists of four learning units (LUs).
1. Define and distinguish between climate variability and climate change.
2. Explain enhanced greenhouse effect and its consequences on climate.
3. Explain climate change scenarios for Bangladesh.
4. Analyse climate change uncertainties in drought-prone areas of Bangladesh.

LU 1: Define and distinguish climate variability and climate change

This LU is designed to differentiate between climate variability and climate change. Participants are introduced to annual rainfall (Fig.1.1) and temperature (Fig.1.3) variability. Two or three participants can be requested to draw a diagram showing annual rainfall and temperature variations for a location of interest based on their experience. Discussions can be based on exercises to:

- analyse Fig.1.1 and Fig. 1.3 and
- discuss Fig. 1.2 and Fig. 1.4.

LU 2: Explain enhanced greenhouse effect and its consequences on climate

This LU is designed to increase understanding of the basic principle of the enhanced greenhouse effect and its consequences on climate variables. In this exercise, the facilitator:

- introduces a practical example of enhanced greenhouse effect,
- requests the participants to explain any enhanced greenhouse effects they have experienced and to discuss the consequences with respect to their own examples and relate to the earth's greenhouse effect,
- leads discussion and asks participants to identify ways the enhanced greenhouse effect alters the climate.

LU 3: Explain climate change scenarios for Bangladesh

The facilitator should give a brief introduction on climate change scenarios referring to Table 1.1. Participants can then develop a climate change scenario for their location. For this exercise, the facilitator:

- distributes a blank table and asks participants to complete all columns under 1960-1990, writing the average rainfall and temperature of a given location;
- distributes table with the actual values for rainfall and maximum and minimum temperatures and requests the participants to compare the values they have written with actual values;
- requests the participants to complete the table with their expected values for 2030 and 2050, based on the climate change scenarios described in Table 1.1;
- presents Fig. 1.5 and discusses the monthly difference in temperature change in 2050 and 2100 compared to current temperature.

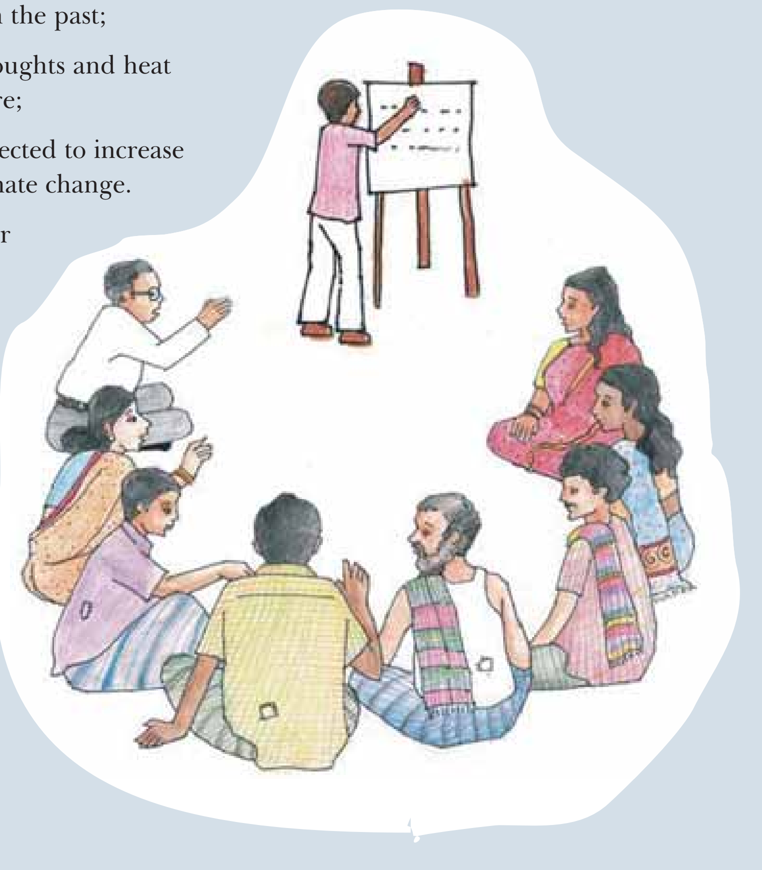
Months	1960-1990			2030			2050		
	Rainfall (mm)	T. Max (ºC)	T. Min (ºC)	Rainfall (mm)	T. Max (ºC)	T. Min (ºC)	Rainfall (mm)	T. Max (ºC)	T. Min (ºC)
Jan	17	24.4	10.9						
Feb	14	27.2	13.1						
Mar	30	31.5	17.2						
Apr	79	33.7	21.4						
May	222	32.7	23.3						
Jun	328	32.2	25.2						
Jul	434	31.7	25.9						
Aug	303	32.1	26.2						
Sep	310	31.8	25.4						
Oct	140	31.2	22.7						
Nov	25	29	17.5						
Dec	21	25.9	12.9						

LU 4: Analyse climate change uncertainties in drought-prone areas of Bangladesh

This LU is designed for participants to analyse each element presented in Box 1.5. The facilitator divides the participants into two groups and requests them to discuss the following topics:

- climate change uncertainties in drought-prone areas of Bangladesh;
- how current climate differs from the past;
- how extreme events, such as droughts and heat waves, might impact in the future;
- why drought conditions are expected to increase in Bangladesh under future climate change.

This LU should allot 15 minutes for briefing, 90 minutes for group exercise and 30 minutes for group presentation.



module 2

MODULE 2

Drought and its impacts

The purpose of this module is to familiarize participants with the key impacts of drought in Bangladesh. At the end of this module, participants should be able to:

1. recognize different types of drought and their characteristics,
2. explain the factors contributing to drought, and
3. describe the impact of drought in Bangladesh.

The earth's climate changes constantly with varying extremes of temperature, rainfall and air movement occurring naturally. Droughts, periods of unusual dryness, are therefore a natural climatic occurrence. They may be regarded as unusual in that they do not occur all the time or occur only rarely in some areas, but droughts are not abnormal.

Box 2.1: Drought

Drought most generally is defined as a temporary reduction in moisture availability significantly below the normal for a specified period.

The key assumptions of this definition are:
- the reduction is temporary (for permanent reductions, terms such as "dry" and "arid" conditions are more appropriate),
- the reduction is significant,
- the reduction is defined in relation to normal expectation,
- the period of the normal expectation is specified.

Normal expectation may be defined:
- technically – a reduction of water availability might qualify as a drought when it falls below about 80% of the average availability of the preceding 30 (or more) years.
- culturally – drought definition depends on local perception.

It is essential to understand local perception of drought. For example, after experiencing a run of ten years with above average rainfall, a society may become used to the wetter conditions and perceive a year of average rainfall as a drought.

Drought is difficult to define and needs different definitions to explain specific situations. It is important that those involved in drought preparedness and mitigation share a common understanding of the ways in which drought may be defined and the assumptions and constraints involved in using particular definitions.

In most cases, drought is temporary. A month-long drought may occur in an area that normally experiences alternating wet and dry periods. Defining a temporary reduction of water/moisture availability as a drought is extremely difficult and depends upon the time period being considered.

Droughts of similar severity may have dramatically different impacts on livelihoods because of ecological, socio-economic and cultural differences. Thus, it is difficult to define drought solely with regard to reduction in water/moisture availability. Invariably, the definition has to consider how the physical event impacts upon society.

Causes of drought in Bangladesh are related to climate variability and non-availability of surface water resources. The immediate cause of a rainfall shortage may be due to one or more factors including absence of moisture in the atmosphere or large-scale downward movement of air within the atmosphere which suppresses rainfall. Changes in such factors involve changes in local, regional and global weather and climate. While it may be possible to indicate the immediate cause of a drought in a particular location, it often is not possible to identify an underlying cause.

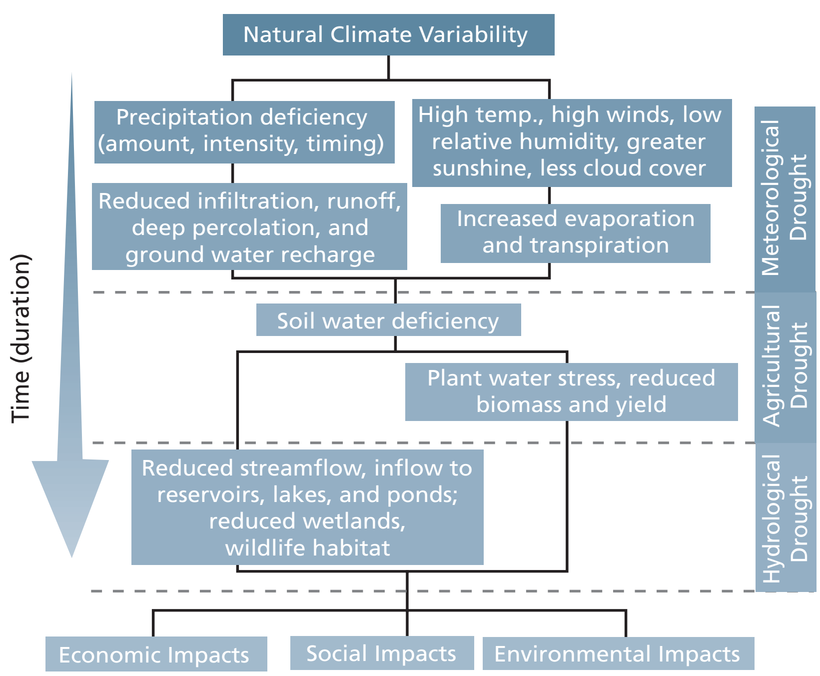
Short-term drought episodes can be linked to global atmospheric and oceanic circulation features. For example, the El Nino/southern oscillation (ENSO) phenomenon, which results from development of warm surface water off the Pacific coast of South America, affects the levels of rainfall in many parts of the world, including monsoon rainfall in Bangladesh. On a larger scale, the link between sea surface temperature and rainfall has been suggested as a possible cause of long, dry regimes.

Increasing levels of carbon dioxide and other greenhouse gasses have been suggested as causes of rainfall changes, which are, in turn, attributed as **climate change**. There is strong evidence that climate change will alter the rainfall pattern and as a result more frequent droughts are expected. Among the local-level causes are human-induced changes resulting from vegetation loss due to over exploitation of resources and deforestation.

Types of drought need to be distinguished in order to understand causes and effects. The types of droughts to be considered are:

- meteorological
- hydrological
- agricultural
- socioeconomic
- seasonal

Fig. 2.1. Types of droughts and their impacts over time, from onset of drought to realization of impacts



Meteorological and agricultural droughts are frequently, but erroneously, considered synonymous. Meteorological and hydrological droughts are physical events but agricultural drought refers to the impact of the first two on agricultural production. It is necessary to distinguish between these types and clarify where and how they overlap (Fig.2.1). Both climate variability and climate change influence such aspects as time (season, intra-season), location and length of drought occurrence.

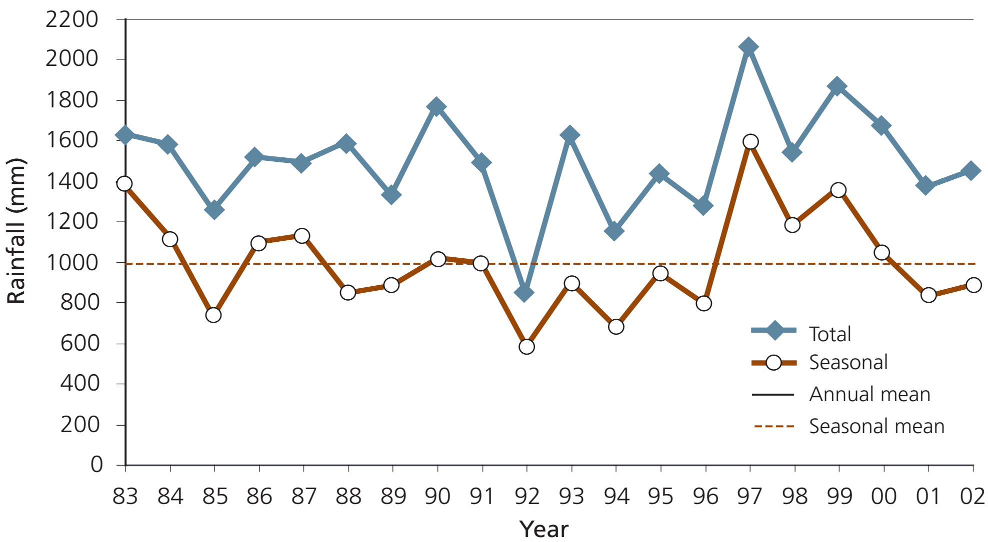
Meteorological drought occurs when the reduction in rainfall for a specified period (day, month, season or year) is below a specified amount – usually defined as some proportion of the long-term average. It is usually an expression of precipitation's departure from normal over some period of time (Fig.2.2). These definitions are region specific and presumably based on a thorough understanding of regional climatology.

Hydrological drought refers to deficiencies in surface and subsurface water supplies based on measurements of stream flow and lake, reservoir and groundwater levels. When precipitation is reduced or deficient during an extended period of time, this shortage eventually will be reflected in declining surface and subsurface water levels. However, hydrological measurements are not the earliest indicators of drought because of the time between reduced periods of precipitation and reduced water in streams, rivers, lakes and reservoirs.

Agricultural drought occurs when there isn't enough soil moisture to meet the needs of a particular crop at a particular time. Agricultural drought happens after meteorological drought but before hydrological drought. Agriculture is usually the first economic sector to be affected by drought.

Socioeconomic drought occurs when physical water shortage starts to affect people, individually and collectively. In more abstract terms, most socioeconomic definitions of drought are associated with its effect on the supply and demand of a product that has market value.

Fig.2.2. Annual and seasonal rainfall variation in drought-prone areas of Bangladesh



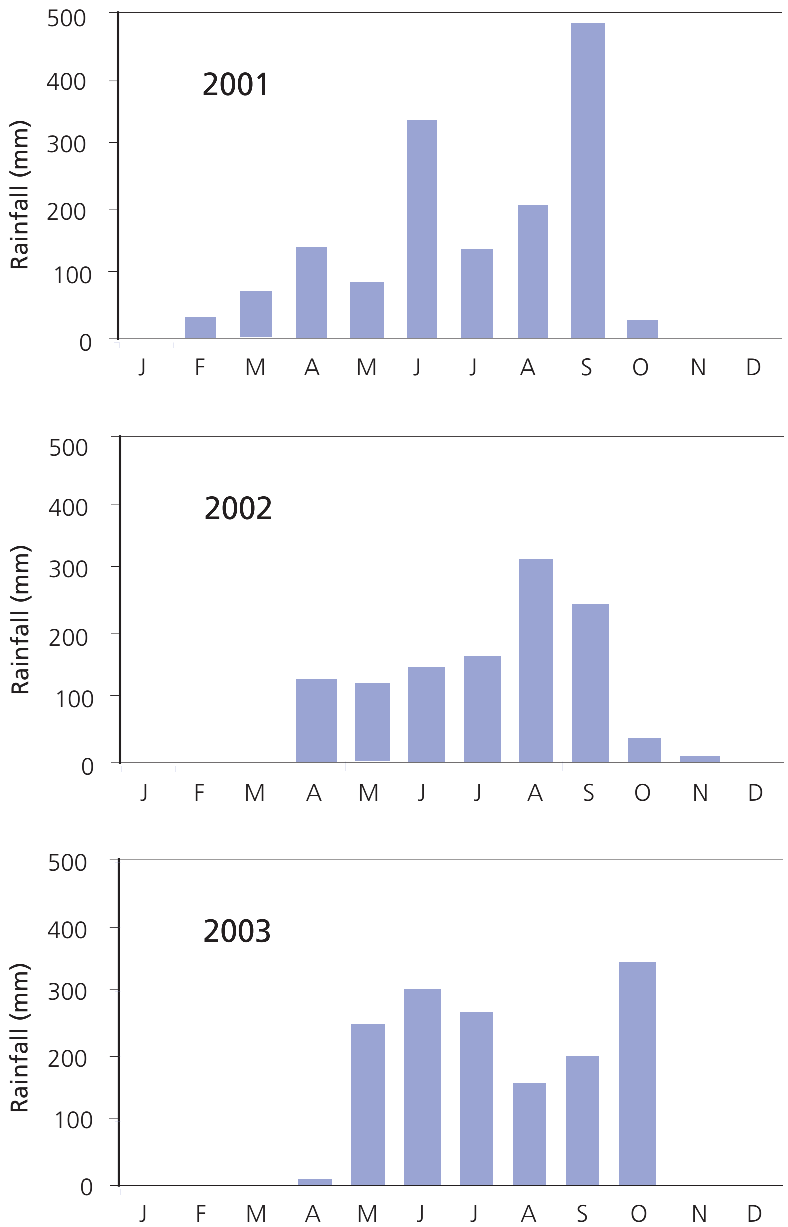
Water used in support of human activity is derived from direct rainfall which is temporarily stored in rivers and lakes or from groundwater aquifers. Some groundwater aquifers, such as those in the Barind areas of Bangladesh, may contain rainwater that fell decades or even centuries before. A temporary shortfall of rainfall or groundwater may cause a drought.

Hydrological droughts may be caused by rainfall reductions anywhere within the catchments of the river or aquifer. Thus, irrigated agricultural areas alongside the rivers in Bangladesh may experience a hydrological drought as a result of low rainfall.

Barind areas that use deep or shallow boreholes to draw water from underground aquifers may experience hydrological drought as a result of geological changes that cut off parts of the aquifers. Over-utilization of the aquifer may also result in its exhaustion after few years.

Agricultural drought results from the impact of meteorological or hydrological droughts on crop yields. For optimum growth, crops have temperature, moisture and nutrient requirements during their growth cycles. If moisture availability falls below the required amount during the crop

Fig. 2.3. Monthly rainfall distribution in Natchole *Upazilla*, Chapai Nawabganj district, Bangladesh



growth, yield will be reduced. However, droughts have different impacts on different crops. Because of the complexity of the relationships of crop growth and water requirement, agricultural drought is difficult to measure.

Seasonal droughts are related to deficit soil moisture during certain periods within a season. In Bangladesh, three types of droughts are recognized during monsoon season:

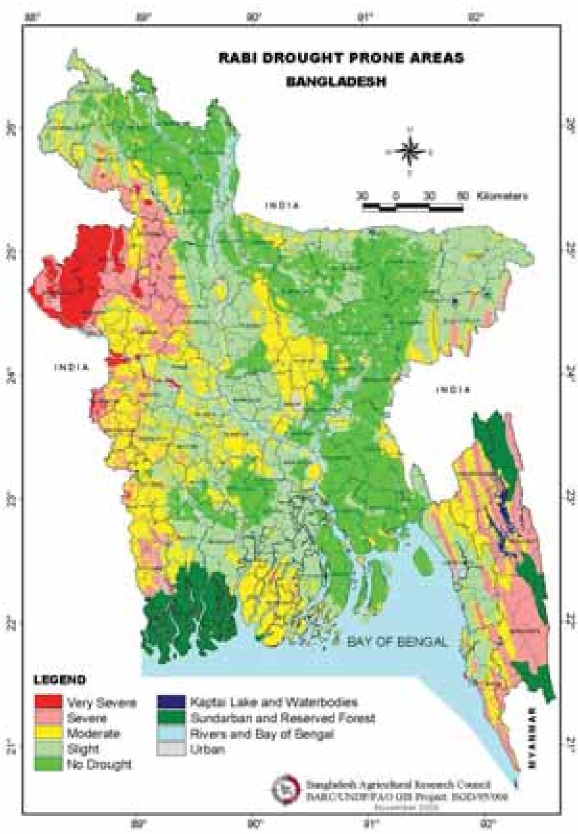
- early-season
- mid-season
- terminal-season

Early-season droughts are due to delayed onset or early breaks in monsoon rainfall. Mid-season droughts are caused by intermittent, short or extended dry spells. Terminal-season droughts are caused by early withdrawal of monsoon rainfall. In the *Barind* tracts of Bangladesh, terminal droughts are more frequent and coincide with the most important growth phases of the rice crop. Fig.2.3 shows monthly rainfall distribution in Northwestern Bangladesh and gives an idea of different types of drought: mid-season drought (2001), terminal drought (2002) and normal monsoon (2003).

Impact of drought

Bangladesh is affected by major country-wide droughts every five years. However, local droughts occur frequently and affect crop life cycles. The agricultural drought, related to soil moisture deficiency, occurs at various stages of crop growth. Monsoon failure often brings yield reduction and famine to the affected regions. A better understanding of the monsoon cycle is clearly of major scientific and social value.

Fig. 2.4. Drought-prone areas of Bangladesh during rabi season



Box 2.2: Critical dry periods in Bangladesh

The two critical dry periods in Bangladesh are *kharif*, and rabi and pre-*khari*:

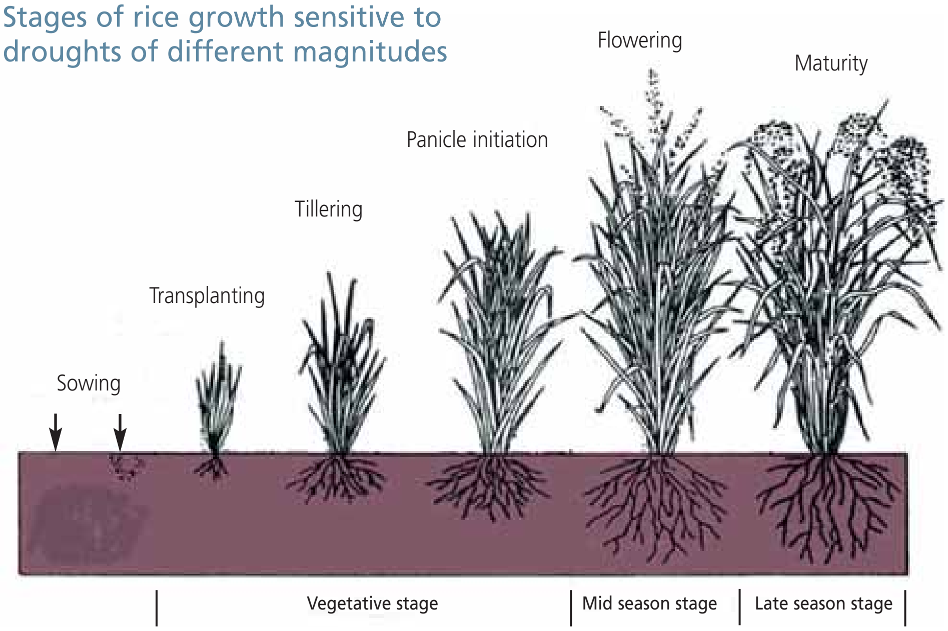
(1) *Kharif* – droughts in the period June/July to October result from dry conditions in the highland areas especially in the *BarindBarind*. Shortage of rainfall affects the critical reproductive stages of t.aman rice, reducing its yield, particularly in those areas with low soil moisture-holding capacity. This drought also affects fisheries and other household-level activities.

(2) *Rabi* and pre-*kharif* – droughts in the period January to May are due to: i) the cumulative effect of dry days, ii) higher temperatures during pre-*kharif* (>40°C in March/May), and iii) low soil moisture. This drought affects all the *rabi* crops, such as *boro*, wheat, pulses and potatoes, and pre-*kharif* crops such as t.*aus*, especially where irrigation possibilities are limited.

Northwestern regions are particularly vulnerable to droughts (Fig. 2.4). A severe drought can cause more than 40 percent damage to broadcast *aus*. Each year, during the *kharif* season, drought causes significant damage to the t.*aman* crop in about 2.32 million ha. In the *rabi* season, 1.2 million ha of cropland face droughts of various magnitudes. Apart from loss to agriculture, droughts have significant effect on land degradation, livestock population, employment and health. Between 1960 and 1991, droughts occurred in Bangladesh 19 times. Very severe droughts hit the country in 1951, 1961, 1975, 1979, 1981, 1982, 1984, 1989, 1994, 1995 and 2000. Past droughts have typically affected about 47 percent of the country and 53 percent of the population.

The associated decline in crop production, losses of assets and lower employment opportunities contributed to increased household food insecurity. Food consumption fell, along with household ability to meet food needs on a sustainable basis. Vegetables and many other pulses are in short supply during drought.

Fig.2.5. Stages of rice growth sensitive to droughts of different magnitudes



Water requirements for rice vary according to variety, but also soil type and season. Water needed for cultivating rice varies from 1000 to 1500 mm in heavy soils and from 1500 to 2000 mm in medium- to light-textured soil. The critical stages of the rice crop for water stress are tillering, panicle initiation, flowering and maturity (Fig.2.5). Adequate water needs to be maintained in the field during these stages. In the *Barind* tracts of Northwest Bangladesh, t.*aman* rice grown during monsoon and *boro* rice during *rabi* (winter) are prone to drought.

Table 2.1. Chronology of major drought events and its impact in Bangladesh

Year	Details
1791	Drought affected Jessore district, prices doubled or tripled.
1865	Drought preceded Dhaka famine.
1866	Severe drought in Bogra, rice production of the district was hit hard and prices tripled.
1872	Drought in Sundarbans, crops suffered greatly from deficient rainfall.
1874	Extremely low rainfall affected Bogra, great crop failure.
1951	Severe drought in Northwest Bangladesh substantially reduced rice production.
1973	Drought responsible for the 1974 famine in northern Bangladesh, one of the most severe of the century.
1975	Drought affected 47 percent of the country and more than half of the total population.
1978-79	One of the most severe droughts in recent times with widespread damage to crops reducing rice production by about 2 million tonnes, directly affecting about 42 percent of the cultivated land and 44 percent of the population.
1981	Severe drought adversely affected crop production.
1982	Drought caused a loss of rice production of about 53 000 tonnes while, in the same year, flood damaged about 36 000 tonnes.
1989	Drought dried up most of the rivers in Northwest Bangladesh with dust storms in several districts, including Naogaon, Nawabganj, Nilpahamari and Thakurgaon.
1994-95 and 1995-96	The most persistent drought in recent times, it caused immense crop damage, especially to rice and jute, the main crops of Northwest Bangladesh and to bamboo clumps, a main cash crop in the region.

Droughts cause major deterioration in household health because their subsequent impact of reducing food consumption leads to substantial increases in illnesses. Drought also leads to an increase in severe chronic energy deficiency among members of the agriculture work force.

Overview of drought in the *Barind* areas of Bangladesh

Causes	Rainfall deficit in any season and non availability of groundwater in Barind tracts cause drought in Bangladesh.
Characteristics	Meteorological drought in the *Barind* tracts is associated with the reduction in monsoon season rainfall. Hydrological drought is associated with reduction of surface water resources in rivers, tanks and traditional ponds. Agricultural drought is associated with deficit soil moisture. Drought conditions are further aggravated by non-availability of deep tube wells, low moisture retention capacity of the soil, highly variable rainfall and low adaptive capacity of farmers.
Predictability	Periods of unusual dryness in Northwest Bangladesh are common during *rabi* season. However, during monsoon season, rainfall variability determines the crop production prospects. Advance warning is usually possible for this region. Recent climate studies have shown opportunities for seasonal prediction of rainfall for this region (for more detailed explanation, see Module 6).
Factors contributing to vulnerability	In the high Barind tract, as dry conditions are increased by drought, farming becomes more difficult, especially in marginal lands. Subsistence farming with monocropping during monsoon season is affected by lack of agricultural inputs, groundwater and deep tube wells, and by lack of electricity and fuel for running pumps.
Adverse effects	Drought leads to reduced income for farmers, reduced yield from aus, t.aman and boro rice and reduction of inputs and investment for the agricultural sector. In addition, it causes increased prices for staple food, and increases chances of seasonal food crises such as monga (famine), illness, reduction of drinking water sources, migration and loss of livestock.

Training strategy

This training module needs to be delivered in at least one session (4-5 hours) on the afternoon of the first day. It consists of three LUs.
1. Introduce types of drought and their characteristics.
2. Explain the factors contributing to drought.
3. Describe the impacts of drought in Bangladesh.

LU 1: Introduce types of drought and their characteristics

This LU introduces types of drought that affect Bangladesh and their causes and characteristics. Figure 2.1, in particular, may be discussed in depth, to reinforce the understanding of drought caused by climate variability. The facilitator asks the participants to:

- observe the annual and seasonal rainfall variability in the *Barind* areas from 1983 to 2002 (Figure 2.2), and then to characterize the years as different categories of drought (mild, moderate and severe) based their experience;
- discuss the short- and long-term causes of rainfall deficiency and their impacts in Bangladesh.

In addition, two or three participants can be asked to draw a diagram showing seasonal rainfall of drought-prone areas in the recent past and to categorize the different types. The group can then discuss the consequences of rainfall patterns on crops, as depicted in Fig.2.3, which also illustrates seasonal droughts.

LU 2: Explain the factors contributing to drought

The facilitator describes the various factors responsible for different types of drought in Bangladesh. The participants can be requested to:

- group factors responsible for drought in the *Barind* areas (as explained in Module 1);
- describe the short- and long-term causes of drought in Bangladesh.

LU 3: Describe the impacts of drought in Bangladesh

The facilitator describes impacts of drought with special emphasis on agriculture and allied sectors (explained in Module 2). The interactive lecture may discuss the following:

- critical dry periods in Bangladesh,
- seasonal impacts of drought,
- sensitive stages of rice during drought,
- history of drought impacts in Bangladesh,
- summary/overview of drought in *Barind* areas.

Group exercise

Participants should be divided into two groups and requested to categorize the impacts of drought in various sectors based on their past experiences. The sectors include:

- agriculture
- livestock
- fishery
- water resources
- health

MODULE 3

Impacts of climate variability and change in drought-prone areas

This module is designed to familiarize participants with vulnerability and impacts of climate variability and change on natural resources and agriculture. At the end of this module, participants are expected to know the following.

1. What factors are responsible for increased vulnerability to climate variability and change?
2. How would future climate change affect the agriculture of drought-prone areas?
3. How would rural livelihoods be affected by increased climate variability and change?

Many of Bangladesh's community and economic activities as well as many of its natural resources are climate sensitive. The impact of climate variability and change depends on where people live, where they work and other livelihood activities. It is essential to understand the regional impact of climate variability and change in order to identify viable adaptation practices.

The impact of climate variability and change on specific regions depends on their **vulnerability** that is, how sensitive they are to even small changes, how exposed they are, and whether they can adapt.

Box 3.1: Impact and vulnerability

Impact is the detrimental and/or beneficial consequences of climate variability and climate change on natural and human systems.

Vulnerability is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed relative to its sensitivity and its adaptive capacity.

Climate change vulnerability is the degree to which a system is susceptible to, or unable to cope with, the adverse effects of climate change, including climate variability and extremes.

Socio-economic vulnerability refers to an aggregate measure of human welfare that integrates environmental, social, economic and political exposure with a range of harmful perturbations.

For farming communities, changes in the frequency and intensity of severe weather events such as dry spells, droughts, wet spells and heat are more important than changes in average conditions. If climate change occurs faster than those affected can adapt, community vulnerability to the impacts of both climate variability and change will increase. It is also necessary to understand how physical, biological and economic systems are likely to respond.

Climate extremes such as days that are very hot, particularly consecutive days when nights stay warm, would increase due to climate change and, in turn, would cause heat-related stress.

Increased summer heat would pose community health risks, especially for women and the elderly, and challenge livelihood activities and the agricultural labour force. Increased frequency of tornadoes and hailstorms during summer would make it difficult to manage current agriculture, especially during *boro* rice cultivation. The high-yielding *boro* rice crop, expanding into the *rabi* season, would be affected both by increased climate variability and climate change.

Table 3.1. Climate change scenarios and drought

Scenario	Drought
Current	Severe drought can affect yield in 30% of the country, reducing national production by 10%.
2030	Temperature increase of 0.5°C and annual rainfall reduction of 5% could reduce runoff into the Ganges, Brahmaputra and Meghna Rivers by 14%, 11% and 8%, respectively. With 12% reduction in runoff, the population living in severe drought-prone areas increases from 4% to 9% under moderate climate change.
2050	Future droughts may increase the probability of a dry year, meaning a year with a certain percentage of below-average rainfall, by 4.4 times. Temperature increase of 1.3°C and precipitation decrease of 9% would reduce runoff into the Ganges, Brahmaputra, and Meghna Rivers by 27%, 21% and 15%, respectively. If runoff drops 22% in kharif season, drought-prone areas would expand to include northwestern to central, western and southwestern regions.

The upland *Barind* tracts may face difficulty coping with increased climate variability and climate change impacts in the future. The region would be more vulnerable to dry spells during both the monsoon and dry seasons and the new climate may not suit some crops and species that are climate sensitive. Increased pressure on natural resources and increased demand for crops would have serious implications, especially on smallholder farming systems.

Fresh water resources, namely surface and groundwater, in drought-prone areas are already declining due to over exploitation to support irrigation in the dry months (Fig.3.1). It has been predicted that by 2018, the demand for irrigation may reach 58.6 percent of the total supply. The demand for other sectors is expected to reach 40.7 percent for inland waterway navigation, salinity management and fisheries, and 0.7 percent for domestic and industrial use.

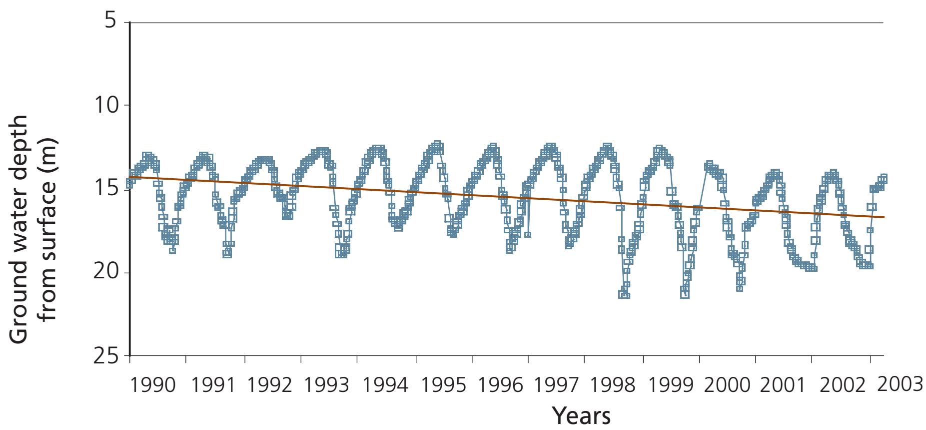
Box 3.2: Climate change and drought

Climate change scenarios indicate that drought-prone areas will face high rainfall variability. A geographical distribution of drought-prone areas under climate change scenarios shows that the western parts of the country will be at greater risk of droughts, during pre-*kharif, kharif* and *rabi* seasons.

Box 3.3: Small farmers are more vulnerable

Average farm size declined and per capita cultivation area decreased from 0.10 ha in the mid-1980s to only 0.06 ha in the late 1990s. In the drought-prone areas where there are mostly subsistence farmers who cultivate rented lands, the average farm size is less than 0.4 ha. Reduced yield levels due to temperature increase and frequent dry spells may lead to decline in household coping strategies.

Fig.3.1. Groundwater levels in Chapai Nawabganj district from 1990 to 2002

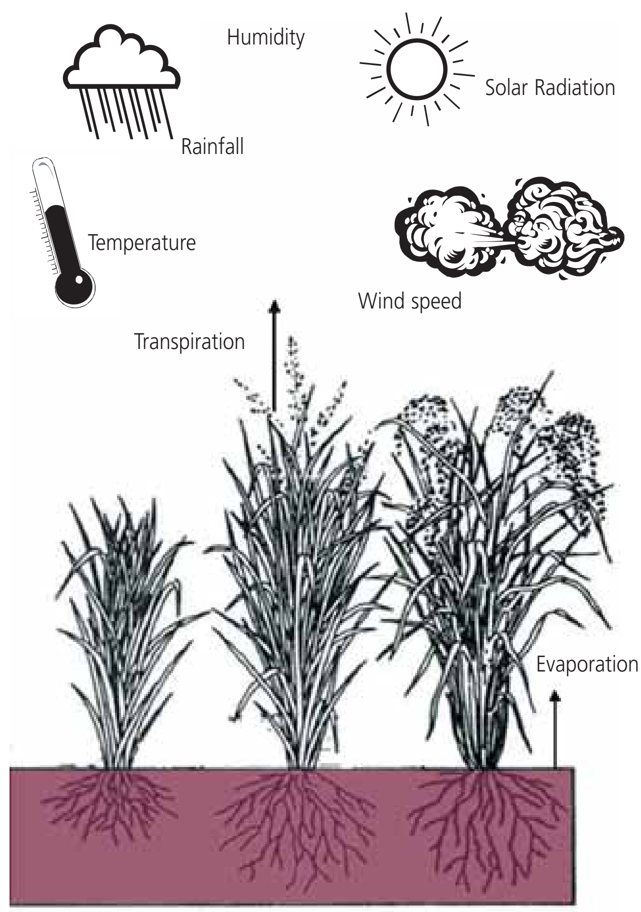


Based on the climate change scenarios (Module 1), surface water would increase during monsoon but would decrease in the winter, meaning more water will be required for irrigation in winter. Irrigation would be more dependent on groundwater withdrawal. Overexploitation of groundwater to meet the growing irrigation requirement would lead to environmental problems such as heavy metal contamination and salinity.

Box 3.4: Climate Change and Water Supply

Change in water supply and demand caused by increased climate variability and change would combine with changing water use due to growth of population and income. Currently, Bangladesh requires 22 500 million m^3 of water annually. By 2020, the total requirement for water consumption will be 24 370 million m^3 yet the available supply will be 23 490 million m^3 – meaning there will be a shortage of 880 million m^3.

Fig.3.2. Factors influencing crop production



The Bangladesh **agriculture** sector contributes about 30 percent to its gross domestic product (GDP). Nearly 75 percent of the population is directly or indirectly dependent on agriculture. Though declining, agriculture is still the highest contributor to the GDP and the main user of water. Its share of water demand will continue to increase, concurrent with efforts to attain food security.

Within the crop sector, food grains, particularly rice, dominate the country's agricultural scenarios in both cropped area and production, claiming a share of 77 percent in 2000. Thus, the effect of climate variability and change on the rice crop would have substantial impact on the sector's performance since most of the production factors (Fig. 3.2) would be altered by climate change.

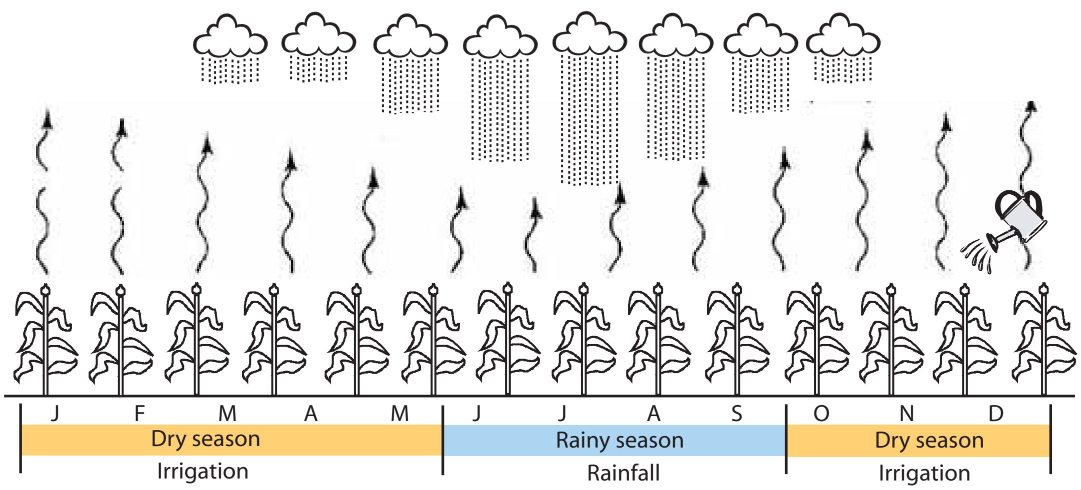
There has, however, been a shift in the composition of agriculture over the past few years with gradual intensification of monocropping *boro* rice during *rabi* season. Such intensification increases vulnerability of the agriculture system to drought and high temperature, which are projected to increase under climate change.

Climate change will seriously affect the total agriculture production in Bangladesh. A rise in the CO_2 level will have a positive fertilization effect, but with a rise in temperature, the yield will be suppressed. Thus, in order to derive the desired benefit, the interaction of CO_2 and temperature has to be synchronized with the choice of crop cultivars.

Box 3.5: Climate Change and rice production

Under a moderate climate change scenario, *aus* production in Bangladesh would decline by 27% while wheat production would be reduced to 61%. Under a severe climate change scenario, yield of *boro* might decrease by 50%. Moisture stress during the dry season might force farmers to reduce the area under *boro* cultivation.

Fig.3.3. Schematic of seasons with relative difference in rainfall and water requirement in Barind areas of Northwest Bangladesh



Climate change would alter crop water requirement in drought-prone Bangladesh. The highest crop water needs (Fig.3.3) are in hot, dry, windy and sunny seasons (November-May). The lowest needs occur when it is cool, humid and cloudy with little wind. It is clear that crops grown in current and future climatic conditions will have different water needs. For example, rice grown in the future will need more water per day.

Of the net cultivable area, 37 percent is single cropped, 50 percent is double cropped and 13 percent is triple cropped. The three cropping seasons coincide approximately with the three meteorological seasons namely, *kharif I* (pre-monsoon), *kharif II* (monsoon) and *rabi* (dry season). *Aus, aman* and *boro* are the three rice crops grown in these three cropping seasons respectively. During the past two decades, the area under boro rice has increased – a trend that is likely to continue in future. Because boro is an input intensive crop and requires use of water in the winter season, such a trend would increase pressure on the limited water supply, leading to land degradation, food insecurity.

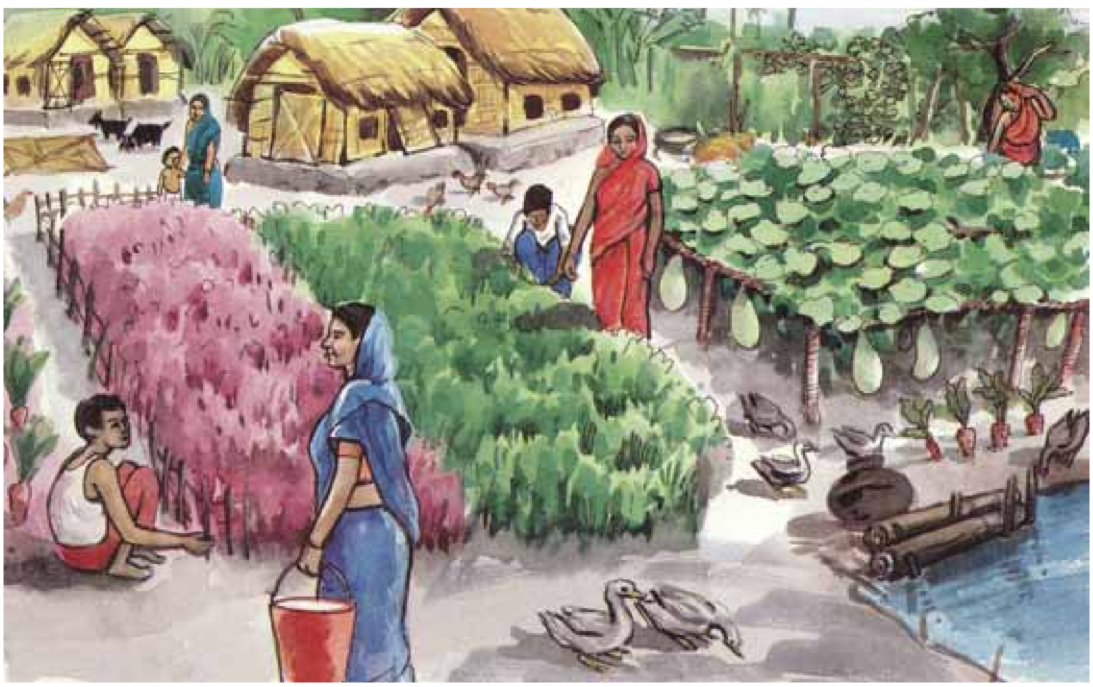
Drought normally affects about 2.3 million ha of cropland from April to September and 1.2 million ha in the dry season, from October to March. Drought during monsoon season severely affects t.*aman* rice and can incur an annual 1.5 million tonne production loss. With climate change, more area would be exposed to severe droughts because of projected change in rainfall pattern and dry spell frequencies.

Box 3.6: Climate change, land degradation and food security

Continuous monocropping leads to land degradation and decline in soil fertility. At present, more than 62% of the land is covered by high-yielding varieties (HYVs). The introduction of high-yielding rice varieties and the expansion of irrigation have both contributed to an increase in food grain production of more than 25 million tonnes in Bangladesh. This has the potential to threaten food security further through overexploitation of resources and increasing demand for food combined with the impact of climate change on crop production.

Incidence of **pests and diseases** may increase with climate variability and climate change. With long dry spells and more intense rainfall, the resulting decline in water quality will lead to greater risk of water-born diseases. Changing temperatures and rainfall in drought-prone areas are likely to shift populations of insect pests and other vectors and change the incidence of existing vector-borne diseases in both humans and crops. The physical and social disruptions caused by these diseases and extreme events such as droughts may affect the community. Under high temperature and humidity, there will be problems of dehydration, especially affecting the elderly and children. A temperature increase of 1-2°C would perhaps not cause significant change, but high intensity of extremes might intensify heat stress and associated health hazards.

Fresh water availability in drought-prone areas also would be threatened under climate change which would affect small-scale **fishery** activities. For example, the duration of water availability in traditional ponds would be shortened due to longer dry periods and increased frequency of dry years, and high temperatures would lead to increased salinity. As the solubility of oxygen in water decreases with high temperature, **fish growth** would be affected. Fresh water fish hatchlings cannot survive under high salinity levels. A temperature rise of about 2°C would have substantial impacts on distribution, growth and reproduction of fish.



Farmers in the drought-prone *Barind* areas maintain **livestock** as a risk management strategy to cope with drought impact, even under current climate variability. These farm animals are affected by climate directly and indirectly. Directly, they are affected by air temperature, humidity, wind speed and thermal radiation which influence their growth, milk production, reproduction, health and well-being. Indirectly, they are affected by the quantity and quality of feedstuffs such as pastures, forages and grain and the severity and distribution of livestock diseases and parasites.

When the magnitude of adverse climatic conditions exceeds threshold limits under climate change, animal functions may become impaired by the resulting stress. Consumption rates of animals would be reduced under high temperature. If short-term extreme events, such as summer heat waves, result in the death of vulnerable animals, it will have a devastating financial impact on the poor.

Livelihood activities that rely on sensitive agricultural systems will be more vulnerable to climate change. Trends such as population growth, pollution, increasing demand for food and water, and market fluctuations can compound the impact of climate variability and climate change.

Table 3.2. Examples of climate variability, extreme events and their impacts

Summary of projected changes during the 21st century in extreme climate	Examples of projected impacts in drought-prone areas of Bangladesh
Higher maximum temperature, more hot days and heat waves	■ Increased incidence of serious illness among elderly, children, the poor Increased heat stress in livestock ■ Increased risk of damage to both monsoon and dry season crops ■ Increased crop pest and diseases ■ Increased energy demand and reduced energy supply reliability
Higher minimum temperature, fewer cold days, and cold waves	■ Decreased cold-related human mortality ■ Decreased risk of damage to a number of crops ■ Increased risk to crops such as wheat and chickpea ■ Increased activity of some pest and diseases vectors
More intensive precipitation events	■ Increased chances of local flood ■ Increased soil erosion ■ Increased loss of topsoil and nutrients ■ Increased pressure on relief
Increased monsoon precipitation variability	■ Frequent dry spells during monsoon season ■ Extended dry spells and drought
Increased summer drying and associated droughts	■ Decreased crop yields ■ Decreased water resources (quantity and quality) ■ Decreased surface water resources in rivers, tanks, ponds, etc. ■ Declining groundwater resources due to over exploitation
Increase in nor'westers during summers and peak wind intensities	■ Increased risk to human life ■ Risk of infectious disease epidemics ■ Increased risk of wind-related damage
Increased incidence of events such as hail storms and whirlwinds	■ Wind-related damage ■ Damage to irrigated summer crops (e.g. *boro*) ■ Damage to fruit trees such as mango and jack fruit

Training strategy

This training module needs to be delivered in at least one session (4-5 hours) on morning of the second day. It consists of three LUs.

1. Discuss factors responsible for increased vulnerability to climate variability and change.
2. Discuss impact of climate change on the agricultural systems.
3. Explain impact of climate change on rural livelihoods.

LU 1: Discuss factors responsible for increased vulnerability to climate variability and change

This LU increases understanding of both climatic and non-climatic factors that can increase a social systems' vulnerability to climate variability and change. The facilitator identifies and defines the factors and discusses the current vulnerability of agricultural systems to climate variability through an interactive lecture with practical examples. Diagrams in Figs. 3.2 and 3.3 showing the role of climate variables on crops may help clarify the information.

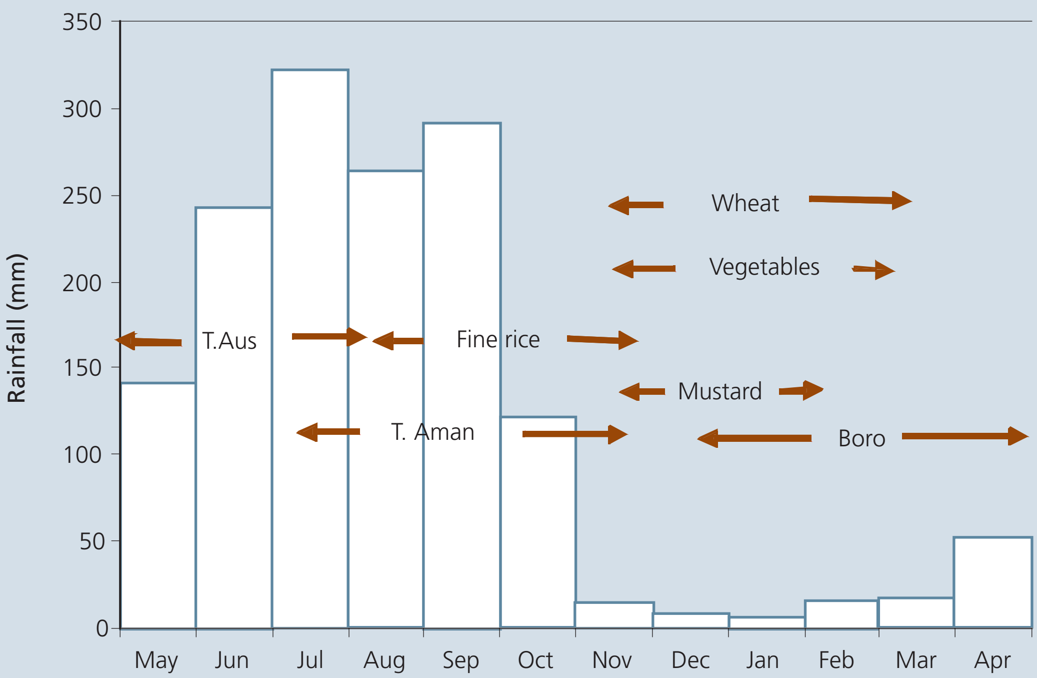
LU 2: Discuss impact of climate change on agriculture sector in drought-prone areas

This LU will help participants understand the impact of increased climate variability and climate change. The facilitator explains their impacts on the agriculture, water resources, livestock and fishery sectors during an interactive lecture with practical examples. Table 3.1, explained in detail, raises awareness of future climate change impacts. This LU's key questions are:

1. How would crops sensitive to high temperatures, such as wheat and chickpea, be affected by future climate change?
2. Why would boro rice face water scarcity under future climate change?

The facilitator also discusses each of the projected changes in extreme climate events and elaborates their impacts relevant to drought-prone areas of Bangladesh.

> **Exercise:**
> **Strengthen understanding of climate change impact on crops and cropping systems**
> Participants can be requested to review the cropping calendar below and identify the crops vulnerable to increased climate variability and future climate change. Discuss the reasons in groups.



LU 3: Explain the impacts on the rural livelihoods in drought-prone areas

This LU increases understanding of the impact of climate change on rural livelihoods. It further strengthens understanding of climate risks and impacts on socio-economic systems. It should contain a brief interactive lecture on climate change and livelihoods, covering agriculture, livestock, fisheries, etc.

> **Exercise:**
> **Strengthen understanding of climate risks and impacts**
> This is an exercise to improve participants' understanding of future impacts of changing climate variables. In this exercise, participants divide into two groups with each group receiving a copy of Table 3.2 (blank except for Column 1: "Summary of projected changes during the twenty-first century in extreme climate"). Working in their groups, they have 30 minutes to fill in the second column of the table. The groups can be requested to make five-minute presentations on the results of their discussions. Then the facilitator presents the complete Table 3.2 and discusses the impacts in detail.

MODULE 4

Climate risk assessment at community level in the agriculture sector

This module identifies the tools and methods needed for assessing climate-related risks at community level, focusing on the agriculture sector[2]. It introduces some of the key concepts and steps for climate risk assessment in the context of livelihood adaptation to climate change in agriculture. This covers a range of climate risks with special emphasis on drought. At the end of this module, participants should:

1. understand the participatory tools and processes for assessing climate-related hazards, vulnerabilities and risks in agriculture,
2. identify key climate risks that have significant impact on communities in general and livelihoods in particular, and
3. assess the community perception of risks associated with past and current climate variability.

Rural communities and individual farmers face **risks** associated with climate variability and climate change. Their livelihoods are exposed to climate risks and associated impacts. Conventionally, risk is expressed by the notation: Risk = Hazards x Vulnerability.

Risk identification and **assessment** are the two important steps that form the basis for successful implementation of adaptation practices. This involves identification and assessment of current (climate variability) and future (climate change) risks and associated societal vulnerabilities.

Box 4.1: Risks, risk identification and assessment

Risk is the result of physically defined hazards interacting with exposed systems – taking into consideration the properties of the systems, such as their sensitivity or social vulnerability. Risk also can be considered the combination of an event, its likelihood and its consequences. Risk equals the probability of climate hazard multiplied by a given system's vulnerability.

Climate risk identification is the process of defining and describing a climate-related hazard, including its physical characteristics, magnitude and severity, probability and frequency, exposure and consequences.

Risk assessment is a methodology to determine the nature and extent of risk by analyzing potential threats and evaluating existing conditions of vulnerability that could pose a potential threat to property, livelihoods and the environment on which they depend.

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[2] Detailed guidelines on community risk assessment with cross-sectoral and multi-hazard perspective can be found in "*A facilitator's guidebook for conducting Community Risk Assessment*" prepared by Directorate of Relief and Rehabilitation (DRR), Ministry of Food and Disaster Management (MoFDM), Bangladesh.

Risk can be considered the combination of an event, the likelihood that it will happen and its consequences. **Hazard** is an event or physical condition that has the potential to cause fatalities, injuries, property damage, infrastructure damage, agricultural loss, damage to the environment, interruption of business or other types of harm or loss. Climate risk identification has three basic elements: **probability**, **exposure** and **consequences**.

Each climate risk can be identified by its own natural characteristics, including geographic area (areal extent), time of year it is most likely to occur and its severity. In most cases, a climate event may create multiple hazards: wind is a factor in thunderstorms and severe thunderstorms spawn tornados. Thus, it is necessary to identify the potential primary hazard but also its triggering effect on secondary hazards. Knowledge of the nature of risks, their geographic coverage and their potential future behaviour is fundamental for designing a viable adaptation practice to reduce the impact of climate change in the agriculture sector.

Box 4.2: Elements of risk identification

Probability measures how frequently an event is likely to occur. Frequency can be expressed as the average time between occurrences of an event or the percent chance or probability of the event occurring within a given time period, such as a year.

Exposure means the number, quality and monetary value of various types of property, infrastructure or lives that may be subject to undesirable outcomes.

Consequence means the full or partial damage, injuries or loss of life, property, environment and business that can be quantified, usually in economic or financial terms.

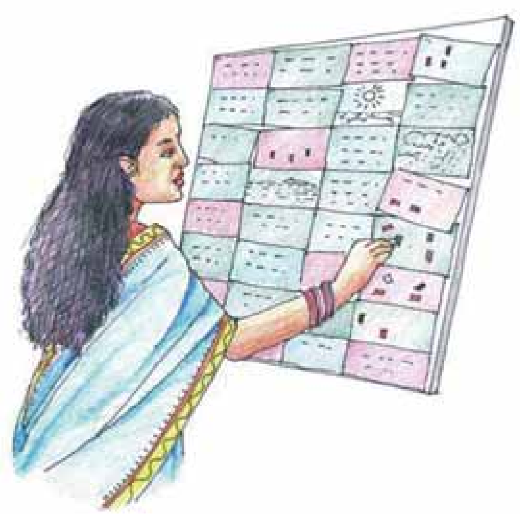
Participatory tools and methods for climate risk identification and assessment

Participatory tools are ideal for climate risk assessment with farmers in particular and the community in general. They can facilitate community participation, exchange of ideas and decisions among the community and other stakeholders. Using participatory methods can lead to community empowerment and commitment to address the risks. The following alphabetical list identifies some tools that can be considered for involving communities in climate risk identification and assessment.

- **Climate risk maps** – identifies areas at risk and vulnerable members of the community. This also includes analysis of available resources that can be used by community members for climate risk management and involves the community in preparing local risk maps.
- **Community history** (time line) – identifies frequency of shocks and local coping mechanisms.
- **Focus group meetings** – brings together community residents, farmers' groups and associations, formal and informal village cooperatives, landless labourers, fishers, livestock farmers, etc., to discuss specific issues.
- **Hazard Venn diagram** – allows participants to identify and analyze the common hazards that take place locally, their magnitude and likelihood.
- **Historical transect** – provides a graphic presentation of the history of climate risks and development in the community with emphasis on the agriculture sector.
- **Household composition** – provides a breakdown of human capital, looking at the labour force, migration, education and dependency status of various socio-economic groups, especially categories of farmers in the agriculture sector.
- **Local resource map** – pinpoints main land types, livelihood activities on each land type and physical infrastructure such as roads, farming methods, irrigated areas, water points, markets, electricity, banks and agricultural extension offices.

- **Matrix ranking** – prioritizes climate risks, needs and options.
- **Problem analysis** – analyses perceived livelihood problems, causes of problems, coping mechanisms, livelihood opportunities of women and men, and the impact of climate risks in the agriculture sector.
- **Ranking** – analyses problems in order to rate community priorities or the significant problems faced by the community.
- **Seasonal calendar** – tracks seasonal changes, climate-related hazards, community events and other activities related to a specific month. In the agricultural sector, this is used primarily to plot seasonal farm activities.
- **Seasonal activity calendar** – identifies times of working with crops or livestock, in forests, off-farm and domestic work as well as pinpointing gender roles.
- **Timeline** – narrates the history of climate risks and significant events that happened in the community.
- **Transect** – involves the facilitator and community members taking a walk together through the community to get a realistic picture of community vulnerability and the resources that are available or may be available for disaster risk management.
- **Vulnerability** – shows proportion of households affected by climate risks and reasons why they are vulnerable.
- **Vulnerability context** – looks at local shocks and stresses, proportion of households that are food insecure in an average year, bad year, good year and why, and the proportion of households/farmers who are income insecure in an average year, bad year, good year and why.
- **Wealth ranking** – identifies typical characteristics of wealth and well-being of groups in the community.

In addition, a certain amount of **secondary information** is needed for climate risk assessment. This includes



- daily rainfall, temperature and evaporation data to assess the moisture deficit and drought periods (early, mid and late season),
- agro-climatic indicators such as crop evapotranspiration and rainfall ratios,
- groundwater depths, dry spells, wet spells, and periods of water deficit,
- Trends of heat waves, extreme temperatures, hail storms and wind storms,
- climate change scenarios and anticipated future impacts on agriculture sector,
- land use changes over the years,
- onset of climate risks such as delayed monsoon, early withdrawal of rainfall, intermittent dry spells, extended wet spells, water stagnation, etc.,
- geographical coverage of the climate risk based on the past records (e.g. droughts),
- frequency of each risk based on past historical records.

Steps of climate risk identification and assessment

The following steps and processes of climate risk identification and assessment at community/farm level are not rigid. Participants are requested to think of these steps as a general guideline for risk identification and assessment. The climate risk assessment in this context serves to develop viable adaptation options for managing potential risks associated with climate change. The current risks need to be identified and future trends assessed based on the climate change scenarios. (Note: Module 1 gives a background of current climate variability and future climate change.)

Step 1: Describe the climate risks and impacts in the community

Tools and methods: Climate data analysis, agro-meteorological analysis, socio-economic data, production changes, past impacts and future anticipated impacts.

Outputs: List and describe the nature of climate risks using both participatory and scientific tools and secondary information.

Step 2: Conduct community-based climate risk mapping

Tools and methods: Mapping of key risks in terms of probability, exposure and consequence.

Outputs: Based on discussions with the community (farmers in particular), map the climate risks affecting agriculture and allied sectors.

Step 3: Assess the local perception on climate risks

Tools and methods: Validation of the identified risks by assessing local perception of the community about the risks using, ideally, participatory methods.

Outputs: Identify the local rules-of-thumb and assess local perceptions of past and current risks.

Step 4: Describe the vulnerabilities and capacities of the community

Tools and methods: Secondary data on vulnerable groups, enabling/disabling institutions, external support.

Outputs: Identify vulnerable groups and their capacities and coping ranges to manage current and future climate risks.

Step 5: Rank the climate risks

Tools and methods: Matrix ranking based on frequency, vulnerabilities, capacities and potential future impacts.

Outputs: Prioritize current and future climate-related risks through farmer's participatory interactions.

Step 6: Decide on acceptance of the risk

Tools and methods: Stakeholder discussion and participatory methods.

Outputs: Identify the thresholds of current and future climate risks in agriculture and allied sectors above which livelihood security is affected.

Step 7: Decide whether to prevent, reduce, transfer or live with the risks

Tools and methods: Stakeholder discussion and participatory methods.

Outputs: Develop strategies for integrated climate risk management. This activity is linked to development of viable adaptation options which is further explained in Module 5.

Climate risk identification and assessment must be conducted at community level through a participatory process in the agriculture sector. More efforts need to be dedicated to bottom-up identification rather than conventional top-down agro-meteorological approaches. The climate risk assessment also facilitates a process for determining the probable negative effects of future climate change.

Assessment of current vulnerability involves responding to several questions, such as:

- Where does the society stand today with respect to vulnerability to climate risks?
- What factors determine the society's current vulnerability?
- How successful are current efforts to adapt to current climate risks?

Answers to these questions become apparent after following these four steps:

- assess local perceptions of climate risks and impacts;
- identify vulnerable groups within the community;
- assess current climate risks (conventional agro-meteorological approaches may be complementary to the community-based participatory approaches);
- assess institutional frameworks, roles, gaps and comparative advantages.

An assessment of the **community perception** of climate risks can uncover the nature of the risk and its underlying factors and associated socio-economic consequences. Table 4.1 illustrates the local perception of climate risks in t.*aman* rice cultivation in the *Barind* areas of Bangladesh.

Table 4.1. Drought risk in t.*aman* rice cultivation as identified by the local farmers in the *Barind* areas of Northwest Bangladesh

The number of solid circles represents the intensity of the risk.

DAT	Stage	Drought intensity			
		July	Aug	Sep	Oct
0 – 10	Transplanting	●●			
10 – 25	Establishment	●●●			
25 – 50	Active tillering		●●●●●		
50 – 65	Panicle initiation			●●●●●	
65 – 70	Flowering			●●●●●	
70 – 85	Ripening				●●●●
85 – 100	Maturity				●●●
100 – 105	Harvesting				●

The risk assessment process also should identify the **rules-of-thumb** or “thumb rules” followed by farmers in particular and the community in general. Participatory risk assessment processes help identify the local thumb rules for risk, such as those developed by small and marginal farmers in the drought-prone *Barind* area to describe drought thresholds based on their experiences. For example, these farmers perceive that 12 days without rain during monsoon season in the high *Barind* tracts of Bangladesh could trigger drought while in the level *Barind* area, 14 days without rain could trigger drought at early stages of rice crop. As a result, farmers in the *Barind* areas respond to drought based on this threshold number of dry days and their visual observations.

Table 4.2. Farmers’ perception of drought, based on the length of dry spells and crop stages in high *Barind* tracts

Stage	Dry spell length (days)	Drought perception
Seedling stage	5 – 7	Mild
	7 – 15	Moderate
	>15	Severe
Vegetative	7 – 8	Mild
	8 – 18	Moderate
	>18	Severe
Flowering	5 – 7	Mild
	7 – 12	Moderate
	> 12	Severe

To explore farmers’ perceptions further, dry spell thresholds were identified for various stages of the crop, as illustrated in Table 4.2. In the high *Barind* areas, the threshold dry spell lengths, meaning the number of consecutive days without rain, varies considerably with respect to stages of growth. On average, a dry spell of five to seven days is considered mild drought at seedling and flowering stages, but in the vegetative state, it is seven to eight days. At flowering stage, the community considers a rainless period of more than 12 days to be a severe drought that could reduce crop yield by up to 40 percent. This analysis needs to be compared with agro-meteorological analysis using long-term rainfall data and projected climate change. Understanding of local thumb rules and local perceptions is necessary to identify a suitable adaptation practice that fits within the rules.

The climate risk analysis is the prerequisite for developing viable adaptation options to manage future anticipated risks. Once the analysis is done, the next step is to identify and prioritize the local adaptation options and test them through demonstration and implementation at local levels.

Training strategy

This training module needs to be delivered in at least one session (4-5 hours) on the afternoon of the second day. It consists of three LUs.

1. Explain the participatory tools and processes for climate risk assessment.
2. Explain steps for assessing climate risks in drought-prone areas.
3. Define the local perception of climate risks.

LU 1: Explain the participatory tools and methods for climate risk assessment

This LU increases participants' understanding of the terminology, participatory tools and methods to be employed during climate risk assessment. The facilitator presents the definitions and step-by-step processes for identification and assessment of climate risks (as covered in Module 3) by means of an interactive lecture and presentation of practical examples. For example, participants are shown tools such as diagrams from participatory Venn diagram, calendar and mapping exercises. The session also requires outlining of secondary information needed for climate risk assessment, indicating their possible sources – at national, district, *upazilla* and local levels.

LU 2: Explain steps for assessing climate risks in drought-prone areas

This LU introduces ways to identify and assess climate risk by using a method that is not prescribed or rigid. The facilitator explains the steps during an interactive lecture and participants undertake a series of practical exercises for assessing both current and future climate risks.

Exercise 1:

Gain your own understanding of climate risks

The facilitator provides a sample frame of the **climate risk calendar** to the participants to identify the risks. It is also necessary to provide data on past climate risks, including frequency and impact, in order for participants to develop the risk calendar. Participants may be requested to recollect their experiences for a specific region to prepare this calendar.

Hazards	*kharif* I				*kharif* II				*rabi*			
	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
False onset of rain												
Early season drought												
Mid-season drought												
Terminal drought												
Seasonal drought												
Hailstorms												
Typhoons												
Wind storms												
High temperature												
Low temperature												

Exercise 2:

Rank (group) the above climate risks according to their frequency and severity based on your own experience and local perception

The criteria for categorizing severity might include an examination of potential damage, loss of produce, and the environmental and economic impacts on agriculture and allied sectors. This requires using the secondary data collected at district, upazilla and local level for impact analysis. The criteria for categorizing frequency might include the following options (although participants can also define their own frequency category based on the nature and severity of risks):

high frequency – events that occur more frequently than once in three years;

moderate frequency – events that occur from once in three years to five years;

low frequency – events that occur from once in five years to once in ten years;

very low frequency – events that occur less than once in ten years.

In this example, both the magnitude and frequency of a climate event are given qualitative measures that permit the prioritization of selected climate risks among multiple risks. Because the low frequency events may become high frequency events under climate change, they need to be given sufficient consideration.

Frequency ↑ / Severity →	Minor	Serious	Extensive	Catastrophe
High	C	B	A	A
Moderate	C	B	B	A
Low	D	C	B	B
Very Low	D	D	C	C

Class A: High-risk condition with highest priority for implementing adaptation measures

Class B: Moderate-to-high risk condition with risk to be addressed by adaptation

Class C: Risk condition sufficiently high to give consideration for further adaptation initiatives

Class D: Low-risk condition with additional adaptation initiatives

LU 3: Define the local perception of climate risks

Exercise:

Identify community/farmers' perceptions of current climate variability

Before prioritizing the identified risks, it is necessary for to evaluate them based on the community/farmers' perceptions. Table 4.1, based on field-level assessments in the ***Barind*** areas, is reproduced without the solid circles that indicate intensity. Participants are asked to complete the table, based on their own experience and perception. After the exercise the original table can be distributed and discussed further.

MODULE 5

Agricultural adaptation options to climate variability and climate change in drought-prone areas

This module can guide participants in developing agricultural adaptation options to manage climate variability and climate change in drought-prone areas of Bangladesh. These adaptation options should be based on the risks identified in the LUs and exercises found in Module 4. At the end of Module 5, participants should be able to:

1. prepare livelihood adaptation options to manage climate variability and change,
2. understand the relevance of adaptation options for livelihood development, and
3. gain understanding of changing livelihood portfolios in drought-prone areas.

Local communities try to cope with climate variability based on their past exposure and experience in managing climate extremes. These coping mechanisms evolve locally to deal with known and observed climate risks. For example, farming communities in the *Barind* areas cope with rainfall variability by adapting cropping systems with short-duration varieties that can be harvested before drought sets in during the later part of the monsoon season. When the variation in climate conditions is within a **coping range**, communities can absorb the risk without significant impacts. However, these local coping practices may not be sufficient to reduce the risk of increased climate variability and climate change appreciably.

Box 5.1: Adaptation and adaptive capacity

Coping range – is the range in which the effects of climate conditions are beneficial or negative but tolerable. Beyond the coping range, the damage or loss are no longer tolerable and a society (or system) is said to be vulnerable.

Adaptation – is a process by which strategies to moderate, cope with or take advantage of the consequences of climatic events are enhanced, developed and implemented.

Adaptive capacity – is the ability of a system to adjust its characteristics or behaviour in order to expand its coping range under existing climate variability or future climate conditions.

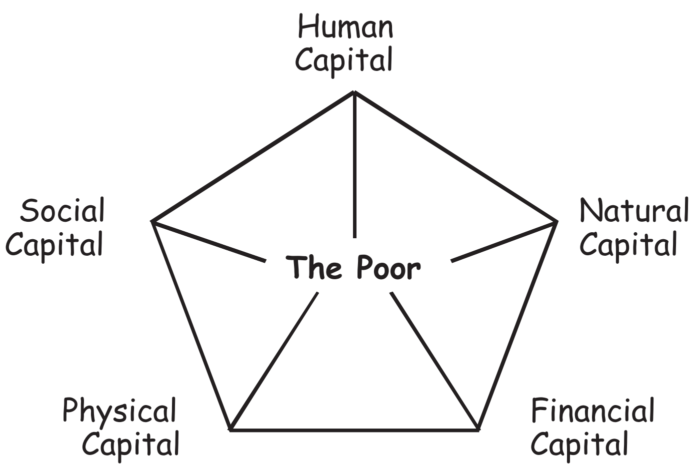
- Actions that lead to adaptation can enhance a system's coping capacity and increase its coping range thereby reducing its vulnerability to climate hazards.
- The adaptive capacity inherent in a system represents the set of resources available for adaptation, as well as the ability or capacity of that system to use these resources effectively in the pursuit of adaptation.
- In reality, success depends on many factors but, theoretically, the practice of adaptation has potential. It is possible to differentiate between the theoretical potential and reality by recognizing that the theoretical will be based on the level of existing expertise and anticipated developments that are dependent on existing information, technology and the resources of the system under consideration.

Future climate change and associated climate variability have the potential to lead to new risks in drought-prone areas of Bangladesh. Preparing for climate change is not something that individuals can do alone. It is a shared responsibility that requires partnerships across the community so that households, community groups, businesses and governments can make the necessary changes effectively and efficiently. Adapting to climate change is a primary way to manage the future climate risks.

Livelihood adaptation

To be effective, adaptation responses need to be tailored to individual circumstances based on the kind of risk faced (identified in Module 4). Adaptation options need to benefit the community and ensure community participation so that experiences of local-level adaptation strategies can be shared. Livelihood adaptation to climate change is a continuous process built on the socio-economic circumstances and adaptive capacity of the community. To implement adaptation measures in the agriculture sector, it is necessary to understand the potential impacts of climate change (identified in Module 3) and local perceptions (identified in module 4). The basic understanding in the context of climate change adaptation in drought-prone areas is that the adaptation option should have the potential to improve the livelihood assets (human, natural, financial, physical and social) of rural livelihoods.

Fig. 5.1. Livelihood assets of the rural poor



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 5.2, 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.

Fig.5.2. Sequential tasks in designing viable adaptation options for drought-prone areas

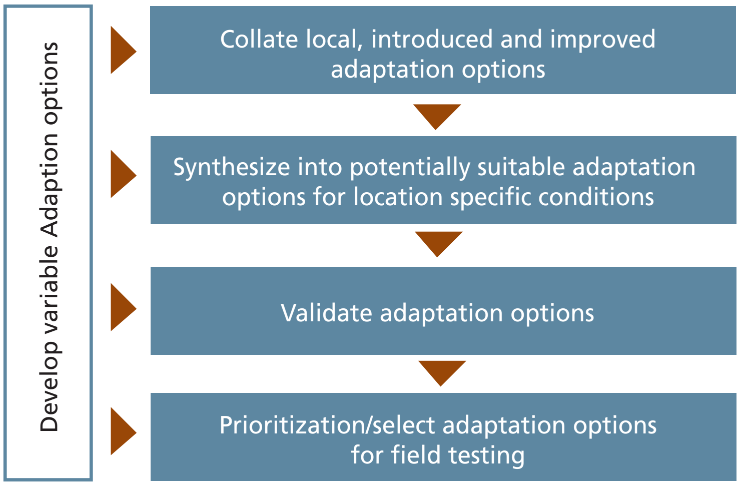
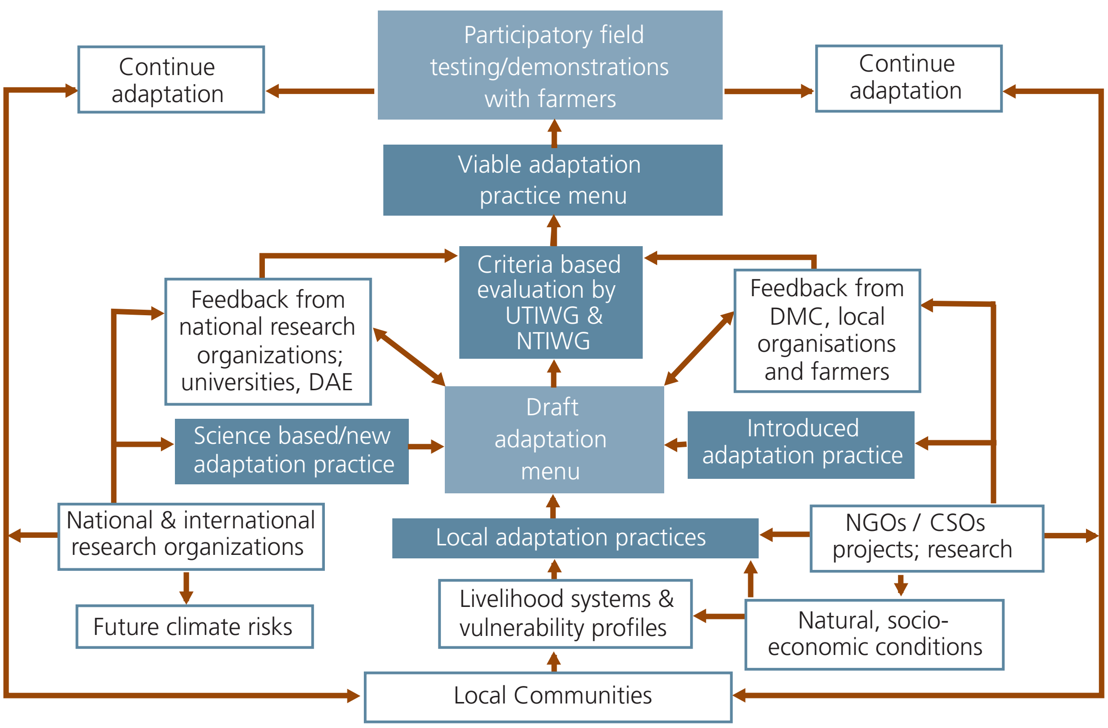


Fig 5.3. Overall framework and institutional structure describing activities and the processes of selection, evaluation and prioritization of adaptation practices for drought-prone areas in Bangladesh



Local adaptation practices and those practices introduced by national development, research and extension organizations need to be collected from the respective organizations and evaluated at different levels. The following example illustrates how current and future climate risks can be managed through adaptation options (identified through the comprehensive methodology presented in Fig.5.3).

Context 1:

Barind areas, currently dominated by rice during monsoon season, face various risks at different stages

Current risks	Future trend	Anticipated impacts	Adaptation practice	Relevance to livelihood asset development
Delayed onset of monsoon rainfall in June	Associated with variability and possibly of future increase	Delayed seedbed preparation and late planting; shortened growing period	Dry seedbed method for t.*aman* rice	Seedlings available for transplanting immediately after onset of rains
Low water-holding capacity of *Barind* soils	Land pressure may increase nutrient mining	Reduced crop yields due to low nutrient content and inadequate soil moisture	Manures and composting from locally available materials	Improves physical capital of local livelihoods
Short, dry spells during early stages of t.*aman*	Climate change may increase dry spell lengths due to greater rainfall variability	Young transplanted seedlings affected by dry topsoil and reduced root proliferation may lead to reduced yields	Transplanting at deeper depths means better root proliferation and facilitates moisture extraction during drought	Reduces labour requirement for re-planting in case of early season drought
Weed infestation competes for nutrients and water	Climate change may aggravate the complex, intense crop-weed competition	Intense competition for solar radiation, nutrients and moisture, weeds' smothering effect reduces yield	Controlling weeds manually combined with closing soil cracks	Saves water and nutrients and leads to financial gain due to yield increase
Loss of field water due to lateral seepage	More intense monsoon rainfall may lead to excessive loss of rain water	Increased exposure to mid-season drought due to lack of water in the field	Strengthening field bunds to conserve more rain water	Increases water availability and adequate water supply throughout the crop growth period

Context 2:

Communities in *Barind* areas of Northwest Bangladesh face water scarcity for their livelihood activities due to lack of rainwater storage facilities and low water use efficiency

Current risks	Future trend	Anticipated impacts	Adaptation practice	Relevance to livelihood asset development
Traditional ponds have lost their full water storage capacity	High intensity rainfall and heavy erosion may aggravate the risk	Lack of water for fish cultivation and supplemental irrigation	Re-excavation of traditional ponds	Improved water storage facilities; water available during dry season
Traditional *khari* canals affected by excess weed growth and silting	Higher rate of erosion and weed spread increases the risk of water loss	Reduced community-level water storage structures; blockage of water flow	Re-excavation of *khari* canals and other water conveyance structures	Assured water availability in dry season; minimized health risk for the rural poor
Improper water control structures and excessive rain water loss	Increased monsoon rainfall intensity; loss of excessive rain water	Excessive run-off, soil erosion and uncontrolled water flow may cause localized inundation	Building of water control structures; check dams across the water ways	Increased access to community water resources and reduced health risks from stagnant water
t.*aman* rice and rabi pulses face drought at various growth stages	Increased rainfall variability and longer dry spells	Reduced crop yield affects diet and nutrition	Construction of mini-ponds, shallow and deep tube wells	Increased farms access to water resources; diversified livelihood activities
Low water productivity in terms of yield/ unit of water	Higher temperature and evaporation lead to excessive water use	Decline in surface and groundwater resources; over exploitation of groundwater causes heavy metal contamination	Adoption of more intense rice cropping system	Increased water use efficiency and yield; water more accessible during dry season
Transplanting method requires more water and longer duration	Low yield due to high temperature and water scarcity	Increased high temperature stress; more evaporation	System of direct-sown rice using drum seeder	Requires less labour because of shorter duration; saves water
Local rice varieties are not tolerant to drought	Local varieties might be more sensitive to drought and high temperature	Excessive yield reduction	Drought- resistant, short- duration varieties that fit in monsoon rainfall pattern	Avoids excessive yield loss

Context 3:
In recent past, crop intensification has taken place in all seasons, exposing the agricultural systems to climate risks throughout the year

Current risks	Future trend	Anticipated impacts	Adaptation practice	Relevance to livelihood asset development
Declining yield of t.*aman* rice due to mono-cropping	Crop intensification, with rice only, to meet growing food needs	Susceptibility of rice varieties to climate events such as drought, intense rainfall	Introduction of green manure before t.*aman* rice system	Increased use of and accessibility to natural resource
Extreme climate events affect current rice systems	Crop intensification, with cereals only, may dominate	Exposure of rice to extreme events	Introduction of *Chini Atap* rice after t.aus season	Increased income at household level
Poor diet due to non-availability of oilseeds	Crop intensification, with cereals only, may dominate	Local poor have unbalanced diet	Introduction of mustard and linseed after t.*aman* season	Improved, proper use of available natural resources
Lack of protein in diets of the rural poor	Crop intensification, with cereals only, may dominate	Non-availability of protein-based diet	Introduction of mung bean and chickpea after t.*aman* rice season	Healthier population and better resource use
Seasonal famine conditions (*monga*)	Anticipated drought conditions would increase the seasonal famine conditions	Reduced capacity for food production and community to absorb seasonal shocks	Growing famine reserve crops such as cassava and yam	Reduced migration; increased employment opportunities; *monga* minimized

Context 4:

Diversified enterprise and enterprise mixing is required in drought-prone areas to improve the household financial position throughout the year

Current risks	Future trend	Anticipated impacts	Adaptation practice	Relevance to livelihood asset development
High temperatures induce ripening of existing mango varieties	Climate change models project increased temperature	All varieties will ripen at the same time causing price drop	Introduction of high- temperature-tolerant mango and jujube (ber) varieties	Autonomous adaptation by farmers in *Barind* tract would expand, to reduce drought impact
Existing crops are not sustainable under climate change	Cereal-dominated systems affected by temperature increase and drought	Yield reduction and decreased income	Mulberry intercropping in rice fields	Drought-tolerant mulberry would not cause shade on rice crop
Livestock face severe fodder problems during drought years	Intensification of food crop cultivation to meet growing food needs leaves less area for fodder cultivation	Area under fodder crop would be reduced	Small-scale fodder cultivation	Maintaining crop-animal mixture in small farms of *Barind* tract would help farm income generation
Lack of water in traditional ponds affects small-scale fish production	Drought intensity and frequency may increase and affect small- scale fish production	Small-scale seasonal fish production would be affected	Small-scale fish cultivation in mini-ponds	Enhanced alternative livelihood options for rural poor
Poor people lack access to financial resources for investment	Livelihood activities in drought-prone areas would face increased impact of drought; livelihood activities would suffer	Household income would be reduced	Enhancing facilities for cottage industries	Alternative earning sources for rural populations to meet household expenses
Household income is not sufficient to meet daily needs, income is seasonal, lack of off-season employment opportunities for family labour	Climate change may increase need for off-farm employment	Household income would be reduced	Homestead gardens	Gender integration in agriculture, nutritional security, year- round income

Examples of good adaptation practices

Mini Ponds for rain water harvesting

Re-excavation of ponds can be undertaken in areas of extreme water scarcity preferably in high Barind Tract areas. If land is found on a voluntary basis, new excavation may be taken up with the concurrence of the owner. In farmlands with no irrigation source, rainwater harvesting can be done through these mini-ponds for supplemental irrigation. Mini-ponds of 5m x 5m x 2m (length x breadth x depth) size is preferred in small farms. It is also proposed to excavate larger ponds (10m x 10m x 2m) as per requirement. Some farmers wanted to have these mini-ponds in a corner of the field. Adequate awareness about the utility of ponds needs to be created with the local community.

Resources required: limited family labour.
Potential maladaptation: none.
Non-climatic benefits: growing short duration vegetables along the farm pond; supplemental irrigation.

Homestead gardening

The indigenous knowledge of the local population regarding environmentally friendly land management needs to be encouraged. In the Barind Tract, tree species such mango, mahogany and jackfruit are being grown in uplands (*chalas*) around homestead, and are some times used for growing vegetables. The lowlands (*baid*) are generally used for growing paddy. This practice increases moisture retention, improves soil fertility and crop yield and reduces surface runoff , thus halting soil erosion.

Home garden systems in drought prone areas provide healthy ecosystem for humans, animals, birds, livestock and miscellaneous flora and fauna. Homestead bamboos are also planted because these develop rapidly and are good soil binders. Use of homestead litter, ash supplements and organic matter in the soil keeps insects away. Homestead gardening helps produce vegetables for household requirements and sometimes for external marketing. Women are engaged in homestead gardening as an income diversification activity. As the rainfed Barind Tract is mostly dominated by rice during *kharif* II season, integration of homestead gardening within the household system provides varied nutrients and thus helps to ensure household nutrient security. Practicing homestead gardening in drought-prone areas helps integrate gender concerns within the climate change adaptation framework.

BARI has developed economically feasible homestead garden models for Barind Tract areas. The components of the homestead garden models include drought-resistant fruit trees and vegetables.

Resources required: homestead land, propagation materials and seeds of drought resistant vegetable seeds.

Potential maladaptation: none.

Non-climatic benefits: gender integration in agriculture, nutritional security, year round income.

Mango and Jujube cultivation

Mango and Jujube (*Ziziphus jujuba* Mill) are alternative and promising crops to manage drought in Barind areas. Area under mango is increasing every year, as the region is known for its quality mango production and higher yield. The crop is many times more profitable than T.*aman* rice. The inter-spaces in the young mango plantations are intercropped with T.*aman* and *boro* rice. Many varieties of different maturity groups are widely grown in this region.

All varieties flower at the same time of the year, normally in February, showing a synchronized flowering behavior. Maturity of these mango varieties depends on temperature pattern during summer months from March to May, and their harvest windows vary from 15 May to 15 August. According to farmers' experience, varieties such as *langra* are highly suitable for the region as damage due to abnormal weather during flowering is not significant compared to other varieties. The disadvantage of mango intercropping, however, is that intercropping with rice is no more possible after three years of growth to the shading cover of mature mango trees.

The jujube (*Ziziphus jujuba* Mill) is a tropical fruit crop able to withstand a wide range of temperatures. One of the outstanding qualities of the jujube is its tolerance of drought conditions. The crop can be cultivated successfully in Barind Tracts with little irrigation. The jujube filed can be intercropped with T.*aman* rice during *kharif* II season.

Resources required: pits for planting mango/jujube saplings, drought tolerant mango/jujube saplings; low cost fencing and limited labour.

Potential maladaptation: synchronized maturity under high temperature and associated market problems. Jujube has the potential to withstand high temperature.

Non-climatic benefits: improved standard of living, additional employment opportunities if pulp industries are developed.

Training strategy

This training module needs to be delivered in at least one session (4-5 hours) on the morning of the third day. It consists of three LUs.

1. Presenting livelihood adaptation options to manage climate variability and change.
2. Explaining the relevance of adaptation options for livelihood development.
3. Increasing understanding of anticipated changes in livelihood portfolios in drought-prone areas.

LU 1: Presenting livelihood adaptation options to manage climate variability and change

This LU explains the steps for preparing livelihood adaptation options to manage climate variability and change. The facilitator conducts an interactive lecture, including material from Box 5.1 and Figures 5.1, 5.2 and 5.3, that introduces key definitions, concepts of livelihood assets and steps for preparing adaptation options. Participants also learn about the methodology and processes for developing viable adaptation options to manage climate risks in agriculture sector.

LU 2: Explaining the relevance of adaptation options for livelihood development

This LU explains current and anticipated future climate risks, adaptation practices and their relevance to livelihood development in drought-prone areas of Bangladesh. The facilitator can explain Context Tables 1-4 briefly, to raise awareness of the identified adaptation practices under future climate change. The adaptation practices are targeted to manage both current and future climate risks. The facilitator need to include the climate change scenarios presented in Module 2.

Exercise 1:

Gain experience in managing drought risks

Facilitator asks participants to prepare a matrix similar to the one used in the Context Tables in order to list new sets of adaptation practices for the agriculture, water resources, livestock and fishery sectors.

Exercise 2:

Suitability of adaptation practices

Facilitator and participants discuss the adaptation practices listed in the Context Tables for their suitability, cost effectiveness and adaptability for drought-prone areas in Bangladesh.

Exercise 3:

Developing extension strategy for pilot testing adaptation practices

It is very important to have follow-up to the climate risk assessment at community level. An appropriate strategy needs to be developed to test viable adaptation practices. Participants are asked to complete the table below. The extension strategy may include brief procedures. The adaptation practices in the following table have been identified through community-level interactions.

Sl. No	Adaptation practice	Extension strategy
1.	Seedbed method for t.*aman* rice	
2.	Manures and composting	
3.	Depth of transplanting for t.*aman*	
4.	Weed control/reduce water seepage	
5.	Manual closing of soil cracks	
6.	Strengthening field bunds	
7.	Re-excavation of traditional ponds	
8.	Re-excavation of *khari* canals	
9.	Canals	
10.	Water control structures	
11.	Mini-ponds	
12.	Supplemental irrigation	
13.	Shallow and deep tube wells	
14.	System of rice intensification	
15.	Direct-sown rice (drum seeder)	
16.	Drought-resistant rice varieties	
17. a)	Green manure – T.*aman* system	
b)	T.aus – *Chini Atap* system	
c)	T.*aman* – mustard/linseed system	
d)	T.*aman* – chickpea system	
e)	T.*aman* – mungbean system	
f)	Famine reserve crops	
18.	Mango/*jujube* (ber) cultivation	
19.	Homestead gardens	
20.	Mulberry intercropping in rice	
21.	Fodder cultivation	
22.	Fish cultivation in mini ponds	
23.	Cottage industries	
24.	Manufacturing industries	
25.	Community-based biogas production and tree planting	
26.	Seed storage for higher viability	

LU 3: Increasing understanding of anticipated changes in livelihood portfolios in drought-prone areas

The following table looks at recent changes in livelihood patterns, some of which are attributed to climatic risk over the years. The fact that the projections for drought-prone areas of Bangladesh predict significant climate change indicates that the livelihood patterns may also change.

Exercise 1:

Review past changes in livelihood portfolios among rural women and men

This includes discussion of possible future changes to livelihood portfolios in drought-prone areas that are likely to occur with increased climate variability and climate change.

Livelihood activities	In the past	At present	In future
Women			
Household work as maid	Common	Less common	
Paddy husking	Common	Rare	
Boiling paddy and selling	Common	Rare	
Cleaning	Common	Less common	
Embroidering and stitching garments	Absent	Common	
Craft manufacturing (rope, containers, hand fans, mats, etc.)	Common	Common	
Earth-work labour sale	Rare	Common	
Running a small grocery store	Absent	Less common	
Sowing seedlings	Absent	Less common	
Weeding	Absent	Less common	
Irrigating commercial vegetable plots	Absent	Less common	
Harvesting commercial vegetables	Absent	Common	
Harvesting root crops	Common	Common	
Post-harvest processing	Common	Common	
Regular private jobs	Absent	Common	
Traditional poultry, goat rearing	Common	Common	
Traditional cattle rearing	Less common	Common	
Small-scale poultry rearing	Absent	Common	
Cocoon rearing	Absent	Common	
Vending foods at markets	Absent	Less Common	
Vending garments at the village level	Absent	Less common	
Pottery	Common	Less common	

Livelihood activities	In the past	At present	In future
Men			
Farming on own land	Common	Less common	
Traditional ploughing	More common	Common	
Mechanized ploughing	Absent	Increasing	
Farming on rented land	Less common	Common	
On-farm (agri) day labour	Common	Less common	
On-farm contract labour	Common	Less common	
Non-agri (off-farm) day labour	Less common	Increasing	
Non-farm (rickshaw/van pulling)	Absent	Common	
Factory/industrial worker	Rare	Common	
Mechanics	Rare	Common	
Bus/truck driving	Less Common	Common	
Fishing	Common	Less common	
Grocery shop in the village	Rare	Common	
Small business (vending)	Less common	Common	
Medium business	Less common	Common	
Service in government offices	Rare	Common	
Service in NGOs	Absent	Common	
Service in private offices	Rare	Common	
Part-time service	Absent	Less common	
Cattle rearing	Less common	Common	
Commercial poultry rearing	Absent	Common	
Commercial vegetable production	Absent	Common	
Cutting of trees for timber and fuel	Common	Common	
Nurseries (fruit trees)	Absent	Common	
Goat rearing	Common	Less common	
Dairy production	Common	Increasing	
Crafts production	Less common	Common	
Pottery	Common	Less common	

MODULE 6

Climate forecast application to improve adaptive capacity

The purpose of this module is to introduce the forecast products currently available in Bangladesh and explain their utility for improving the adaptive capacity of rural livelihoods to climate risks. Upon completion of this module, participants should be able to:

- describe the various types of forecast products available in Bangladesh,
- elaborate how current forecast products may be used for drought risk management in agriculture and allied sectors, and
- understand rainfall forecasts and their use in decision-making

Improved climate information and prediction is one of the most important elements of adaptation. Adaptation requires working in multiple time scales, from short term to the very long term, addressing climate variability and change through a range of forecasting systems to add incremental value to the entire adaptation process.

Climate change models possess inherent uncertainties. Thus, generating locally usable climate change information in drought-prone areas requires additional considerations. There will be a need to incorporate short-, medium- and long-lead climate forecast information products in order to develop location-specific impact outlooks and agricultural response options.

Box 6.1: Weather and Climate forecasting

Weather forecasts predict the behaviour of the atmosphere over the course of a few days.

Climate forecasting looks at the likely patterns of climate variables such as rainfall and temperature for longer periods (months or seasons) with sufficient lead-time (before the start of the season).

Forecasting weather refers to the likely behaviour of the atmosphere in advance or foretelling the likely status of the atmosphere in relation to various weather parameters such as rainfall, temperature or wind. Generally, forecasts involving weather and climate are divided into three major types based on their lead-time: short range, medium range and long range.

Short-range forecasts, covering a period of 24 to 72 hours, are based on atmospheric circulation patterns that are monitored by satellites and synoptic observatories. Their accuracy is high, as they cover only a few days. This method is used to forecast cyclones, associated wind speed and temperature and is useful for timing decisions on sowing/planting, harvesting, fertilizer application and post-harvest operations.

Medium-range forecasts, covering a period of three to ten days, are based on numerical weather prediction models (mathematical formulae) that explain physical atmospheric processes. This method can provide information about rainfall, wind speed, wind direction, cloud cover and temperature and, on occasion, can extend forecasting to 25 or 30 days. This type of forecasting is useful for timing decisions on such activities as sowing/planting, irrigation or harvesting.

Long-range forecasts, covering a period of a month up to a season or more, are generated using statistical relationships between rainfall and various atmospheric and oceanic variables. Currently, General Circulation Models (GCMs) are used for seasonal or long-range forecasting which is also referred to as climate forecasting or seasonal climate forecasting. Seasonal climate forecast maps are usually qualitative, indicating probability of wetter/drier than normal conditions. Such seasonal forecasts, including analog and climatology forecasts, are adequate for understanding general trends. The long-range forecasts are highly useful for drought risk management in agriculture. The long-range forecasts support decisions on such matters as choice of crop/cropping systems, selection of crop varieties and resource allocation.

Weather and climate forecasts in Bangladesh

The Bangladesh Meteorological Department (BMD), under the Ministry of Defense, provides relevant weather forecasts on a regular basis. It operates 35 meteorological stations throughout the country, of which ten provide agro-meteorological data, reporting daily to the central office in Dhaka. The BMD Storm Warning Centre (SWC) issues daily forecasts based on analysis of meteorological charts and satellite and radar images.

Special bulletins on drought

In addition to routine daily forecasts, BMD issues special weather bulletins for heavy rainfall, droughts, tropical cyclones and associated storm surges. In addition, it issues one-month forecasts for the general public and authorities and long-term agro-meteorological forecasts valid for three months (updated every month). Medium-range, 10-day agro-meteorological advisories are also issued.

Observation network

In the above forecasts, meteorological observations are used as basic input. BMD has a meteorological observation network throughout the country consisting of 35 surface observatories recording observations eight times a day. Ten Pilot Balloon Observatories record upper wind direction and speed four times a day, three Radiosonde Stations record upper-air wind, temperature, humidity and pressure twice a day. The BMD also operates 10 agro-meteorological stations.

The Agro-meteorological Division of BMD issues a bulletin every ten days with meteorological data from 32 meteorological stations, highlights the rainfall situation and offers 10-day forecasts. The Department of Agricultural Extension (DAE) operates 64 rainfall stations, one at each district agricultural office. Daily rainfall data is compiled by the BMD Deputy Director's office and communicated to the DAE in Dhaka.

Application of climate forecasts

The effective use of climate forecasts requires that:

- the right audience receives and correctly interprets the right information at the right time,
- the information is relevant to decisions concerning drought risk reduction, and
- the forecast information is supplemented with impact outlooks and a drought management plan.

The criteria for effective communication of climate forecasts are:

- forecast products should contain relevant information that is important to the user community (local extension officers and farmers),
- a probabilistic forecast should accompany information on the possible impact of drought and risk management measures.

Preparation of drought risk and management plan matrix

The adaptation options to climate change require appropriate use of climate information. Achieving potential crop yield requires increased resource management through appropriate use of climate information. It is essential to identify the key drought risks during the crop growth cycle and the management alternatives.

Drought during the monsoon as well as in the dry season is very common due to the high level of rainfall variability. Aus rice is affected by early drought or the false start of monsoon rains with breaks at the beginning that cause poor crop establishment. The *aus* and t.*aman* crops are constantly affected by mid-season and terminal drought in the high *Barind* tracts. In medium highlands, t.*aman* is affected by late season drought during October and November. Adjusting the time of transplanting of t.*aman*, based on climate forecast information, can reduce the impacts of drought. Alternative options would be to select drought-tolerant varieties.

Table 6.1. Key drought risks and management plan matrix for applying climate forecasts

Crop	Agri-practice	Decision window (time)	Type of climate risk	Information needed for drought preparedness	Time lag (days)	Management plan to reduce risk
Aus	Sowing	Mar 15 – Apr 30	False onset of rain and subsequent dry spell	Onset of rains	15	Timely or delayed sowing
T.*aman*	Sowing	July 1 – Aug 15	Dry spell affects the early establishment in highlands	Chance of dry spell	15	Delayed sowing
Boro	Sowing/ seed bed	Nov 15 –Dec 31	Inadequate rainfall during Nov/Dec affects establishment	Chance of rainfall	15	Early/delayed sowing of *boro* coinciding with rainfall during Nov/Dec
Boro	Harvesting	Apr 1 – May 15	Hail storms damage crop	Hail storms/ Nor'westers	10	Advanced harvest to reduce yield loss

Short- to medium-range rainfall forecasting is useful for decision-making related to:

- planning for early harvesting,
- planning rice transplanting,
- planning for extra seedlings to replant,
- managing water scarcity for culture fisheries,
- taking precautionary measures to protect livestock from excess heat.

Long range/seasonal forecasts are useful for decision-making related to:

- planning cropping systems,
- planning drought-response activities,
- organizing logistics for humanitarian response.

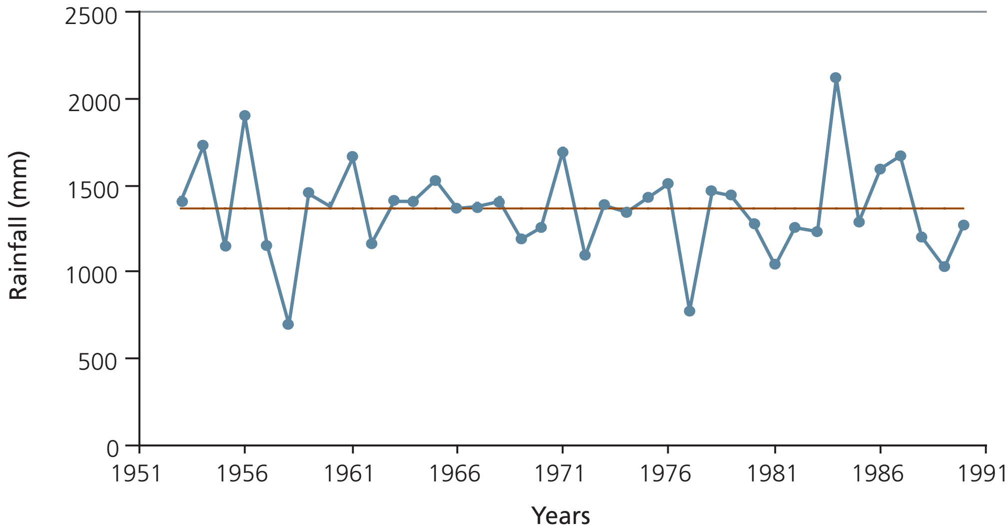
Table 6.2. Key decisions associated with climate related risks and decision responses

Crop	Key decisions	Decision window	Type of risk	Information requirement	Time lag (days)	Decision response
Wheat	Sowing	Nov 10 – Dec 31	Low temperature during flowering causes yield reduction	Possible range of minimum temperature	30	Advance/delayed sowing to skip low temperature injury
Rabi crops	Sowing	Nov 10 – Dec 15	Inadequate soil moisture could cause low plant stand	Possible soil moisture content	15	Arranging seeds and other inputs
	Plant protection	Dec 15 – Jan 30	Pest and disease attack due to unfavourable weather	Possibility of pest and disease outbreak	10	Arranging plant protection chemicals

Understanding probabilistic climate forecasts

Considering the uncertainty of the atmosphere, probability forecasts are considered the most appropriate method for predicting possible future events. Probability forecast methods generally are used in long-range/seasonal forecasts. Probability here refers to the chance of a certain amount of rainfall occurring.

Fig.6.1. Times series of monsoon season rainfall for Dhaka from 1953 to 1990 (38 years)



For example, Fig. 6.1, which gives the monsoon (June to September) rainfall of Dhaka from 1953 to 1990, shows that the rainfall varies from 703 mm to 2 120 mm in four months. The mean seasonal rainfall is 1 361 mm but that is an average, it does not mean that one can expect 1 361 mm during summer monsoon.

Table 6.3. Expected quantity of rainfall at Dhaka (1953-1990) under various probability levels

Rainfall (Jun to Sep)	Rainfall (mm)
Highest on record (mm)	2 120
10% of years, rain was at least	1 692
20%	1 541
30%	1 449
40%	1 408
50% (median rainfall)	1 377
60%	1 280
70%	1 248
80%	1 161
90%	1 032
Lowest on record (mm)	703
Years in historical record	38
Standard deviation (mm)	273
Average rainfall (mm)	1 361

Table 6.3 indicates the lowest recorded rainfall in the 38-year period 1953-1990 was 703 mm (1958). Based on the records, one can expect that the rainfall during the coming season will be more than 703 mm as it was the lowest amount ever recorded. Note that all 38 monsoon seasons had at least 703 mm of rainfall. The second driest monsoon rainfall on record was 772 mm in 1977. Out of 38 years, 37 years had at least 772 mm of rainfall. If the expectation is more than 703 mm, the chance declines considerably.

The same is true for the wettest year. The highest amount of rainfall recorded in the 1953-1990 period was 2 120 mm (1984). The second wettest year had 1 896 mm (1956). Interpreting this indicates that the chance (probability) of getting at least 1 896 mm is only 5 percent. In 50 percent of the years, the rainfall was at least 1 377 mm. This further indicates that there is only a 50 percent chance to receive 1 377 mm and above.

Extension personnel and farmers understand and regularly employ a range of drought preparedness strategies. Climate forecasts decrease the risk of drought impact only when uncertainty associated with forecasts is communicated properly. Failure to communicate or understand the uncertainty of forecasts exposes users to excessive risk.

Figure 6.2 indicates the summer monsoon rainfall recorded at Dhaka in the 38 year-period from 1953-1990. The curve indicates that there is an extremely high chance of receiving the lowest amount of rainfall. In other words, the chance of receiving 1 100 mm of rainfall is 88 percent, while the chance of receiving 1 500 mm is only 22 percent.

Fig. 6.2. Monsoon rainfall amount and associated probabilities

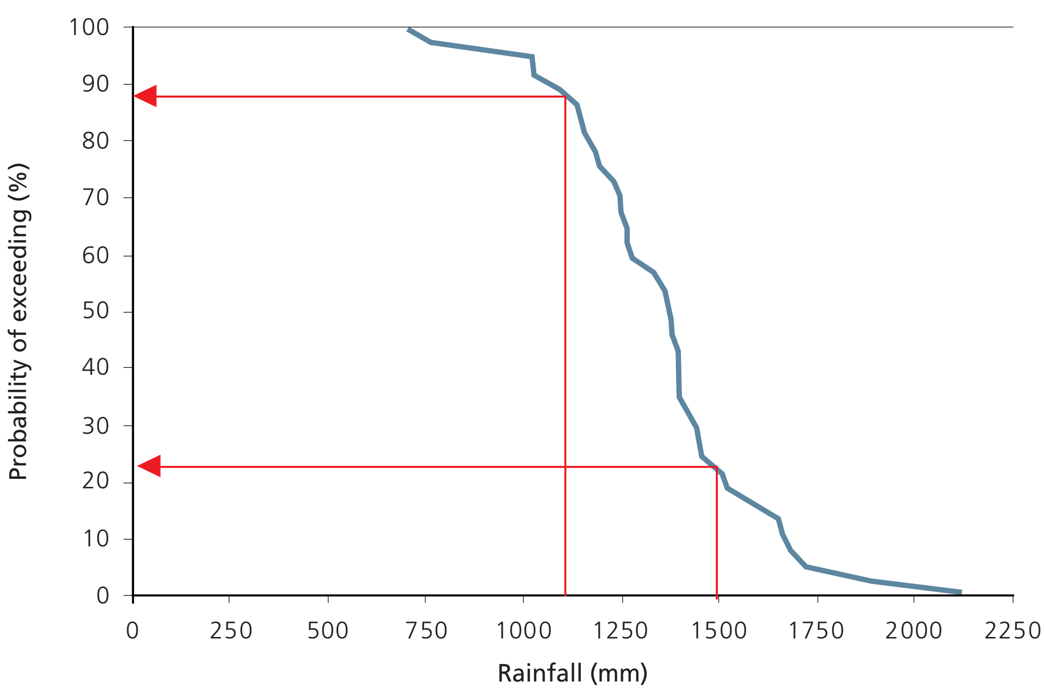
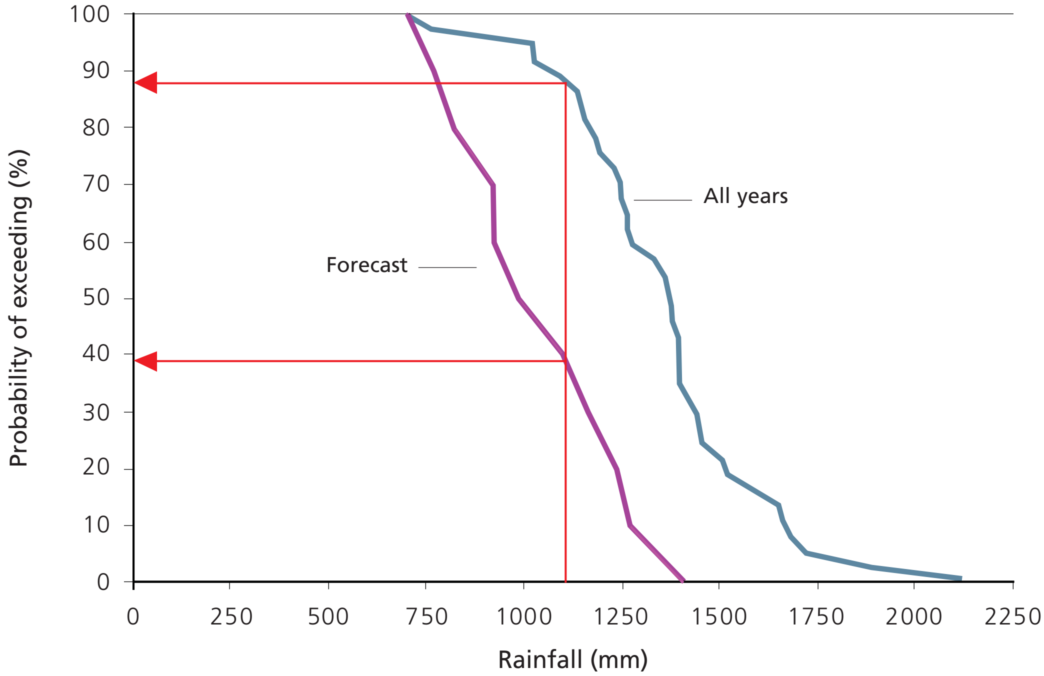


Fig.6.3. Monsoon rainfall amounts and associated probabilities based on all year distribution and forecast distribution



On the other hand, Fig. 6.3 indicates the rainfall received in two groups of years. One line describes the observed rainfall in all years between 1953 and 1990, while another line describes a group of years that received lowest rainfall. Obviously the two lines are different – the “all years” line indicates that the chance of receiving 1 100 mm is 88 percent, while the line describing the rainfall amount for selected years (forecast distribution) indicates the chance of receiving 1 100 mm is only 38 percent. This second line actually indicates that the chance of receiving the amount of rainfall necessary for a successful crop season is comparatively lower. Thus, in order to make an agricultural adjustment to manage cropping, it is important to consider the forecast distribution as well as the “all years” line, because it indicates the higher risk of drought. With the forecast line giving this extra information that an upcoming season will be drier than normal, it is possible to advise farmers to initiate their drought management practices.

Training strategy

This training module needs to be delivered in at least one session (4-5 hours) on the afternoon of the third day. It consists of three LUs.

1. Explanation of the types of forecast products available in Bangladesh.
2. Guidance on use of current forecast products for drought risk management.
3. Looking at probabilistic rainfall forecasts and their potential use for decision-making.

LU 1: Explanation of the types of forecast products available in Bangladesh

This LU is designed to explain different types of forecast products available in Bangladesh. This includes an interactive lecture on key definitions and background about each forecasting type.

Exercise: Review of forecast bulletins – Participants review the forecast products and interpret them. The facilitators should ensure that all participants understand how to interpret the bulletins. Alternatively, selected participants can be requested to present forecast bulletins that can then be discussed by the group.

LU 2: Guidance on the use of current forecast products for drought risk management

This LU is prepared to familiarize the participants with how to use the forecast products for drought risk management. Application of forecast information for climate risk management involves three major steps: interpretation, translation and communication. Interpretation is addressed in LU 1. Translation involves preparation of alternative management plans to reduce the impact of drought. This task may be addressed by use of the following table. The facilitator introduces the subject and then gives a copy of the table to the participants and asks them to complete it. Once it is completed, the facilitator presents tables 6.1 and 6.2 for review.

Crop	Agricultural practices	Decision window (time)	Type of climate risk	Information needed for drought preparedness	Time lag (days)	Management plan to reduce risk
aus						
T.*aman*						
Boro						
Wheat						
Other rabi crops						

LU 3: Looking at probabilistic rainfall forecasts and their potential use for decision-making

Understanding probabilistic forecasts is one of the challenges in forecast application. In this LU, the facilitator introduces the participants to probabilistic forecasts. This session involves a brief lecture and exercise. The section "understanding probabilistic forecasts" needs to be explained to the participants. The lecture should be followed by an exercise using available long-term rainfall data (preferably 30 years). Participants are asked to prepare a table similar to Table 6.3, putting the highest rainfall amount on top and then in descending order with the lowest rainfall on record at the bottom. The facilitator should explain the chance of getting each amount of rainfall. The following questions may be helpful to increase understanding:

- What is the expected rainfall at 50 percent chance?
- What was the wettest monsoon?
- What was the driest monsoon?

Further reading

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Climate variability and change: adaptation to drought in Bangladesh

A resource book and training guide

The impacts of increasing climatic variability and change are global concerns but in Bangladesh, where large numbers of people are chronically exposed and vulnerable to a range of natural hazards, they are particulary critical. Agriculture is the largest sector of the economy, but agricultural production is already under pressure from increasing demands for food. Increasing climate variability and climate change are expected to aggravate vulnerabilities further by causing more frequent and intense droughts and increasing temperatures. Within this context, FAO and the Asian Disaster Preparedness Center are guiding the project "Livelihood adaptation to climate variability and change in the drought-prone areas of Northwest Bangladesh", which is implemented under the Comprehensive Disaster Management Programme and in close collaboration with the Department of Agricultural Extension. It is specifically designed to characterize livelihood systems, profile vulnerable groups, assess past and current climate impacts, and increase understanding of local perceptions of climate impacts, coping capacities and existing adaptation strategies.

As part of this initiative, a series of capacity-building and training activities on climate change impacts and adaptation to drought has been undertaken for national and local-level technical working group members, disaster managers and community representatives.

This resource book, *Climate variability and change: adaptation to drought in Bangladesh*, has been tested and prepared as a reference and guide for further training and capacity building of agricultural extension workers and development professionals to deal with climate change impacts and adaptation, using the example of drought-prone areas of Bangladesh. It also presents suggestions for a three-day training course that would be readily adaptable for any areas of Bangladesh affected by climate-related risks. The information presented on climate change adaptation would enable participants to prepare, demonstrate and implement location-specific adaptation practices and, thus, to improve the adaptive capacity of rural livelihoods to climate change in agriculture and allied sectors.

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