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

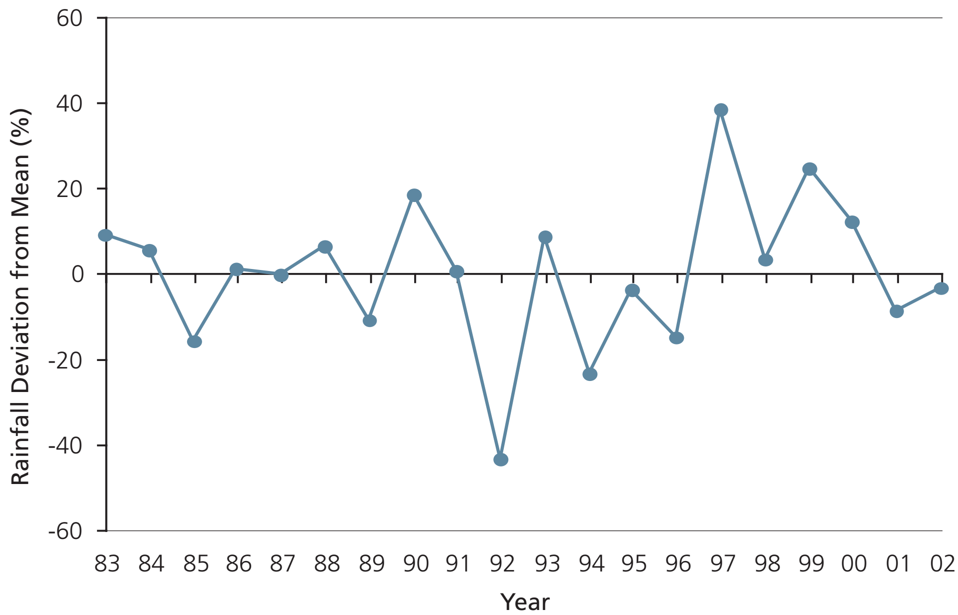
Weather is the day-to-day state of the atmosphere and its short-term (from hours to a few weeks) variations such as temperature, humidity, precipitation, cloudiness, visibility or wind.

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)

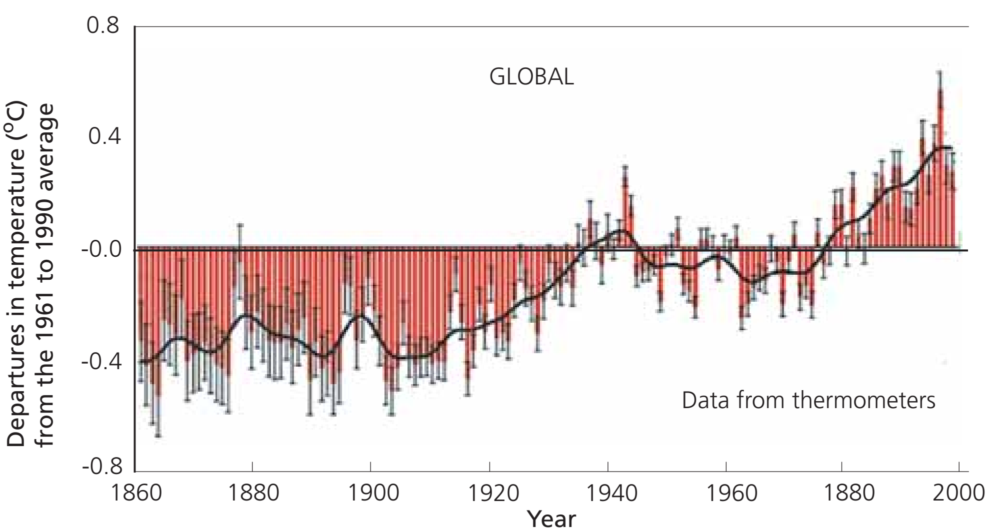
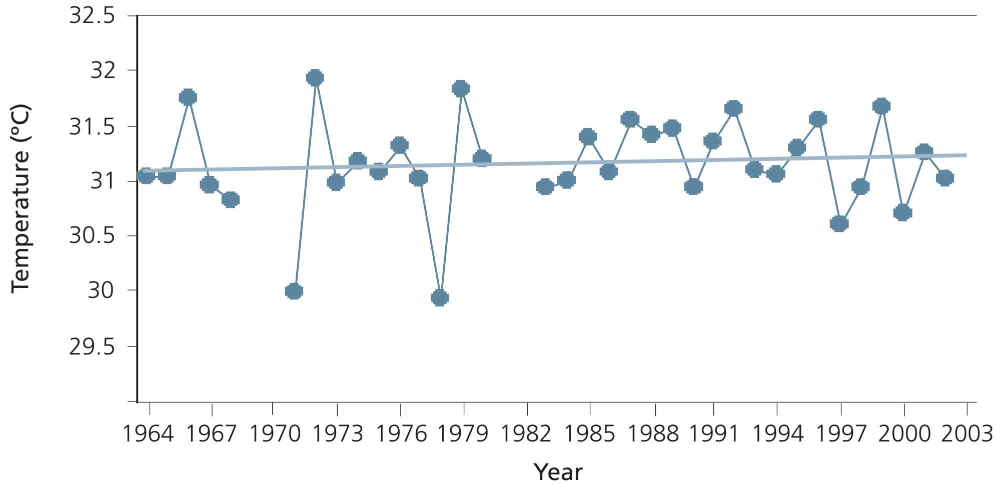


Fig. 1.3 displays the year-to-year variation of average temperature for the period from 1964 to 2003 in Northwest Bangladesh. It shows a slight increase in temperature. The year-to-year change in temperature was substantially larger than the long-term average, with fluctuations up to plus or minus 1°C.

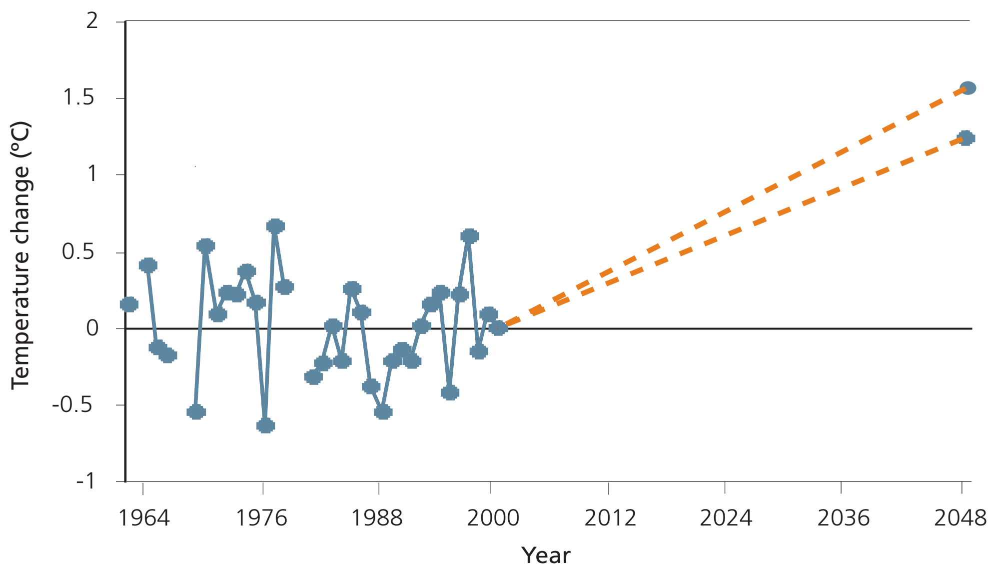
Fig.1.3. Annual average maximum temperature variations (1964-2003) in Northwest (Barind tract) Bangladesh



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)



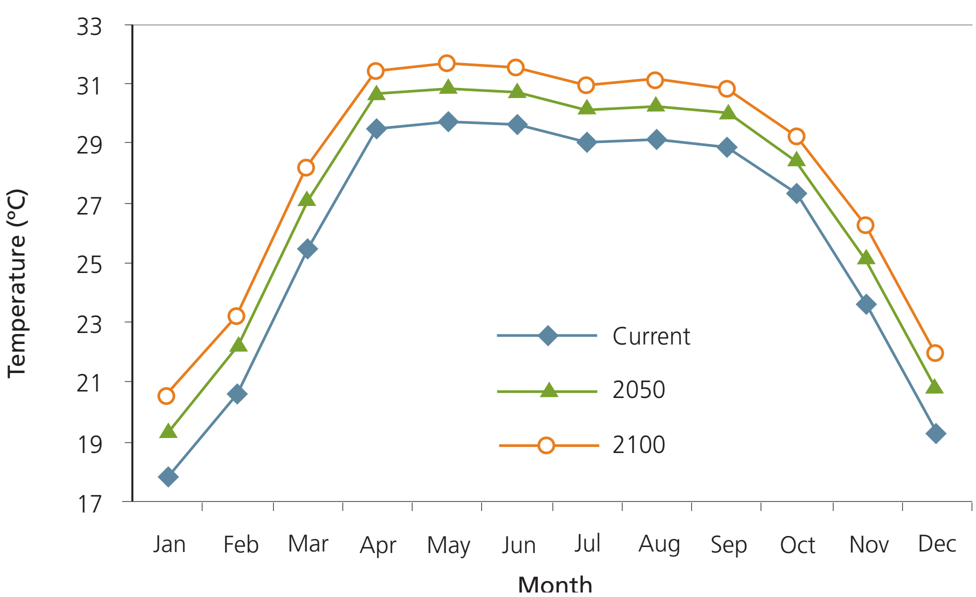
GCM analysis indicates that the average temperature of Bangladesh will increase by 1.4°C (±0.16) by 2050. Fig. 1.4 shows the average temperature variations from 1964 to 2003 and projects the temperature for Bangladesh until 2050. The two doted lines, representing the lower and upper bounds of the 2050 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.

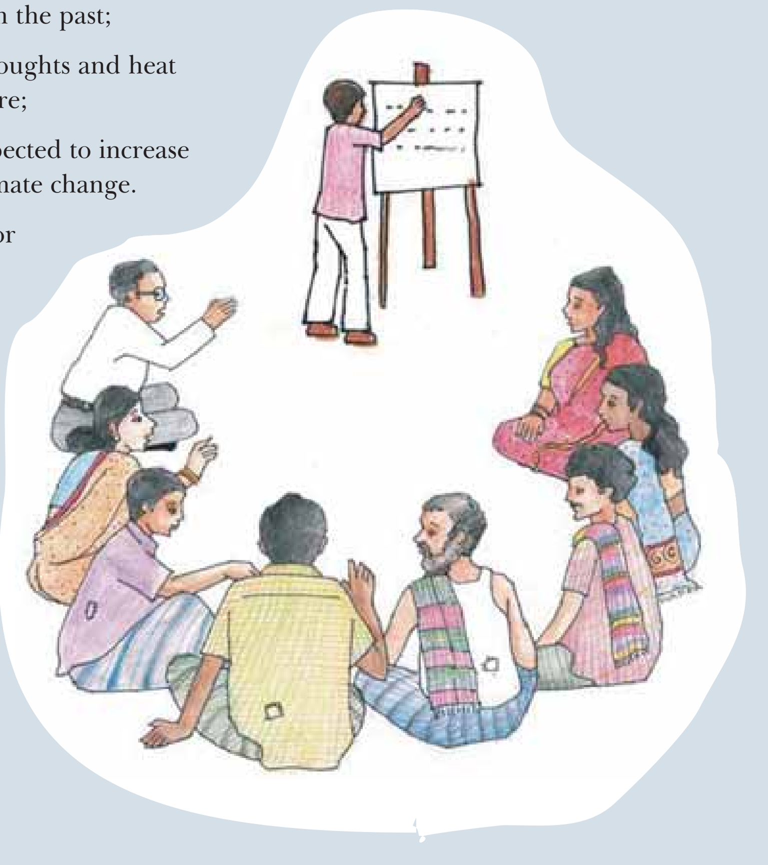
Months	1960-1990			2030			2050		
	Rainfall (mm)	T. Max (ºC)	T. Min (ºC)	Rainfall (mm)	T. Max (ºC)	T. Min (ºC)	Rainfall (mm)	T. Max (ºC)	T. Min (ºC)
Jan	17	24.4	10.9						
Feb	14	27.2	13.1						
Mar	30	31.5	17.2						
Apr	79	33.7	21.4						
May	222	32.7	23.3						
Jun	328	32.2	25.2						
Jul	434	31.7	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

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.

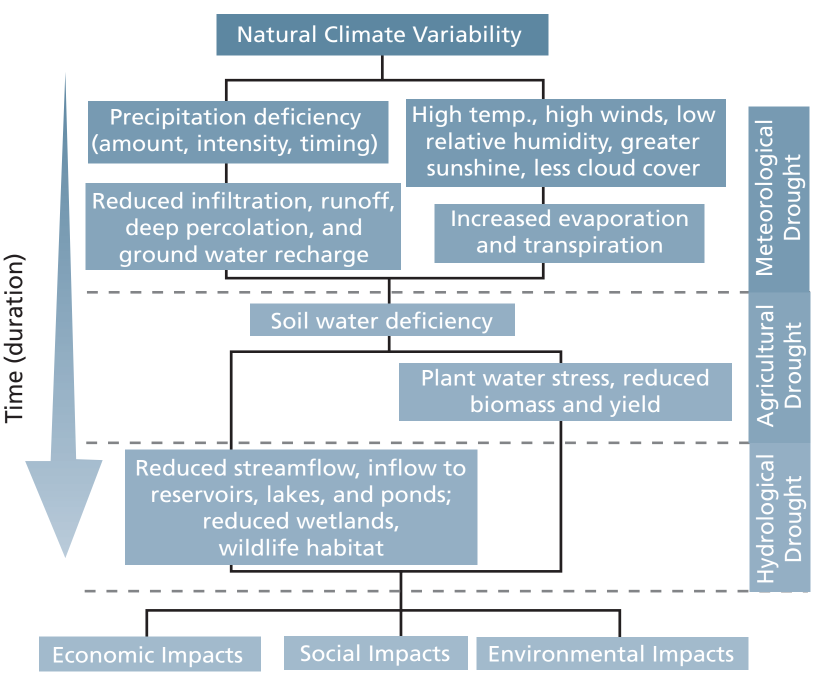
Short-term drought episodes can be linked to global atmospheric and oceanic circulation features. For example, the El Nino/southern oscillation (ENSO) phenomenon, which results from development of warm surface water off the Pacific coast of South America, affects the levels of rainfall in many parts 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.

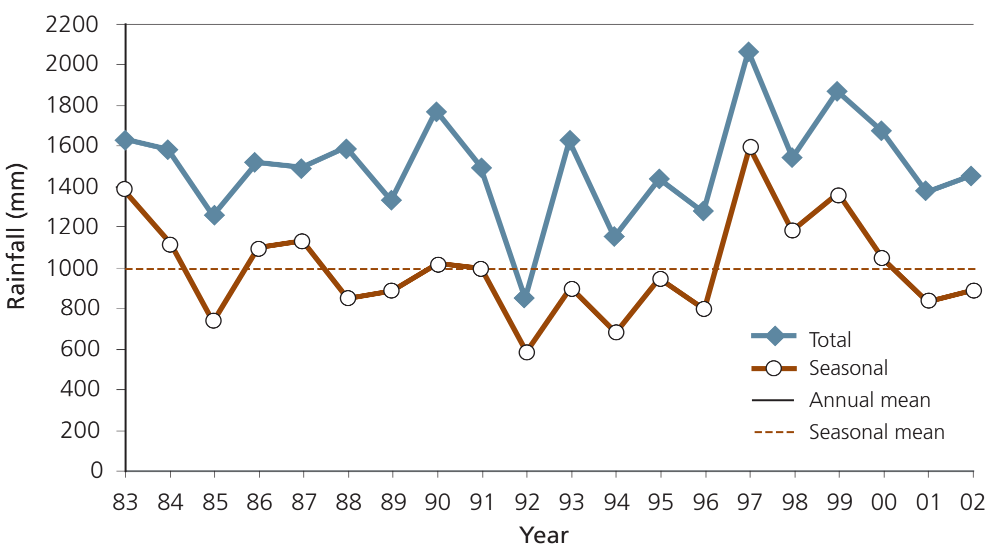
Meteorological drought occurs when the reduction in rainfall for a specified period (day, month, season or year) is below a specified amount – usually defined as some proportion of the long-term average. It is usually an expression of precipitation's departure from normal over some period of time (Fig.2.2). 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



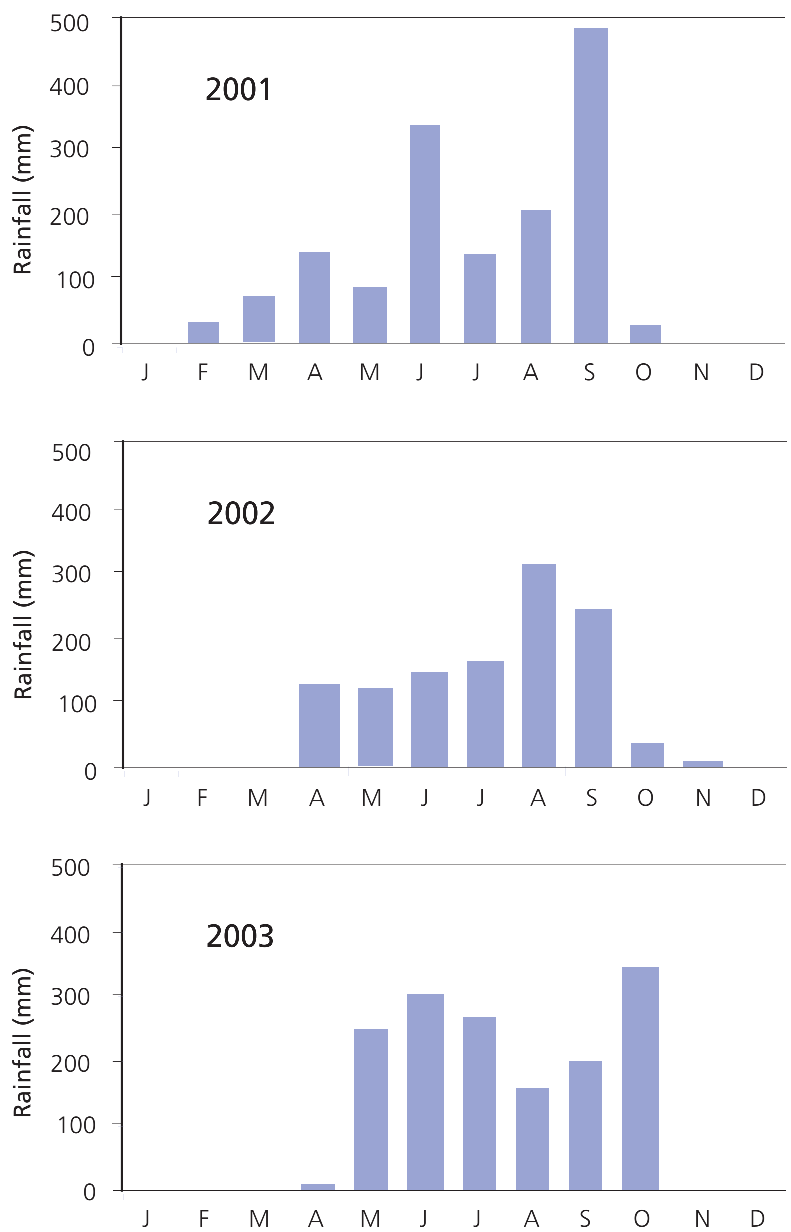
Water used in support of human activity is derived from direct rainfall which is temporarily stored in rivers and lakes or from groundwater aquifers. Some groundwater aquifers, such as those in the Barind areas of Bangladesh, may contain rainwater that fell decades or even centuries before. A temporary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

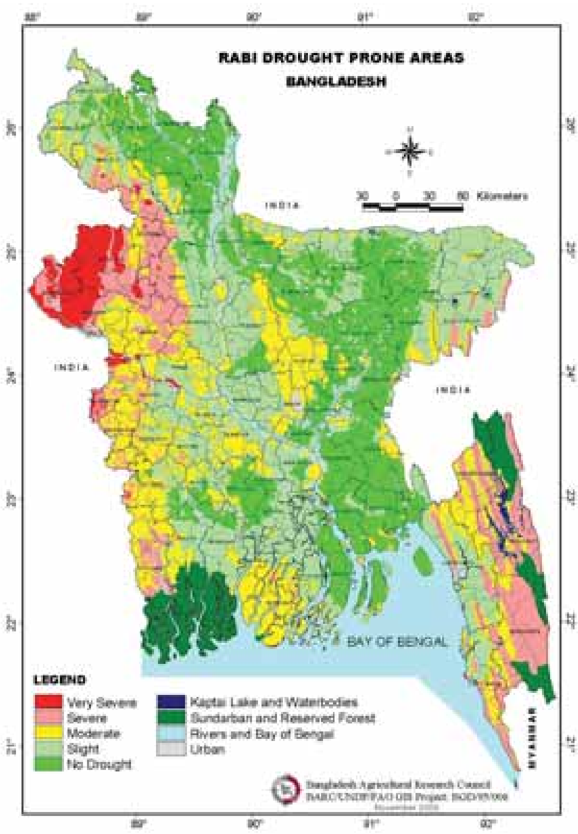
- early-season
- mid-season
- terminal-season

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*:

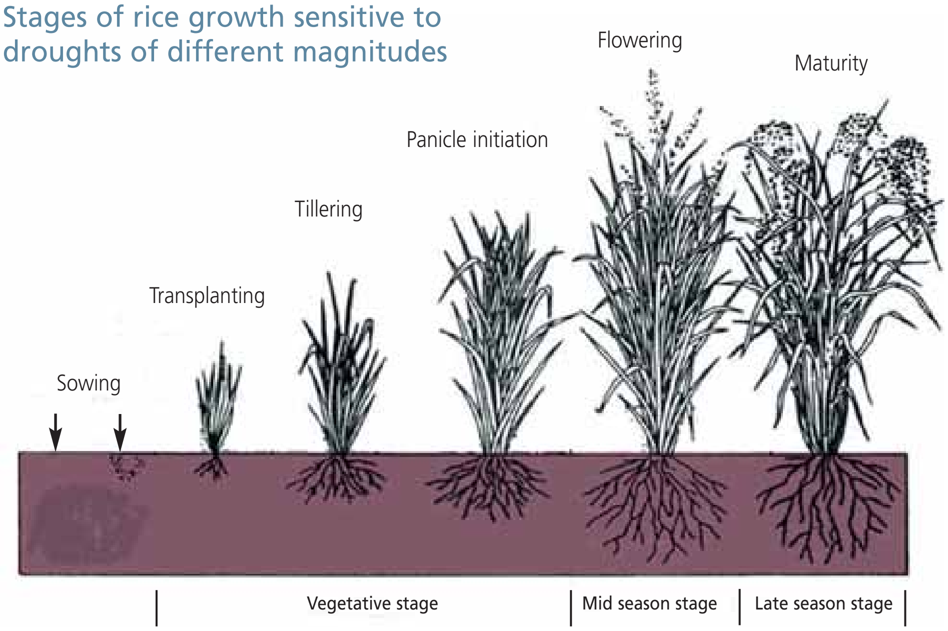
(1) *Kharif* – droughts in the period June/July to October result from dry conditions in the highland areas especially in the *BarindBarind*. Shortage of rainfall affects the critical reproductive stages of t.aman rice, reducing its yield, particularly in those areas with low soil moisture-holding capacity.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

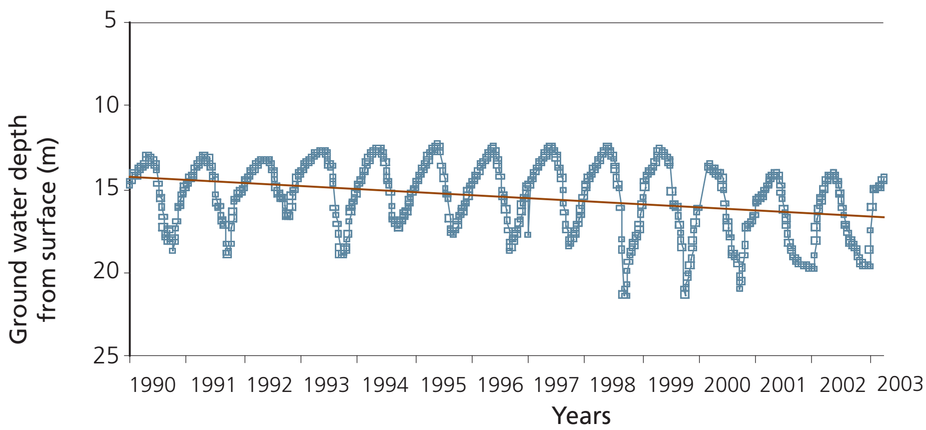
Box 3.2: Climate change and drought

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

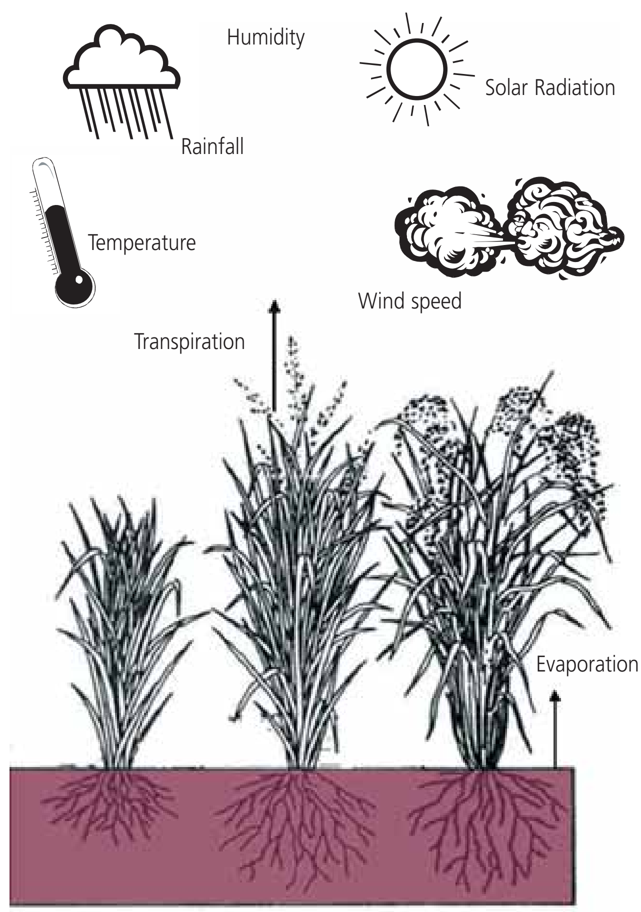


Based on the climate change scenarios (Module 1), surface water would increase during monsoon but would decrease in the winter, meaning more water will be required for irrigation in winter. Irrigation would be more dependent on groundwater withdrawal. Overexploitation of groundwater to meet the growing 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.

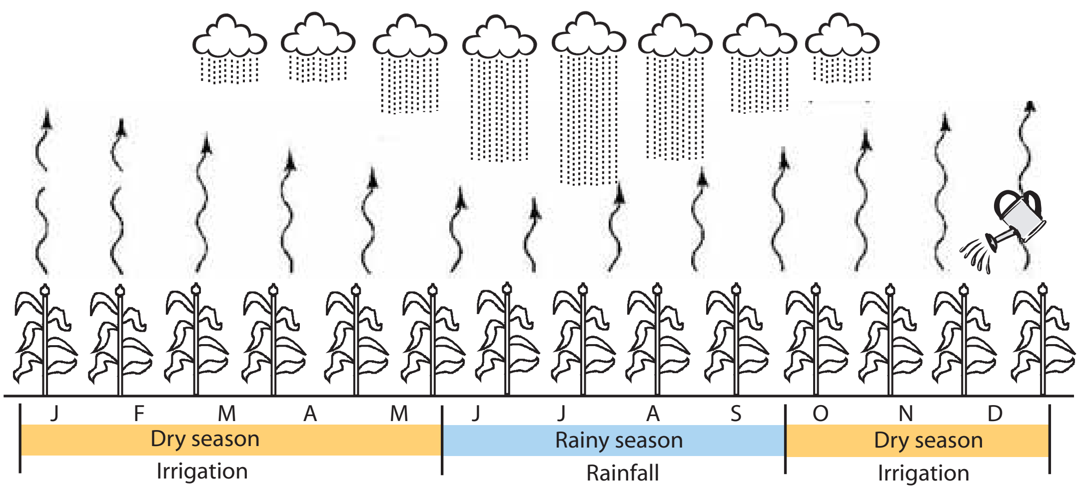
There has, however, been a shift in the composition of agriculture over the past few years with gradual intensification of monocropping *boro* rice during *rabi* season. Such intensification increases vulnerability of the agriculture system to drought and high temperature, which are projected to increase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

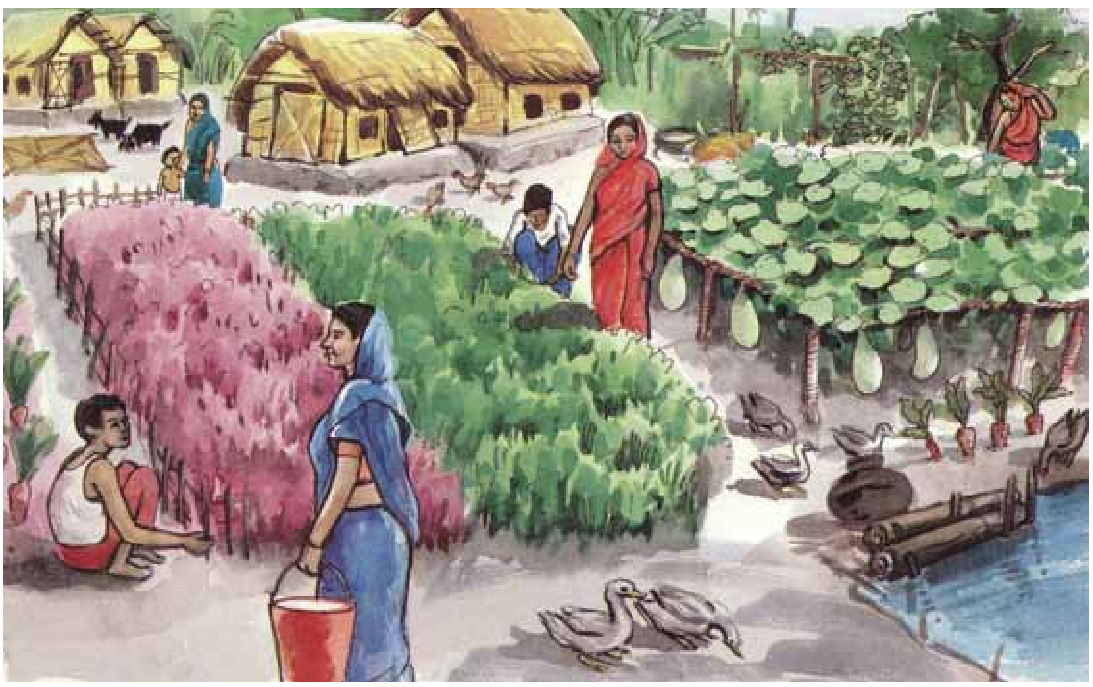
Drought normally affects about 2.3 million ha of cropland from April to September and 1.2 million ha in the dry season, from October to March. Drought during monsoon season severely affects t.*aman* rice and can incur an annual 1.5 million tonne production loss. With climate change, more area would be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

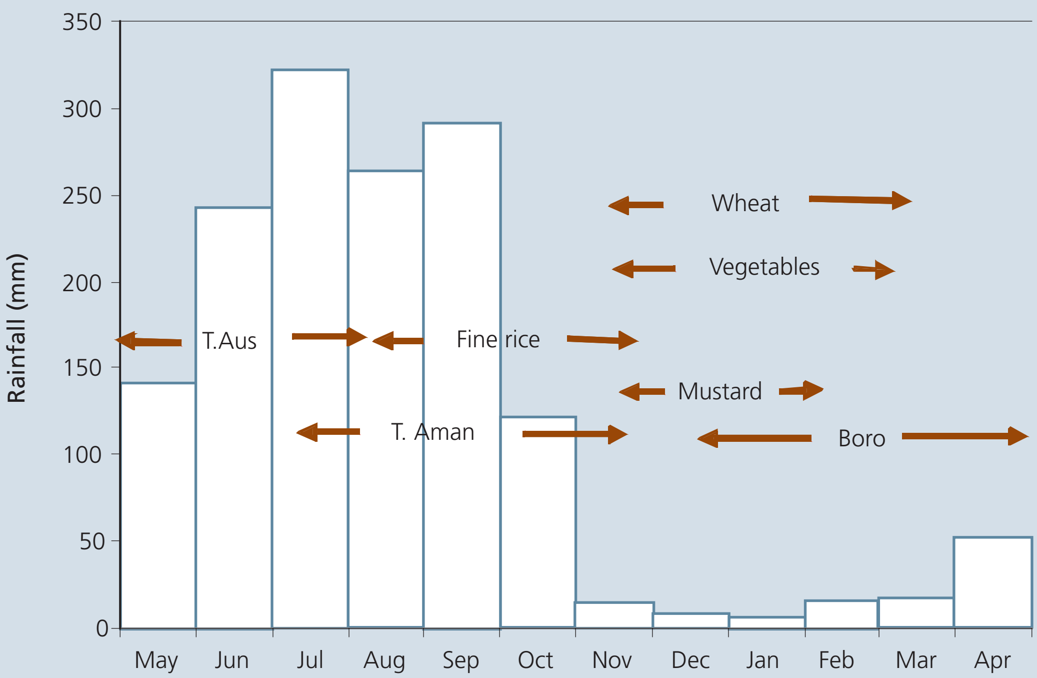
1. How would crops sensitive to high temperatures, such as wheat and chickpea, be affected by future climate change?
2. Why would boro rice face water scarcity under future climate change?

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.