Training Modules for

Climate & Flood Forecast Applications in Agriculture

Enhancing early warning systems for disaster preparedness and mitigation in the agriculture sector in Bangladesh.

adpc
Asian Disaster Preparedness Center

Food and Agriculture Organization of the United Nations

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Enhancing early warning systems for disaster preparedness and mitigation in the agriculture sector in Bangladesh (Ref. LOA/FAO/RAP/2904-3)

in support of the Food and Agriculture Organization's (FAO) project to strengthen disaster preparedness of the Department of Agriculture Extension (DAE), Government of Bangladesh

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contents

introduction

Purpose and Scope

These training modules on climate and flood forecast applications in agriculture were developed for the Food and Agriculture Organization (FAO) of the United Nations to build the capacity of the Department of Agriculture Extension (DAE) of the Government of Bangladesh to interpret probabilistic climate and flood forecast information, translate these into location-specific **impact outlooks**, prepare locally relevant **response options**, and communicate these to vulnerable farming communities to reduce disaster risks in agriculture.

These training modules, designed based on a training need assessment of DAE functionaries at the national, district, sub-district (upazilla), and block levels, provide the base material for the training workshops for DAE at each level. The workshop program for each level is designed around participants' needs.

Training Modules

These modules, utilizing the exploration, analysis, decision-making, and action (EADA) technique, guide participants through the following topics:

1. Introduction to weather and climate of Bangladesh
2. Climatic hazards and societal impacts
3. Existing early warning systems in Bangladesh
4. Probabilistic forecast products and their application in reducing flood and drought impacts in the agriculture sector
5. Climate-related risks at each stage of crop growth, and opportunities for climate and flood forecast application
6. Interpretation, translation, communication and application of climate and flood forecast information
7. Understanding uncertainties in forecasts
8. Incorporating climate and flood forecast information into decision-making at farm level
9. Economic value of using climate and flood forecasts

Each module is structured as follows:

1. Purpose and objectives
2. Background and principles
3. Problem analysis and identification of optimal decisions
4. Definition of key words
5. Questions and practical exercises

Practical exercises reinforce participants' learning in agro-climatological concepts and local application of climate and flood forecasts.

Training Methods

These modules are intended for participants in the training workshops, as well as for the self-study learner. The following training methods are recommended to be used along with these modules:

1. Supplementary handouts
2. Review sessions
3. Self-assessment exercises
4. Group exercises

The self-study learner can use this manual as a workbook. In addition to note-taking on the margins, the learner can stop and examine his learning by answering the questions after each key concept before proceeding, to ensure that he has captured the vital aspects of the module.

Participation is a shift from teaching to learning. It proceeds through dialogue, and relies on understanding the concepts and sharing experiences.

Climate and flood forecast information generation for application in the agriculture sector involves the analysis of historical climate and agricultural data in the generation of climate and flood forecasts.

Climate and flood forecast application for disaster preparedness in agriculture refers to the use of the emerging ability to provide timely and skilful climate and flood forecasts as tools to improve decision-making in the agriculture sector for enhancing disaster preparedness and reducing societal vulnerability to climate-related risks.

module 1: weather and climate

The purpose of this module is to familiarize participants with the key weather and climate features of Bangladesh.

At the end of this module, participants should be able to:

1. Define and distinguish between weather and climate
2. Analyze how physiographic features of Bangladesh influence its climate
3. Identify rainfall types and related hazards
4. Descibe the spatial and temporal distribution of rainfall and their impacts

Weather refers to the behavior of the ***atmosphere*** on a day-to-day basis in a relatively smaller area. Weather parameters are daily temperature, relative humidity, sunshine, wind and rainfall. Describing these parameters for a location defines the weather for that locality. The weather of a day during the monsoon season may be described as rainy and windy; hot during summer; and cold during winter.

Climate refers to the behavior of weather parameters for a relatively longer period of time for a larger region. In defining the climate of a region, the effects of various weather parameters are combined. For example, the climate of Bangladesh is described as tropical monsoon type.

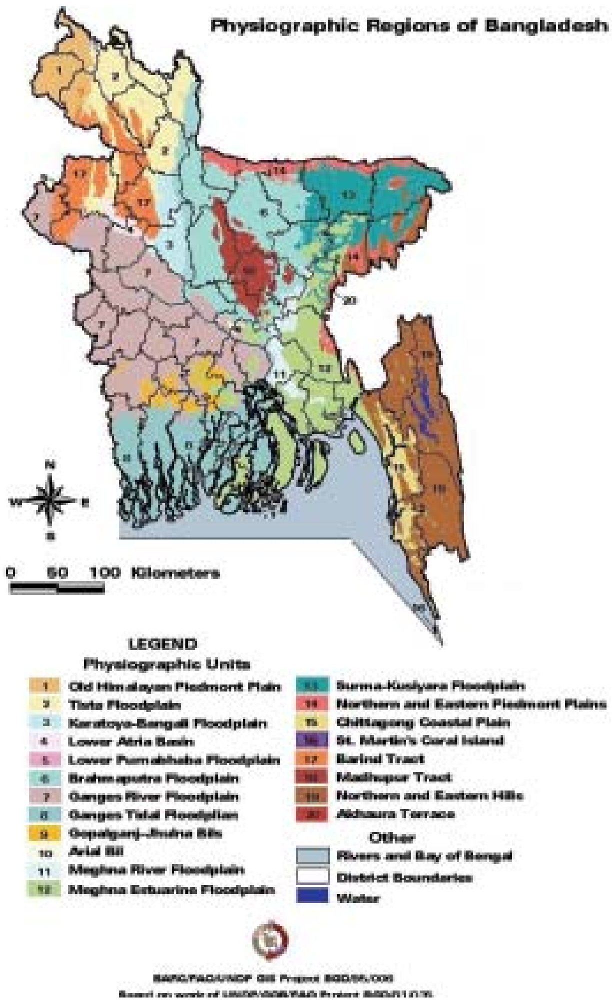

Figure1.1: Physiographic Regions of Bangladesh (source: www.fao.org)

Physiography and Climate

Bangladesh extends from 20° 45' N to 26° 40' N latitude, and from 88° 05'E to 92° 40'E longitude. Most of the country is a low lying plain, with hills in its south-eastern part. The country is surrounded by the Assam Hills to the east, the Meghalaya Plateau to the north, with the lofty Himalayas beyond. The Bay of Bengal lies to the south of the country.

Bangladesh is located in the tropical monsoon region. Its climate is characterized by cool dry winter, hot humid summer, and the rainy monsoon seasons. The maximum summer temperature ranges from 33.3°C to 37.7°C, and minimum winter temperature is 10°C. Annual average rainfall is 2,350mm, highly influenced by the summer monsoon. Less than 5 percent of the annual rainfall occurs during the dry season from December to February.

March to May is the pre-monsoon hot season. It is characterized by high temperatures and the occurrence of localized storms. In late summer, Bangladesh suffers from destructive ***tropical cyclones***. Rainfall during this season accounts for 15 to 20 percent of the annual rainfall.

The rainy season coincides with the summer monsoon from early June to middle of October. During this time, 75 to 80 percent of the annual rainfall occurs (Fig.1.2). The rainfall pattern is similar throughout the country. South and southeast winds, widespread cloud cover, high humidity, and long spells of rain characterize this season. The eastern part of the country receives more rain than the western regions. There are significant rainfall variations in Bangladesh, largely due to the monsoon pattern and difference in elevation. Natural hazards affecting the country include floods, drought and cyclones (Table 1.1) particularly during the summer monsoon.

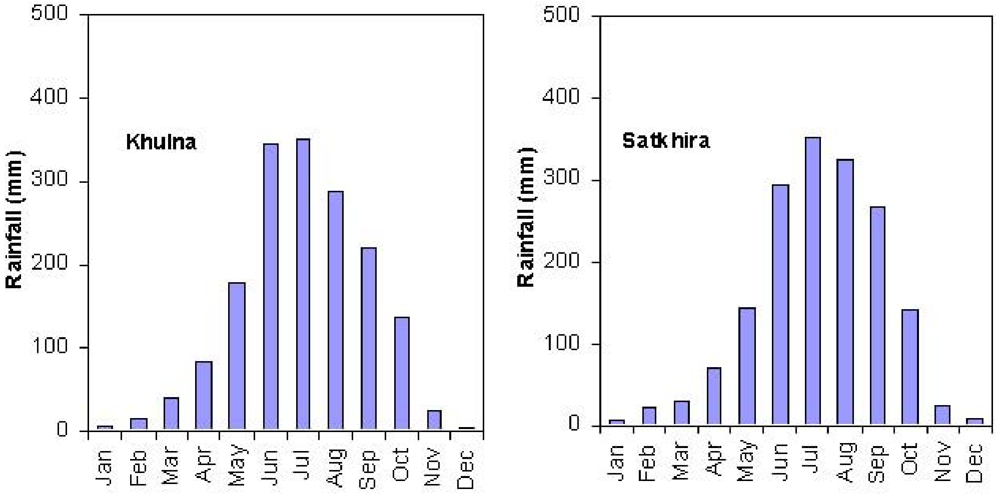

Figure1.2: Monthly rainfall distribution for two selected locations in Bangladesh

Q. *How does physiography affect the rainfall pattern in Bangladesh?*

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Table 1.1. Climate-related hazards calendar for flood- and drought-prone areas of Bangladesh

Hazards	RABI			KHARIF I			KHARIF II			RABI		
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Early floods					■	■						
Mid floods							■	■				
Late floods									■	■		
Flash floods				■	■							
Local floods/inundation						■	■	■	■			
False onset of rains						■						
Early season drought						■						
Mid season drought							■	■	■			
Terminal drought										■	■	
Seasonal drought	■	■	■	■	■							■
Hailstorms				■	■							
Northwesterly				■	■	■						
High wind velocity				■	■							
High temperature				■	■	■						
Low temperature	■	■										

Rainfall Processes

Air masses pick up moisture predominantly over the ocean. When the moist air rises, it cools and results in condensation of ***water vapor***. Generally, three types of rainfall processes occur:

1. convectional
2. cyclonic
3. orographic

Convectional rainfall is the result of free convection due to heating. Water evaporates due to heating and moves up and then condenses. Such type of rainfall is localized and occurs in an area between 10 and 200 km^2. Normally, convectional rainfall occurs during summer. Thunderstorms and ***hailstorms*** can also accompany this type of rainfall, and damage agricultural crops and create localized floods.

Where does cloud come from?

Two thirds of the earth's surface is covered with water. During a hot day, water in the oceans, seas, etc. gets heated, leading to evaporation of water. Hot moist air rises up into the air and cools. Since temperature decreases with height, water vapor condenses into minute droplets of water. These droplets appear as clouds. When the cloud becomes colder, water drops are formed and fall as rain, as they cannot be retained in the atmosphere.

Cyclonic rainfall is produced by a circular area of low pressure over the ocean/sea. The circular low pressure move towards the coast and produces intense rainfall inland. Normally, cyclonic rainfall is accompanied with high wind velocity (Fig.1.3). In the northern hemisphere, the air spirals anti-clockwise in a cyclonic storm. Cyclonic storms come from the Bay of Bengal and damage crops, uproot perennial vegetation, and lead to flood and storm surges.

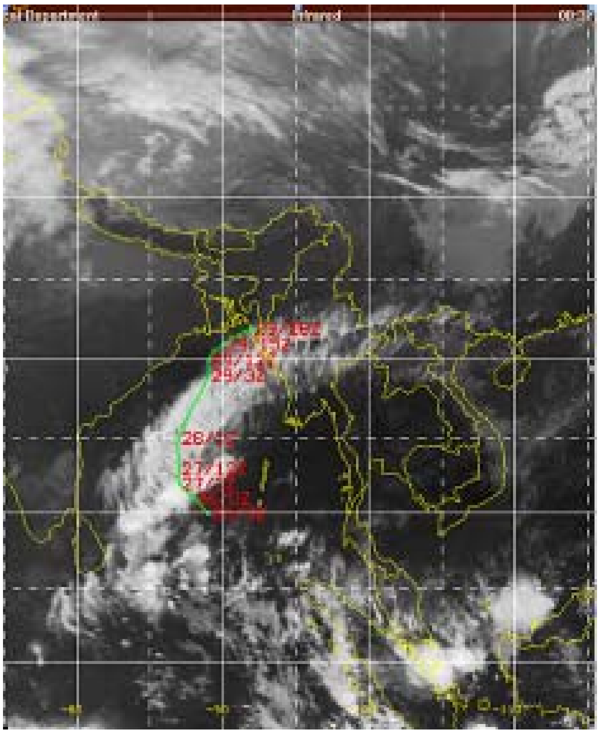

Figure 1.3: Geostationary Meteorological Satellite (GMS) picture of 29 April 1991 cyclone

Orographic rainfall occurs due to the upward movement of moist air over topographic barriers like mountains. The windward side of the mountain gets very high rainfall, while the leeward side becomes a rain shadow area. Orographic rainfall occurs during the monsoon season in the western part of Assam Hills, leading to heavy flooding in Bangladesh.

Monsoon

During summer (March – May), winds blow from the Southern Hemisphere, accumulating moisture from the Indian Ocean and brings abundant amount of rainfall over the South Asian sub-continent. In winter, dry winds blow from the cold land areas of Asia towards the warm southern ocean. The driving mechanism of the monsoon cycle is the ***atmospheric pressure*** difference resulting from the differential heating of land and ocean. The rotation of the earth, and the exchange of moisture between the ocean, atmosphere, and land also drive the monsoon. In addition to the strong wind and rainfall patterns, the monsoon regions also experience a high degree of variability.

Rainfall Variability

Rainfall variability during the summer monsoon season is the most important phenomenon related to the onset of dry and wet spells. The onset of summer rainfall in a particular location can vary considerably from one monsoon season to the next. Large regions can also experience "break" in monsoon activity within the season, during which there is little or no precipitation, and causes moderate to severe drought conditions. Late onset of monsoon reduces the length of growing period and sometimes create early season drought.

Monsoon Depression

Much of the rainfall over Bangladesh during the summer monsoon is due to the formation of depressions and low pressure systems in the Bay of Bengal. An average of two to three depressions are observed per month during the monsoon season. The highest depressions are observed in the months of July and August. The horizontal distance of these low pressure systems are around 500 km and their usual life span is about a week. Rainfall generated by depressions or low pressure systems in the Bay of Bengal is usually concentrated in southwestern Bangladesh. The structure of a Bay of Bengal depression usually indicates the direction of movement. Pre-monsoon Bay of Bengal depressions cause widespread damage to *Boro* rice.

Monsoon

The word ***monsoon*** appears to have originated from the Arabian Sea region where the word mausim means "season". Monsoon is a dominant characteristic feature in South Asia, bringing widespread rainfall. The social and economic welfare of many tropical countries are intimately linked to the vagaries of the annual monsoon cycle. At the same time, monsoon rainfall variation creates distress, like drought and flood.

Q. *Choose a cyclonic storm event that you are familiar with and describe its major impacts.*

A.

The Monsoon Trough

The **trough** is an extended low pressure area in the monsoon region. Normally, the trough is oriented in an east-west direction, roughly parallel to the southern periphery of the Himalayan Mountains. The *"active"* phase (wet phase) of the monsoon is observed when the axis lies to the south of its normal position, and its eastern end extends into the northern part of the Bay of Bengal. On the other hand, when the axis moves north and is located close to the Himalayan foothills, rainfall is concentrated over the northeastern parts of India, and Bangladesh experiences a "*break"* in the monsoon. As several major rivers of Bangladesh have their origin over the Himalayas, a *break* in the monsoon leads to heavy discharge, and resultant floods occur in Bangladesh. Deforestation in the Himalayan foothills, combined with heavy flood, increases the rate of sedimentation in Bangladesh, causing riverbeds to rise, which has made the country more vulnerable to disastrous floods. The position of the monsoon trough drives the ***active*** or ***break*** monsoon.

Q. *Differentiate the active and break phases of the monsoon. Why is Bangladesh flooded during the break phase than during the active phase?*

A.

Rainfall Trend

Heavy rainfall along the monsoon troughs in northern Bangladesh and adjacent India during the break monsoon phase and the transitional period from the break to the active phase cause floods from July to August. Intraseasonal variation of monsoon activity indicates that rainfall increases when the monsoon trough is located at the foot of the Himalayas. Monsoon rainfall over Bangladesh varies with a periodicity of 20 days.

Q. *What is the significance of the monsoon season (June - October)?*

A.

Q. *What is the significance of the dry season (November - February)?*

A.

Q. *What is the significance of the pre-monsoon hot season (April - May)?*

A.

Synoptic Chart Exercise

(The weather map)

Try the following:

1. Forecast map and messages of local dailies may be interpreted to locally relevant information.
2. Daily weather summaries in newspapers may be discussed.

Examine the map provided by the facilitator and answer the following:

Q. *What season does the map represent and why? (summer monsoon season)*

A .

Q. *Examine the map and identify the area in which one may expect climate-related hazards. Give reasons for your choices.*

A .

- end of module 1 -

module 2: climate and society

This module aims to understand how climate influences society. Upon completion of this module, participants should be able to:

1. Differentiate hazard, vulnerability and disaster
2. Describe the impacts of climate-related disasters on society

Vulnerability to Climate-related Hazards

Bangladesh has an area of 145,600 km^2 with a population of over 140 million. Agriculture and related enterprises are the major activities influencing its growth. The agriculture sector played a key role in providing employment to its people and in reducing rural poverty during the last four decades. Foodgrain production nearly tripled from a level of 10 million tons in early 1970s to 27 million tons in 2000. Despite its phenomenal agricultural growth, Bangladesh continues to be a food deficit country. Floods and drought within a year, or even within a cropping season, are very common in Bangladesh.

Q. *Why is Bangladesh agriculture highly vulnerable to climate-related disasters?*

A.

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Bangladesh is heavily reliant on agriculture. Its agricultural system is largely dependent on summer monsoon rainfall. ***Vulnerability*** to climate related disasters in this region is very much a function of physical location, topography, magnitude of climatic events, land use, state of economic underdevelopment, and high population density and growth rates. The three main weather/climate-related phenomena that affect Bangladesh are the summer monsoon and associated flooding, drought, and tropical cyclones in the Bay of Bengal. The tropical cyclones in 1970 and 1991 originated from the Bay of Bengal and caused the worst tragedies and loss of life in the memories of people in the country.

Q. *What are the weather- and climate-related hazards that affect Bangladesh agriculture?*

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Flood Impacts on Agriculture

Poor *Aman* harvests often coincide with flood years in Bangladesh (Fig 2.1). The major flood years of 1988/89 and 1998/99, for example, recorded maximum negative deviations in *Aman* rice production. Fluctuations due to climate variability associated disasters could upset the delicately balanced food security in the country.

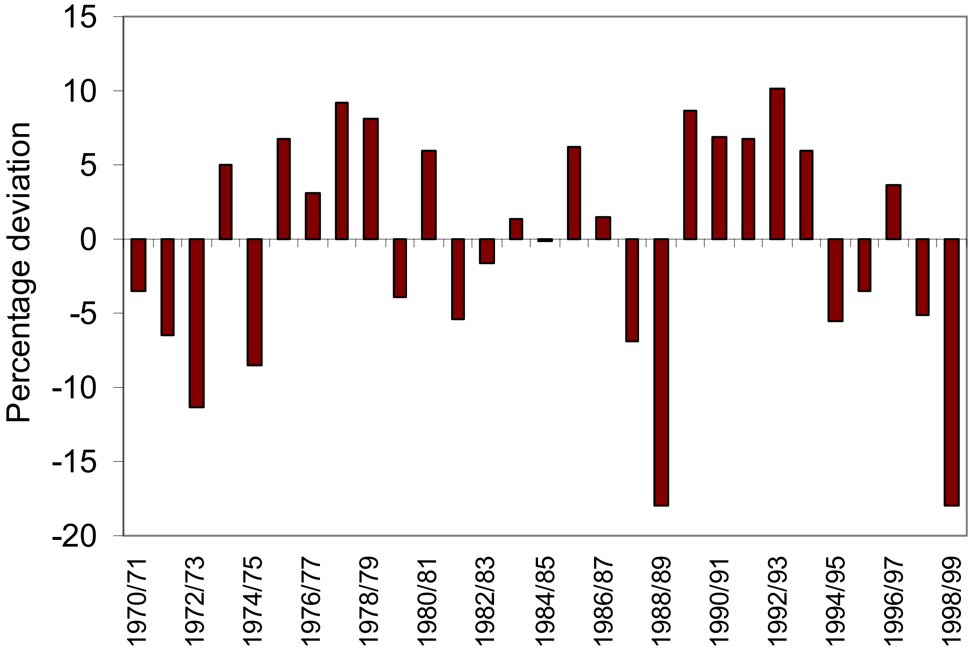

Figure 2.1: Percentage deviation of Aman rice production from trend in Bangladesh

Early floods in May and June, peak floods in July and August, and late floods in September have negative impacts on food crop production causing national and local food insecurity. Major damaging floods occurred during 1974, 1987, 1988, 1997 and 1998. The 1998 floods caused food crop production losses of 10-20% of annual production. Besides damage to agricultural systems, the floods displaced a large section of people living in river banks and low lying areas, and claimed thousands of lives.

Q. *Choose a flood event that you are familiar with and describe its major impacts. Which season rice do major floods commonly affect?*

A.

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Drought Impacts on Agriculture

Drought and floods are twin hazards affecting the people of Bangladesh. The country experiences major droughts once in 5 years. Droughts at local scale are much more frequent and affect part of the crop life cycle. Agricultural drought, related to soil moisture deficiency, occurs at various stages of crop growth. It can be classified as:

1. early season drought
2. mid-season drought
3. terminal/ late season drought

The western parts of the country are vulnerable to droughts during the pre-monsoon season. Severe droughts occurred in the country in1966, 1969, 1972, 1978, 1979, 1989, 1992, 1994 and 1998.

Monsoon failure often brings ***famine*** to the affected regions, and strong monsoon years can result in devastating floods. An accurate long-lead prediction of monsoon rainfall can improve planning to prepare against the adverse impact of climate-related hazards. Monsoon forecasting uses atmospheric wind circulation, land surface conditions, and oceanic ***Sea Surface Temperature (SST)*** parameters.

Vulnerability, Hazards and Disasters

Vulnerability is defined as conditions determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards.

A hazard is an event or an occurence that has the potential of causing injuries to life, or damage to property and/or the environment.

A disaster happens when a hazard hits a vulnerable community whose capacity is limited that they need outside assistance.

Q. *Choose a drought event that you are familiar with and describe its major impacts.*

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Disasters and Household Food Security

Decline in crop production, loss of assets, and lower employment opportunities as a result of floods or droughts increase household food insecurity. Food consumption falls along with households' abilities to meet their food needs on a sustainable basis. Vegetables and many other foods are in short supply during floods and drought. As a consequence, calorie consumption of flood-exposed households is lower than that of households not exposed to flooding.

Disasters and Health

Floods not only damage or destroy people's homes, but also reduce access to safe water. Combined with a reduction in food consumption, floods lead to a substantial increase in illness, even after floodwaters had receded. In the immediate post flood period, there is a possibility of infection by diarrhea and respiratory illness. Flood leads to an increase in severe chronic energy deficiency in the agriculture work force.

Q. *Choose a flood event that you are familiar with and describe its major impacts on human health.*

A.____________________________________

Disaster Impacts on Assets and Employment

In addition to crop losses, floods also damage household assets, reducing wealth as well as future productive capacity. The rural economy suffers serious disruption. Average monthly days of paid work decreases during flood events. Day laborers are most severely affected, with reduction in earnings of up to 50% and an increase in unemployment rate in the labor market.

Q. *How does flood or drought affect work efficiency in agriculture and allied enterprises?*

A.

Notes:

- end of module 2 -

module 3: existing early warning systems

The purpose of this module is to explain the existing early warning systems and forecast products available in Bangladesh and their utility for disaster preparedness in agriculture.

Upon completion of this module, participants should be able to:

1. Describe the various types of early warning systems and forecast products available in Bangladesh
2. Evaluate currently available climate and flood forecast products
3. Elaborate how current forecast products may be used for disaster preparedness in the agriculture sector

Weather/Climate Forecasting

Forecasting refers to the likely behavior of the atmosphere days in advance, or foretelling the likely status of the atmosphere in relation to various weather parameters like rainfall, temperature, wind etc., Forecasting the behaviour of the atmosphere for only a few days is normally referred to as *weather forecasting*. Forecasting the likely pattern of climate variables like rainfall and temperature for a longer period (usually months and season) with sufficient lead-time before the start of the season is referred to as *climate forecasting*.

Generally, early warning systems involving weather and climate forecasting are divided into three major types based on available lead-time:

1. Short range
2. Medium range
3. Long range

Short range forecasts are given for a period of 24 to 72 hrs. Short range forecasts are based on the atmospheric circulation pattern, monitored through satellites or *synoptic* type *observatories*. Their accuracy is relatively higher as they are given for only few days. Forecasts of cyclones, associated wind speed, and temperature are provided based on this method. Short-range forecasts are useful for taking emergency decisions such as securing livelihoods.

Medium range forecasting is given for a period of 5 to 10 days. Medium range forecasts are based on numerical weather prediction models, which are mathematical formulations explaining physical processes in the atmosphere. Based on this method, information about rainfall, wind speed, wind direction, cloud cover and temperature are provided. On occasions, extended range forecasting of up to 20 to 25 days is also given using this method. The medium range forecast is useful in making planting/harvesting decisions, storage of water for irrigation, etc.

Long range forecasting is given for a period of a month up to a season or more. This type of forecast is generated using statistical relationships between rainfall and various atmospheric and oceanic variables. Currently, the ***General Circulation Models*** (GCMs) are used to produce seasonal or long range forecasts. The GCMs consist of mathematical equations describing the physical processes associated with the ocean and the atmosphere, which influence global climate. Long range forecasting is also referred to as *climate forecasting or seasonal climate forecasting.* These forecasts are highly useful for *disaster preparedness planning* in agriculture. They aid in taking better strategic decisions like crop/cropping system choice, variety selection, and resource allocation.

Q. *What is the difference between short range and long range forecasts? Why are long range forecasts more useful for disaster preparedness in agriculture?*

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Current Status of Forecasts in Bangladesh

The Government of Bangladesh is operating an early warning system with three distinct but inter-related components to manage rainfall variability and associated risks like floods and drought as follows:

Forecasts		Organization
1. Weather/Climate forecast	:	Bangladesh Meteorological Department (BMD)
2. Flood forecast	:	Flood Forecasting and Warning Center (FFWC) of the Bangladesh Water Development Board (BWDB)
3. Early warning and food information system	:	Food Planning and Monitoring Unit, Ministry of Food

Weather and Climate Forecasts of BMD

The Bangladesh Meteorological Department, under the Ministry of Defense, provides relevant weather forecasts on a regular basis. BMD operates 35 meteorological stations throughout the country, out of which 10 stations provide agro-meteorological data. These stations report daily to the central office in Dhaka. A list of weather and climate forecast bulletins released by BMD are given below. Sample forecast bulletins are given in Figure 3.2. The Storm Warning Centre (SWC) of BMD issues the forecasts, as shown in Table 3.1, on daily routine basis after analyzing different kinds of meteorological charts, satellite and radar imageries.

Table 3.1: Forecasts/warinings issued by the Storm Warning Center of the Bangladesh Meteorological Department

SI No.	Forecasts/ Warning	Time of Issue
	Morning	
1.	Weather Forecasts for Dhaka and Neighborhood valid for 24 hrs commencing 9 a.m. for the general public	09:00 a.m.
2.	Weather Forecast with 24 hrs rainfall for the Hon. Prime Minister valid for 24 hrs.	09:00 a.m.
3.	Inland River Port Warning valid up to 6 p.m.	11:30 a.m.
4.	Fleet forecast for Bay of Bengal commencing 4 p.m. and valid for next 12 hrs.	12:00 noon
5.	Sea Bulletin	12:00 noon
	Afternoon	
1.	Morning Inference	12-30 noon
2.	Bangladesh Daily Weather Summary (BDWS)	01-30 p.m.
3.	Bangladesh Weather Bulletin (BWB) valid for 36 hrs.	01-00 p.m.
4.	Weather forecast for Bangladesh South of Lat.24°N and adjoining North Bay North of Lat. 21°N valid for 24 hrs commencing 4 p.m.	02-00.p.m.
5.	Weather forecast for Cittagong, Cittagong Hill Tracts, Noakhali, and Comilla districts valid for 36 hrs commencing 6 p.m.	02-30 p.m.
6.	Inland River Port Warning (IRPW) valid up to 1 a.m. of the following day	04-30 p.m.
7.	Weather Forecast to Dhaka and Neighborhood commencing 6 p.m. valid for next 24 hrs.	05-00 p.m.
8.	Weather Forecast for Dhaka and Neighborhood valid for 24 hrs. commencing 6 p.m. for the general public	06-00 p.m.
	Night	
1.	Fleet Forecast for Bay of Bengal commencing 4 a.m. valid for next 12 hrs.	08-30p.m.
2.	Inland River Port Warning (IRPW) valid up to 9 a.m. of the following day	09-00p.m.
3.	Evening Inference	09-00p.m.
4.	Weather Forecast for Chittagong, Sandwip valid for 0500-1230 hours.	04-00p.m.
5.	Inland River Port Warning (IRPW) valid up to 1 p.m.	05-00p.m.
6.	Farmer's Weather Bulleting (FWB) valid for 24 hrs	05-30 p.m.
7.	Weather Forecast for Dhaka and Neighborhood commencing 6 a.m. valid for 12 hrs.	05-00 p.m.
8.	Weather Forecast of Dhaka and Neighborhood commencing from 3 p.m. valid for 15 hrs.	02-30 p.m.

Besides the above routine warnings, special weather bulletins for tropical cyclones and associated storm surge, warnings for heavy rainfall, and droughts are issued by BMD. In addition, long-term forecasts valid every month for the general public and authorities, and long-term agro-meteorological forecast valid for three months (updated every month) are issued. Medium range agro-meteorological advisories for every 10 days are also issued. Route and Landing Forecasts for all flights, both national and international, are also issued from the Airport Meteorological Offices.

Q. *List existing forecast products from Table 3.1 that have direct application towards disaster preparedness in agriculture.*

A.

Observation Network

Meteorological observations are used as basic inputs in weather and climate forecasting. BMD has a network of observation stations throughout the country consisting of 35 surface observatories recording observations eight times a day; 10 Pilot Balloon Observatories recording upper wind direction and speed four times a day; three radiosonde stations recording upper air wind, temperature, humidity, pressure, etc. twice a day; and 10 agro-meteorological stations recording observations for agricultural operations.

Q. *Choose a forecast product that you are familiar with and describe how the product has been interpreted for disaster management in agriculture.*

A.

The Agro-meteorological Division of BMD issues every ten days a two-page bulletin containing meteorological data for 32 meteorological stations; highlights on the rainfall situation; and the weather forecast for the following 10 days. DAE also operates 64 rainfall stations, one at each district agricultural office. The Deputy Directors' Office collects daily rainfall data, which are communicated to the DAE Headquarters in Dhaka. However, all collected weather related data are not analyzed and interpreted with a view to reliably predict crop yields and to evolve practices for better management of agro-climatic resources at farm and village levels.

Q. *How can the agro-meteorological services provided by BMD and DAE be utilized for reducing climate-related risks in Bangladesh?*

A.

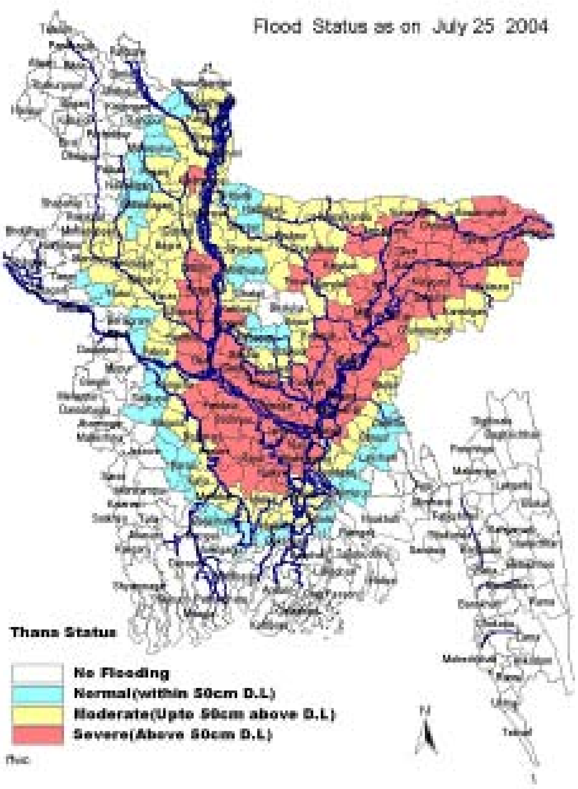

Figure 3.1: A flood status map showing the intensity of high floods in Bangladesh in July 2004 (Source : FFWC/BWDB, 2004)

Flood Forecasting

The Flood Forecasting and Warning Center of the Bangladesh Water Development Board is responsible for flood monitoring in the country in a unified and multi-purpose basis. There are 30 forecasting stations where 24, 48 and 72-hour forecasts are prepared daily. A daily bulletin, based on observed data, as well as results of model forecasts, is prepared and distributed everyday at around 12:00 noon to various administrative tiers. The bulletin, mostly in tabular form, includes the following:

1. A cover page showing geographical settings of Bangladesh and location of all monitoring stations
2. River stage of all monitoring stations with respect to danger level followed by rise/fall of water level of the respective date
3. Rainfall situation for a specific date followed by monthly normal and cumulative rainfall
4. Rainfall and river situation summary text based on major findings
5. Forecasts for 24 and 48 hours of some important stations affected by shallow, moderate, and severe flooding
6. Flood warning messages that display trends of water levels (if close to or exceeds the danger levels, at which flooding becomes a serious threat)
7. A detail statistics on river stage and rainfall for three consecutive days.

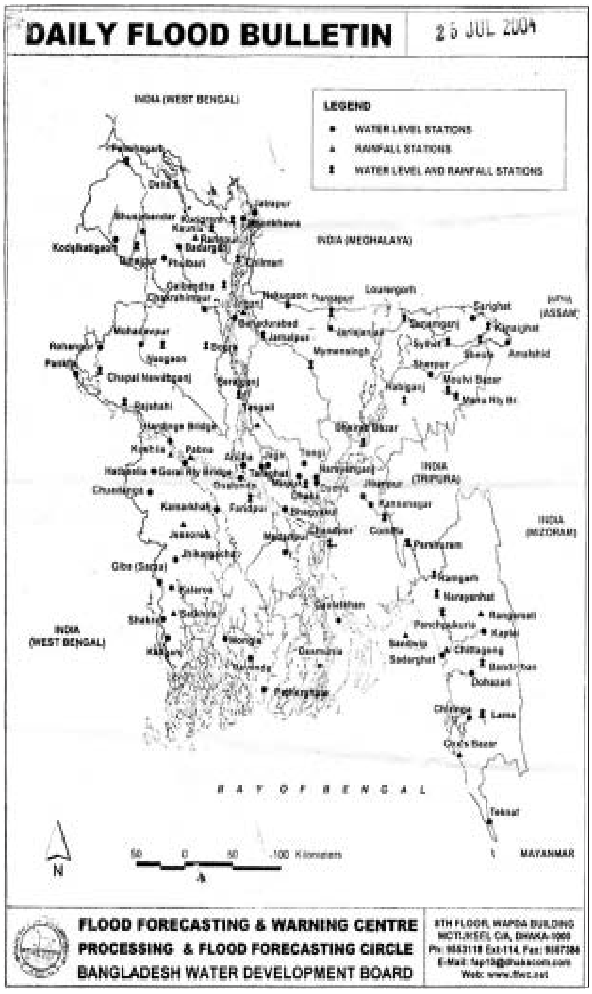

Figure 3.2: Daily flood bulletin of FFWC, BWDB, Bangladesh

Q. *Review the daily flood bulletin and give your inference. How can it be integrated into DAE's efforts in reducing the impacts of flood in agriculture?*

A.

Q. *How will you interpret the 'danger level' to prepare location-specific impact outlooks?*

A.

Flood Categories

Shallow or normal flood (depth is 50 cm below *Danger Level* (DL)): Occurs during the months of April-May and submerges low lands only.

Moderate flood (depth is within 50 cm above DL): Occurs between July-August and inundates low to lower middle lands

Severe flood (depth is more than 50 cm above of DL.): Occurs between July/August – September/ October and submerges low/lower and upper middle lands.

The current flood forecasting arrangement provides 48-72 hours lead-time, which is useful for undertaking emergency actions, such as tactical management practices to minimize agricultural losses due to floods. The classification of flood categories along with flood forecasts provides an opportunity to decide the land allocation for cropping to minimize the impact of disasters.

Q.

Which section of the flood forecast bulletin is of much interest to you for decision making in agriculture to reduce the impact of floods?

A.

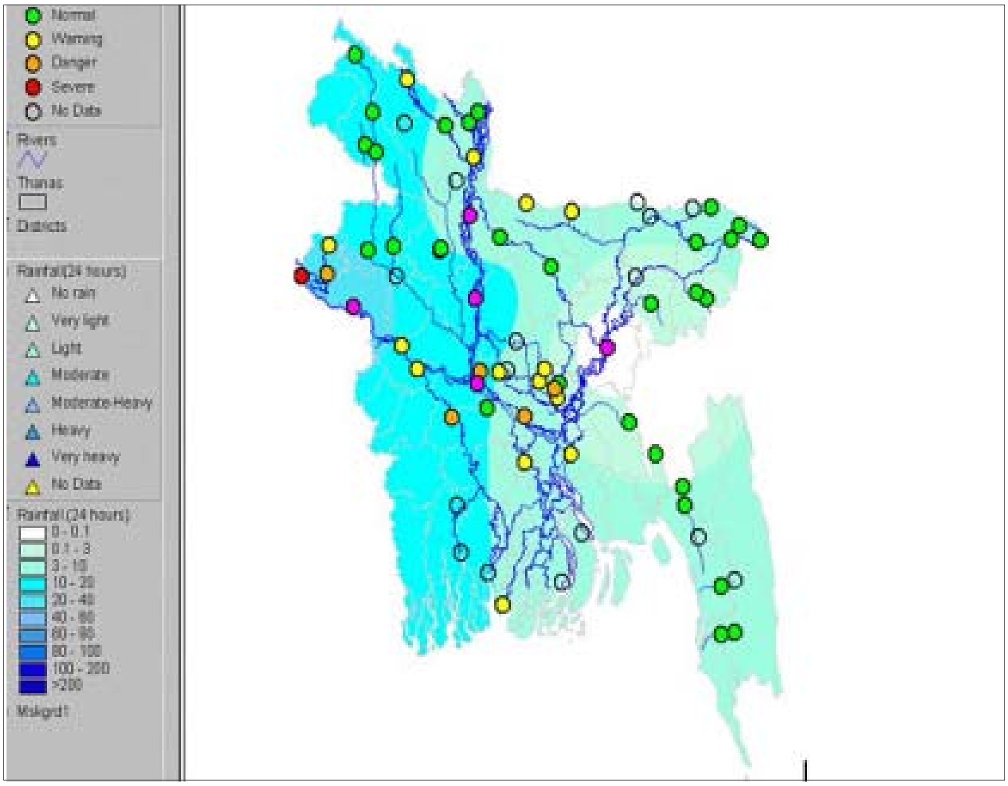

Figure 3.3: Rainfall surface and flood warning, Bangladesh (Source : FFWC/BWDB, 2002)

Notes:

- end of module 3 -

module 4: probabilistic climate and flood forecast products

The module aims to familiarize participants with probabilistic seasonal climate and flood forecast products for disaster preparedness in the agriculture sector.

At the end of this module, participants are expected to:

1. Describe how ocean-atmosphere interactions influence rainfall in Bangladesh
2. Distinguish between El Niño and La Niña phenomena
3. List the factors considered in rainfall forecasting
4. Identify the type of forecasts and describe how each is used in reducing risks from floods and drought

Climate Forecasting

Attempts to forecast seasonal variations of monsoon patterns started in the late 1800s. The first attempt to predict the monsoon (Blanford, 1884) considered the impact of the snow cover over the Himalayas during the previous winter. In 1924, Sir Gilbert Walker found that the difference between the atmospheric pressure over the eastern Pacific Ocean and the Indian Ocean has particular relevance to the monsoon rainfall in the South Asian region. The see-saw pattern of atmospheric pressure difference between the Pacific Ocean and the Indian Ocean is referred to as **Southern Oscillation (SO)**. This scientific achievement initiated the possibility of forecasting climate variations and associated floods and drought, which are of importance to agrarian societies in the South Asian region, including Bangladesh.

Variations in climatic conditions and climate-related hazards from year-to-year are primarily due to the interaction of the ***ocean and atmosphere***. Generally, warm ocean water (high sea surface temperature) creates a low pressure in the overlying atmosphere. This creates a rising air leading to widespread heavy rainfall. The **Sea Surface Temperature (SST)** increases due to less activity of winds over the ocean surface. When the winds are less active over the ocean, the surface water is not disturbed and, being constantly exposed to the atmosphere, becomes heated. This type of overheating of surface water alters the rainfall of the tropics. For example, above average SST over the tropical Pacific Ocean during winter and spring reduces subsequent monsoon rainfall in Bangladesh. However, above average SST in the North Indian Ocean and the Bay of Bengal, especially during June, increases the summer monsoon rainfall in Bangladesh.

Q. *How do ocean and atmosphere interactions influence the rainfall in Bangladesh?*

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During normal periods, warm water (SST > 27°C) covers the eastern Indian and the western Pacific Oceans. This condition produces maximum precipitation in the South Asian region, including Bangladesh. During an El-Niño event, warm water covers the eastern Pacific Ocean, bringing more rainfall over the central and eastern Pacific. During these periods the eastern Indian Ocean and South Asia, including Bangladesh, have greater chance to get lower than normal rainfall associated with drought conditions.

Year-to-year variability of the summer monsoon and associated hazards are also linked with ocean-atmospheric phenomena like the **El-Niño Southern Oscillation (ENSO)**. The occurrence of *El-Niño* is more likely associated with a weak monsoon, while La-Niña is associated with a strong monsoon. El-Niño events are mostly associated with rainfall deficit over Bangladesh. The absence of monsoon depressions and cyclonic storms was found to be the main factor causing deficient rainfall and consequent drought conditions in the individual monsoon months. Similarly, likely high rainfall during *La-Niña* years produces flood in major rivers when compared to El-Niño years. Figure 4.1 shows that the *chance* of flooding in Bangladesh is more during La-Nina years compared to El-Niño years.

Q. *What is El-Niño? How does it influence Bangladesh rainfall and associated droughts and floods?*

A.

El-Niño is a Spanish word that means 'Child Jesus', which Peruvian fisherman used to refer to the warm waters that typically appear in the eastern Pacific coasts during Christmas time. El-Niño is defined as the anomalous appearance of warm sea surface temperature in the central and eastern equatorial Pacific Ocean.

La-Niña is the opposite condition of El-Niño, characterized by unusually cold ocean temperatures in the equatorial Pacific Ocean.

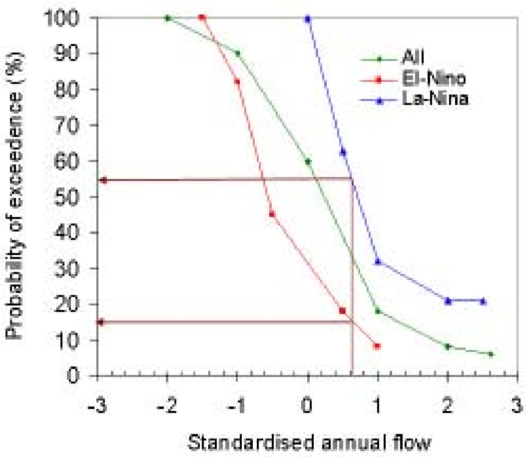

Figure 4.1: Chance of flooding in the Ganges during El-Niño and La-Niña years (Source: Whitaker et al., 2001)

Observations show that with the progression of the seasons, the regions of warmest SST in the Indian Ocean also progresses northward, establishing the monsoon and rainfall in Bangladesh. Apart from ocean-atmosphere interactions, **solar radiation** and associated heating of land mass is generally considered to be the most important driving mechanism for the monsoon. It has also been recognized that anomalous excessive **snow cover** over Eurasia may lead to the weakening of the summer monsoon. The above factors are responsible for the success or failure of monsoon rainfall in Bangladesh, and are thus used for forecasting monsoon rainfall and associated floods and drought.

Q. *List the important factors to be considered for forecasting rainfall and associated floods and drought in Bangladesh, and state the reason why you chose these factors.*

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Flood Forecasting

Water flow into Bangladesh comes not only from rainfall but also from upstream basins in adjoining India and the Himalayas, with a combined area 12 times the size of Bangladesh. Thus, flood forecasts are not based on rainfall alone. River flow forecasts also consider soil moisture conditions in the larger **catchment** areas of the Ganges and Brahmaputra, which lie in India and other adjoining areas. A catchment is an area in which rainwater is collected and water drains into low lying areas, usually into a river (the hydrological cycle may be elaborated as given in Fig.4.2).

Q. *Why is it essential to understand the scientific background of probabilistic climate and flood forecasting?*

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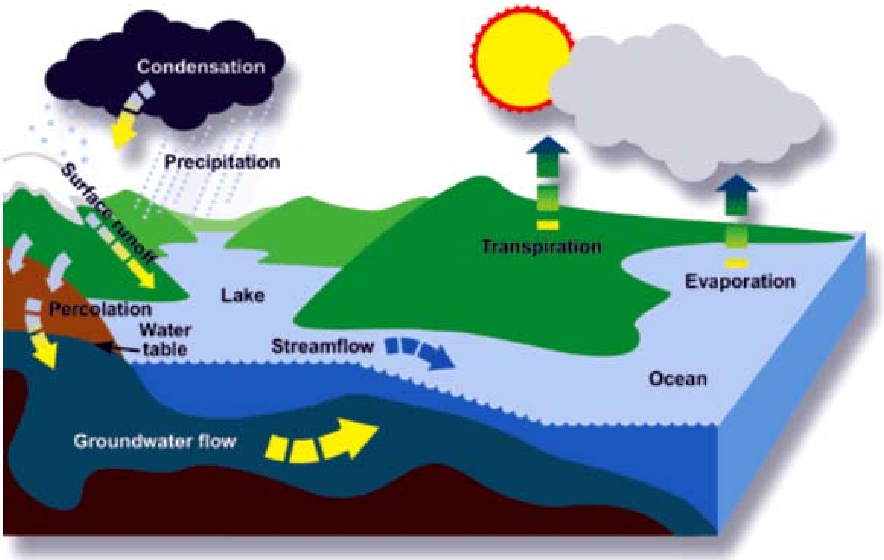

Figure 4.2: Components of and reservoirs in the hydrological cycle

Hydrological Cycle

The hydrological cycle describes the storage and movement of water between the earth, atmosphere and the oceans. Water on the planet can be stored in the atmosphere, oceans, lakes, rivers, soils, glaciers, snowfields and underground. Water is transported from one reservoir to another by processes such as evaporation, condensation, precipitation, runoff, infiltration, transpiration, melting, and groundwater flow. The oceans supply most of the evaporated water found in the atmosphere. Out of this evaporated water, about 91% returns to the oceans through rainfall. The remaining 9% is transported to areas over land. The resulting imbalance between rates of evaporation and precipitation over land and ocean is compensated by runoff and groundwater flow to the oceans.

Water covers 70% of the earth's surface. Oceans contain 97.5% of the earth's water, land 2.4%, and the atmosphere holds less than 0.1%, which may seem surprising because water vapour plays such an important role in weather. The annual precipitation for the earth is more than 30 times the atmosphere's total capacity to hold water. This fact indicates the rapid recycling of water that must occur between the earth's surface and the atmosphere.

Q. *What is a catchment? How does it influence floods in Bangladesh?*

A.

The types of probabilistic flood forecast products are:

1. Long-term flood forecast (1-6 months lead time)

FFWC proposes to produce long term flood forecasts every month (on the 15th) valid for the next six months (e.g. forecast issued on 15th May is valid for the next six months up to November 15th). The forecasts are based on the European Centre for Medium Range Weather Forecast (ECMWF) **climate forecast models**. These models consist of mathematical equations explaining the physical relationship between the ocean and the atmosphere and its influence on rainfall. The forecasts are expressed as probabilities. Figures 4.3 and 4.4 show examples of long-term flood forecast products. The likely river flood levels are known at least three months in advance. Agricultural decisions like changing of crop varieties, and modifying long-term cropping system can be taken based on the flood forecast. Monthly updates provide opportunities to modify decisions within the season.

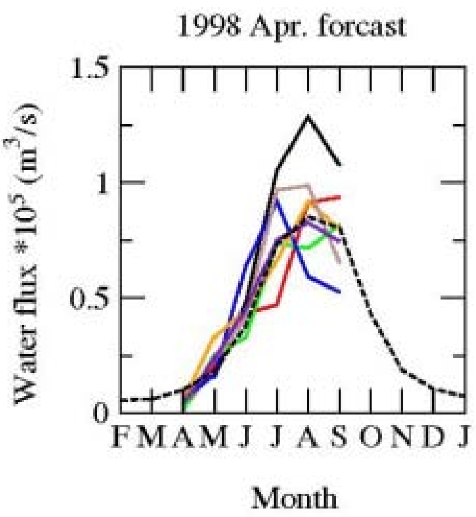

Figure 4.3: "Forecast" of the 1998 Ganges and Brahmaputra flood into Bangladesh from 1 to 6-month periods starting in April 1998. The figure shows forecasts generated from the models (coloured lines). The long term-average Ganges flow quantity is given as dashed line and observed discharge is given as solid line. (Source: CFAB, 2002)

Figure 4.4: Probabilities of Ganges flood levels for up to four months (upto August, forecast is issued during April.) (Source: CFAB, 2002)

Q. *How are long range flood forecast products useful for managing potential impacts of floods or drought in agriculture?*

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2. Medium-term flood forecasts (20 – 25 days lead time)

Medium range flood forecasts are issued 20-25 days in advance to explain the variation of flood levels within a season (Fig. 4.5). This type of forecast is useful in flood or drought mitigation as it gives the possible status of river flow at least 20 days in advance. This forecast is provided based on **empirical equations**, which are simple statistical equations, involving parameters such as rainfall, soil moisture, and vegetation conditions for calculating flood levels. Figure 4.5 provides an example of such forecasts for Brahmaputra.

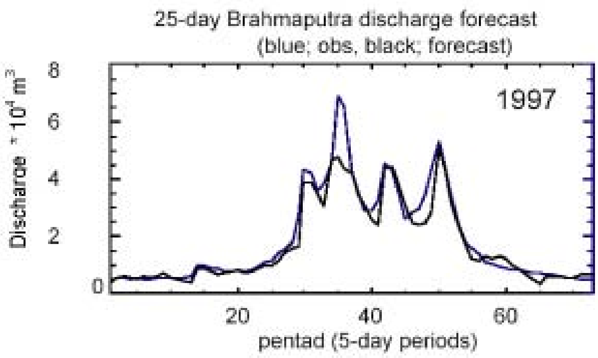

Figure 4.5: A 25-day flood forecast for Brahmaputra (blue line is observed flow and the black line is forecast) (Source: CFAB, 2002)

3. Short-term flood forecasts (2-6 days lead time)

Short-term flood forecasts at the boundaries of Bangladesh, can be combined with flood forecasts issued by FFWC. The method can provide forecasts for up to 8 days, which are useful for early decisions for flood mitigation and in preserving livelihoods, particularly in planting and harvest operations, minimizing crop loss, etc. Figure 4.6 shows the probabilities of flood levels issued daily for the next 5-6 days.

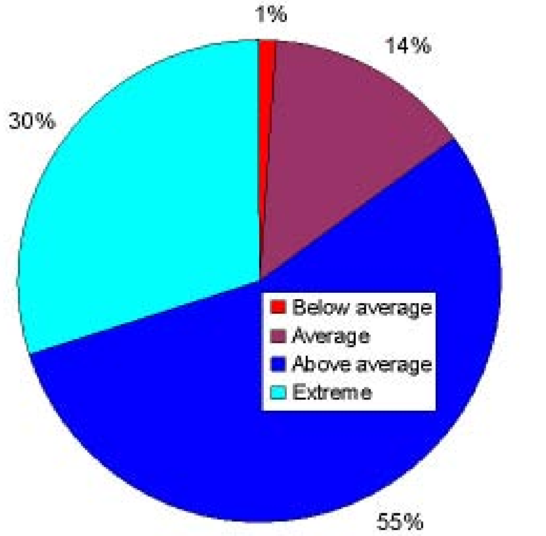

Figure. 4.6: Probability of various intensities of discharge into Bangladesh during forthcoming 6 days

Q. *Which type of flood forecasting method do you consider most important for reducing disaster risk in agriculture? Why?*

A.

Table 4.1: Climate and flood forecast types and their use for disaster risk management in agriculture.

Types of flood forecast	Frequency	General use
Short-term (2 – 6 days)	Daily	• Most accurate forecast compared to medium and long-term forecasts • Detailed information of river discharge into Bangladesh • Allows early decisions for flood mitigation and disaster management
Medium-term (20 – 25 days) Made separately for the Ganges and the Brahmaputra	Every 5 days	• Applicable for time of planting and harvesting • Storage of water for irrigation • Logistics planning for flood management
Long-term (1 – 6 months) Produced every 15th of the month for the next six months (most accurate for the ensuing 3 months)	Beginning of the season and every month	• Provides an overview of the coming season • Application includes long-term agriculture and water management planning and anticipatory actions to manage disaster risk.
Long term rainfall forecasts (3-4 months) for the monsoon season	Beginning of the season and every month	• Planning cropping strategies including irrigation • Opting for drought tolerant crops in drought prone areas • Choosing crop area Resource allocation

- end of module 4 -

module 5: cropping calendar and climate-related risks

The purpose of this module is to understand the cropping system calendar followed in Bangladesh and identify disaster risks in agriculture.

At the end of this module, participants should be able to:

1. Identify the crops and describe the cropping systems in Bangladesh
2. State when these crops are sown and harvested
3. Explain the climate-related risks at each stage of crop growth

Historical Perspectives

Rice is the main staple food crop of Bangladesh grown in about 10 million hectares of farm land. Its production and yield increased gradually over the last five decades. This increase, however, cannot keep pace with the increase in population growth of Bangladesh. Among the four rice crops, the wet season second (July to December) rice crop (Transplanted Aman rice) is grown in about 40% of the rice area in Bangladesh. In dry years, this crop suffers from high yield reduction due to inadequate rainfall (drought) during transplanting period, as well as during critical growing period. Farmers do not practice supplemental irrigation during drought in many districts as it requires substantial investment. Delayed transplanting of Aman rice reduces the yield as the critical crop growth falls during November, a low rainfall month (Fig.5.1). Further, delayed transplanted Aman leaves no land to grow short-duration vegetables, oil seeds, and pulses before *Boro* rice cultivation. Delayed transplanted Aman also has a subsequent effect on recently evolved short-duration crops. Hence, early warning systems involving weather and climate forecasting play a major role in disaster preparedness and mitigation.

Q. *What are the climate related risks associated with cultivation of transplanted Aman rice?*

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Until the early 1970s, wheat was grown mostly by marginal and subsistence farmers. However, since the 1970s, wheat is the dominant principal cereal import due to high demand, particularly in the food rationing system. Currently, wheat is the second major cereal crop of Bangladesh, and accounts for about 9% of the total cereal production.

Q. *Why does delayed planting of transplanted Aman lead to reduced yield?*

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Wheat is grown during the dry season (November – March), usually after the harvest of the previous Aman rice, in competition with other crops such as dry season rice (Boro rice). Higher water requirements for growing Boro rice relative to wheat (7.4 times more irrigation cost for Boro rice than for wheat) encourage farmers to grow wheat in some areas. Among the physical factors, climate is responsible for high instability of wheat yield. This is because the sowing of wheat may get delayed due to either the late planting of Aman rice, or use of long duration Aman cultivars, which increases the risk of exposing the wheat crop to high temperatures during the grain filling stage in March-April, reducing the grain yield. Therefore, the productivity of transplanted Aman rice and wheat in a rice-wheat rotation is much dependent on timely establishment of transplanted Aman and water availability.

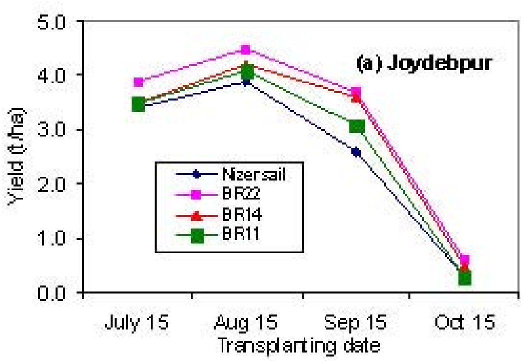

Figure 5.1. Average variation in calculated rice yield (t/ha) at Joydebpur, Bangladesh

Q. What is the climate-related risk affecting wheat production in Bangladesh?

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Cropping Systems

Agricultural crops are grown during three distinct crop seasons (Table 5.1): kharif – I (March 15 – June 30), kharif-II (July – September/October) and winter (November – February). *Aus* is the first rice grown between March and June, but it is becoming less important due to the risk of both drought during mid-season, and flood at the time of harvest. *Aman* is the second rice crop grown between April and August. Transplanted *Aman* is the major rice occupying almost 40% of total rice area. Rabi crops are wheat and potato grown from mid-October to March. Yield fluctuation is more when rice is transplanted late, particularly in cooler regions, because of annual variations in weather (e.g. air temperature). In the warmer southern regions, rice yield is relatively stable with variation in transplanting date. The nature of disaster risk on various crops differs with crop stage and cropping calendar.

Q. *Why does transplanted Aman rice crop play a dominant role in rice-based cropping systems?*

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The summer paddy crop, *'Boro'*, grown from January to May, is becoming very important: area planted and production nearly tripled during the last 15 years. Boro rice is a high-yield crop, but cultivation cost is more due to investment on irrigation. Vegetables, oil seed crops and pulses are also grown during the dry season between November and February.

Q. *Give climatological reasons for the increased crop area under Boro rice.*

A.

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Q. *List factors responsible for the change in cropping pattern over the years. Did climate-related risks influence the cropping systems?*

A.

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Q. *Study Table 5.1 and list the crops and corresponding stages that are threatened by flood or drought based on your experience.*

A.

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Q. *What agronomical practices would help in protecting the above crops from floods or drought?*

A.

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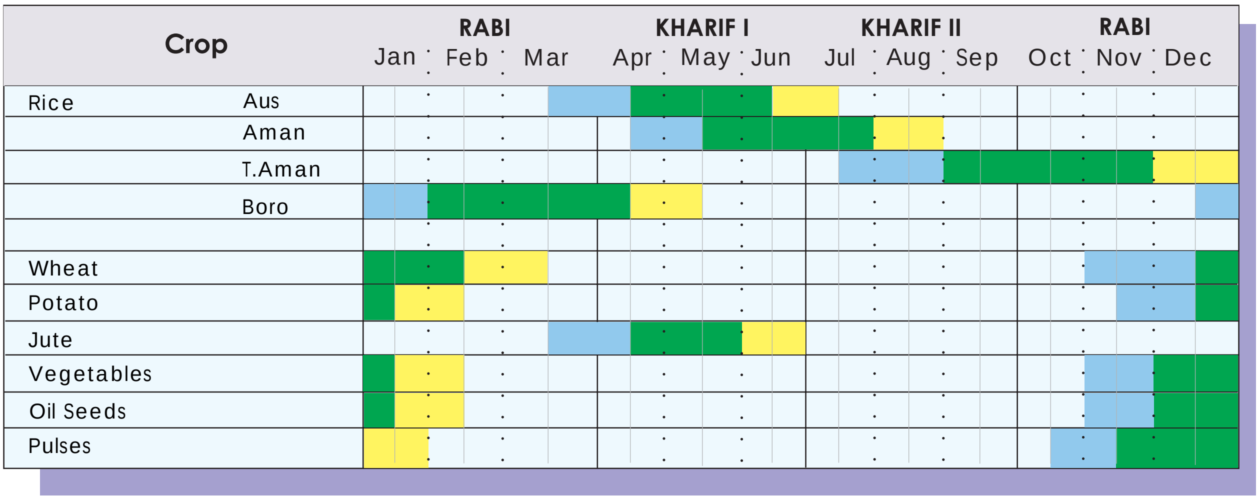
Table 5.1: Cropping systems in Bangladesh



Analyzing the crop calendar diagram provides an opportunity to use climate and flood forecast information at various times of the year to reduce the impacts of flood and drought.

Notes:

- end of module 5 -

module 6: application of climate and flood forecast information

This module aims to guide participants in assessing disaster risks and preparing a risk management plan for risk reduction in the agriculture sector.

At the end of this module, participants should be able to:

1. Identify the key considerations for communicating climate and flood forecast information
2. Identify climate-related risks and prepare a risk management plan for crops, livestock and fishery

Communication of Climate and Flood Forecasts

Climate and flood forecast information, even if forecasts are perfect, have limited value if they cannot be understood and used by the recipient to support decision making. Communicating uncertainties in forecasts is a challenge since people, often, do not perceive forecasts as probabilistic. Engaging intermediaries, such as the DAE, and encouraging stakeholder participation can reduce these problems.

Translation into impact scenarios and preparation of response options

Predictions need to be given meaning for them to be understood and guide responses by users. The local climate and flood forecast information should be translated into impact outlooks, keeping in view site-specific vulnerabilities (e.g. with reference to different seasons and different cropping systems). Response options can then be drawn, for communication to farmers.

Communicating risks

People's perception of risks associated with a forecasted event is often anchored to their most recent experience. It is therefore important to provide information in clear and simple language on what is happening, what it means to the person, and what the person can do.

The **user metric** is a tool that aids the interpretation of probabilistic forecasts and the assessment of the cost/ benefit of a particular response option to help farmers in making an optimal decision. It incorporates:

1. Information from the forecast of the probability of occurrence of a particular event with specific intensity and duration
2. User community assessment of the impacts of occurrence of a particular event. For example, DAE understands the variations in yield of a particular crop type with rainfall extremes and can calculate the associated loss/ gain.

Q. *What are the key considerations in communicating climate and flood forecast information?*

A.

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Preparation of Disaster Risk and Risk Management Plan Matrix

In Bangladesh, the perfect weather for crops hardly ever occurs -either there is too much water (flood), or too little (drought). This requires greater level of resource management through appropriate use of climate information. It is very much essential to identify the key disaster risks during crop growth cycle and the management alternatives in the context of disaster preparedness.

In the very low lands of the country, local Boro rice is cultivated after the monsoon rains. In the low lands, where floodwater can rise to more than 180cm, Boro rice face flood risk at the time of harvest. In medium high lands, where flood depths are from 90-180 cm, Boro rice and wheat are cultivated with less risk of flooding. However, the Aus and transplanted Aman face the risk of severe floods from the monsoon rains between June and October.

In medium high lands with flood depths from 0 to 90cm, flood risk is relatively less. However, the transplanted Aman is often subjected to early flooding. Floods also sometimes affect the Aus rice during harvest time. As floods often affect the Aus and transplanted Aman, area under high yielding Boro rice is increasing and have, in some flood years, increased rice production.

In high lands, agriculture is relatively safe, but drought during the monsoon as well as in dry season is very common due to high level of rainfall variability. The Aus rice is affected by ***early drought*** causing poor crop establishment due to false start of monsoon rains with breaks at the beginning. The Aus and T.Aman crops are constantly affected by ***mid season drought*** during the cropping season.

In medium highlands, T.Aman is affected by late season ***terminal drought*** during October and November. Adjusting the time of transplanting of Aman based on climate and flood forecast information can reduce the impacts of drought and flood. The strategic alternative option would be to select *flood tolerant* varieties.

Q. *Why is T.Aman rice crop affected by both flood and drought? Suggest a disaster risk management plan.*

A.

Table 6.1. Crops, agricultural practices, disaster risks and risk management plan matrix for applying climate and flood forecasts in rice-based systems.

Crop	Agricultural practices	Decision window (time)	Disaster risk and impacts	Information requirement for preparedness	Time lag (days)	Management plan to reduce risk
Aus	Sowing	Mar 15 - Apr 30	False onset of rains and subsequent dry spell	Onset of rains	15	Timely or delayed sowing
	Planting	May 1 – Jun 15	Early flooding causes submergence	Chance of early flooding	10	Protection from floods
	Harvesting	Jun 15 – Jul 30	High flood causes heavy damage to crops and submergence	Chance of high floods and warning	10	Advance harvest after physiological maturity
Broadcast Aman	Sowing	Mar 1 – Apr 30	Early season dry spell and poor establishment	Onset of rains and chance of early dry spells	15	Delayed sowing of broadcast Aman
	Harvesting	Augt 15 – Oct 31	Late season flood causing submergence, low quality grains and loss of investments	Chance of high floods	10	Advance harvest
Transplanted Aman	Transplating	Jul 1 – Aug 15	Dry spell affects the early establishment in high lands.High floods affects early seedling	Chance of dry spell Chance of high floods	15	Delayed sowing / adjusting sowing time Planning for extra seedlings for transplanting
	Fertiliser application (split)	Sep 1 – Sep 20	Inundation reduces the efficiency of applied fertilisers	Chance of late flood	15	Skipping first split application
Boro	Sowing/seed bed	Nov 15 - Dec 31	Inadequate rainfall during Nov/Dec affects establishment	Chance of rainfall	15	Early sowing of Boro coinciding with rainfall during October
			Flooding in low lands affects establishment	Chance of late flooding after October	15	Delayed sowing in late December
	Harvesting	Apr 1 – May 15	Flash floods or hail storms causes damage to the crop	Flash floods/ hail storms	10	Advanced harvest to reduce yield loss

Table 6.2: Crops, agricultural practices, disaster risk and risk management plan matrix for applying climate and flood forecasts in various crops.

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 unfavorable weather	Possibility of pest and disease outbreak	10	Arranging plant protection chemicals
Jute	Harvesting	May 15 – Jul 15	Yield loss and poor quality	Chance of early flood	20 days	Early harvest
Summer vegetables	Harvesting	Jun 1 – Jul 15	Yield loss and poor quality	Chance of early flood	2 months	Pot culture, use of resistant variety

Application of potential climate and flood forecast products

The medium to short range flood forecast products are useful for taking the following decisions:

1. Early harvesting to avoid major crop damage
2. Planning of transplanting of rice crops
3. Planning for extra seedlings to replant
4. Taking protection measures to save assets and livestock
5. Taking precaution for culture fisheries
6. Planning flood response activities
7. Taking precautionary measures to protect infrastructure

Long range flood forecasts can help in:

1. Planning cropping strategy
2. Planning national budget for relief, rehabilitation and reconstruction
3. Planning flood and drought response activities
4. Crop area and yield forecasting

Q. *Choose a drought event that you are familiar with and briefly describe how it could have been managed by using climate and flood forecast information.*

A.

Table 6.3: Risks, impacts and management plan matrix for the livestock sector

Risks	Type of livestock	Season/month	Impacts	Time of climate and flood forecast	Alternative management plan
High temp	Cattle	May-Aug	Disease like FMD,PPR in cattle	Mar	Early vaccination
	Poultry	May-Aug	Heat stroke and production loss	3 -10 day forecast	Free ventilation, water supply
Flood (early, high and late)	Cattle	Jun-Sep	Crisis of food and shelter. Diseases like cholera, worm infestation	Early June	Food storage, flood shelter, vaccination de-warming
Drought	Cattle	Mar - May	Disease like black quarten, anthrax etc.,	Early Mar	Vaccination against diseases
Cold stress	Cattle and poultry	Jan - Feb	Cold stress and production loss	Dec - Jan	Shed management

Table 6.4: Risks, impacts and management plan matrix for the fisheries sector

Risk	Stage of growth	Season/ month	Impacts	Time of climate and flood forecast	Alternative management plan
Cold wave (<10° C)	Fingerlings Prawn & Cat fish	Dec to Feb	Damage to fingerlings Appearance of disease on prawn and catfish; Hazard to Gonanold development of brood fish; Loss of appetite	Before the season	Changing the culture period
Flood	Nursery table fish & Brood fish	June to Aug	Inundation of fish farms; Damage to pond embankments; Infestation or diseases	Apr - May	Pre-flood harvesting, Net fencing/bana, Fingerlings stocked in flood free pond, High stock density
Drought	Fry production of fingerlingsBrood fish	Mar - May	Damage/late start of nurseries; Not maintaining optimum depth of water for brood fish; Scarcity of water sources	Jan - Feb	Create water sources, Ensure reservoir for brood fish, Make small pond in a high location

Q. *Choose the season and crops that are frequently affected by various climate related risks and fill the information required to minimize impacts.*

A.

Climate induced disasters	Crop and season	Impact of disaster	Climate Information requirement for disaster preparedness	Management plan to reduce the risk
River flood				
Flash floods				
Tidal waves				
Water inundation				
Salinity				
Soil erosion				
Pest attack				
Disease attack				

- end of module 6 -

module 7: understanding probabilistic climate and flood forecasts

This module aims to enhance the understanding of probability forecasts.

At the end of this module, participants should be able to:

1. Give at least two reasons for uncertainties in forecasts
2. List the advantages of using probabilities in forecasting
3. Interpret a probabilistic forecast

Forecast Uncertainty

Uncertainty is an integral part of the forecasting process. Forecasts from numerical weather prediction models are always sensitive to errors in the initial state. This means that small differences in the initial conditions during computation can lead to significantly different forecasts over a period of time. Even if the model produces the correct synoptic development, there is uncertainty about whether a given particular location will experience a particular weather event.

Using probabilities in forecasting:

1. expresses the uncertainty inherent in a forecast in a precise and unambiguous manner,
2. provides quantitative information needed by users to make rational decisions in uncertain situations, and
3. makes it easier for users to recognize changes in risk between successive forecasts.

Understanding Probabilities

The probability of an event is just a numerical indication of a forecaster's judgment about the chance or likelihood of an event occurring. It is no different in principle from someone making a judgment that there is an 85% chance that his team will win in a football game.

Understanding Probabilistic Climate and Flood Forecasts

Refer to Figure 7.1, which shows the monsoon (June-September) rainfall for Dhaka for the past 38 years. Note the rainfall variability from 703 mm to 2,120 mm. The average seasonal rainfall is 1,361 mm, which means that one can expect a rainfall of 1,361 mm during a summer monsoon.

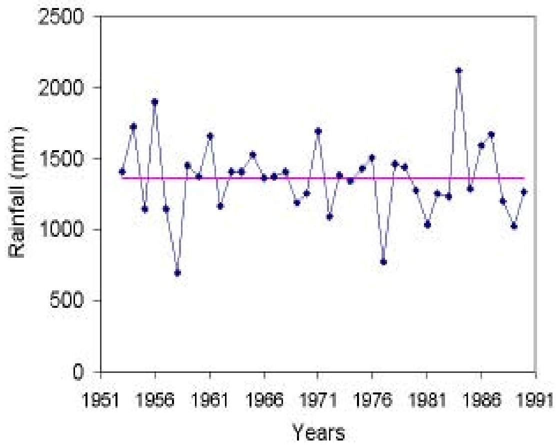

Figure 7.1: Time series of monsoon season rainfall for Dhaka from 1953 to 1990 (38 years)

Q. *Explain the fluctuations of summer monsoon rainfall amounts from the mean line over the years.*

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Q. *Do you remember any of these years? If yes, what is the significance of that year?*

A.

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Q. *What was the wettest monsoon?*

A.

Q. *What was the driest monsoon?*

A.

Q. *What is the range of rainfall expected during this season?*

A.

Table 7.1: Expected quantity of rainfall at Dhaka under various probability levels

Rainfall (Jun to Sep)	Rainfall
Highest on record (mm)	2,120
In 10% of the yrs, rain is 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

Why probabilistic forecasts?

Probabilistic forecasts are appropriate for disaster preparedness in agriculture sector, because:

- Rainfall and flood forecasting models are imperfect. Even though they are based on physical laws, many approximations are included in their formulation.
- Data available for the initialization of the models are not sufficient. The physical state of the atmosphere is known only approximately at any time. Thus, the initial conditions of the model cannot be accurately determined.
- Very small differences in the initial conditions may lead to very different outcomes.

Inadequate data and inexact models result in varying degrees of uncertainty in the forecast. It is therefore common to quantify the rainfall or flood event with associated probabilities.

From Table 7.1, the lowest recorded rainfall in the past 38 years is 703 mm (1958). Based on records, one can expect that the rainfall during the coming season will be more than 703 mm. Note that all 38 monsoons (Fig. 7.1) had at least 703 mm of rainfall.

The second driest monsoon on record had 772 mm rainfall (1977, Fig. 7.1). Out of 38 years, 37 years (97%) have at least 772 mm rainfall. Note that the chances of getting a higher rainfall decline. For example, the chance of getting more than 1,000 mm rainfall is 36 out of 38 years or 95%.

Now refer to the wettest years (Fig. 7.1). The highest rainfall amount recorded in the past 38 years is 2,120 mm (1984). The second wettest year had 1,896 mm rainfall (1956). The chance of getting at least 1,896 mm rainfall during a summer monsoon is 2 years out of 38 years (about 5%). The chances improve with expectations of lesser rainfall. Hence, the chance or probability of receiving at least 1,377 mm rainfall is 50% (Table 7.1).

Figure 7.2 is a plot of probabilities of exceeding a particular summer monsoon rainfall utilizing the data set of Table 7.1. The chance of receiving the lowest amount of summer monsoon rainfall is highest. Chances decline with expectations of higher rainfall. For example, the chance of getting 1,100 mm rainfall is 88%, while the chance of getting 1,500mm is only 22%.

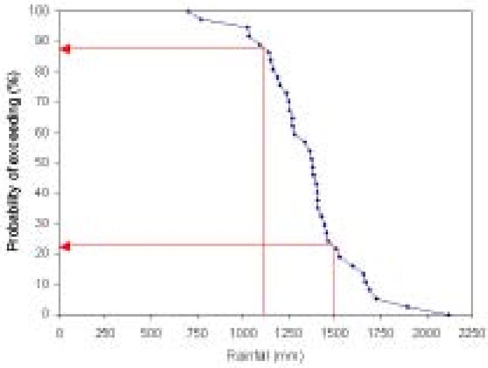

Figure 7.2. Relationship between monsoon rainfall amounts and probabilities for Dhaka.

Figure 7.3 compares a) the plot from observed rainfall data (Figure 7.2) with b) that of forecast values based on selected driest years. The plot from observed rainfall data (a) has a range of 703 – 2,120 mm, while that from forecast values (b) has 703 – 1,407 mm. This indicates that, most likely, rainfall will not exceed 1,407 mm. The chance of receiving 1,100 mm from a) is 88%, but from b) is only 38%. The forecast distribution (b) provides a relative drought risk (an indication that the coming season would be drier than normal) compared to that without forecasting (a). The forecast distribution (b) is therefore useful in making crop management decisions. Based on the forecast, agricultural extension officers can then prepare location-specific impact outlooks and corresponding risk management plans.

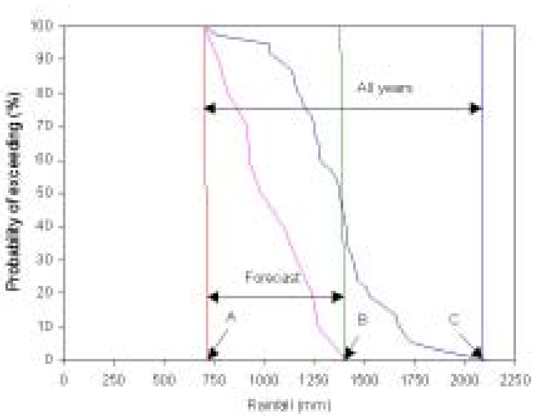

Figure 7.3: Uncertainty in rainfall expectations under all year scenario and forecasts scenario.

Q. *Refer to Fig.7.3. What do the curves mean to you?*

A.

Q. *What is the expected rainfall at 50% chance during the coming monsoon season at Dhaka?*

A.

Notes:

- end of module 7 -

module 8: incorporating climate and flood forecasts in decision-making

The purpose of this module is to demonstrate how climate and flood forecast information may be incorporated into decision-making for disaster preparedness in agriculture.

At the end of this module, participants should be able to:

1. Illustrate how farm level strategic and tactical decisions can be made using climate and flood forecast information by preparing impact outlooks and risk management plans

The exercises provided here are merely tools to help participants to become familiar with use of climate information for farm level decision-making to reduce disaster risks.

Exercise 8.1
Aus rice crop harvesting decision: Whether to harvest now or wait until complete maturity?

Situation: It is early July, and you are preparing to harvest your Aus rice crop which has been sown during mid March in a medium high land. The crop will attain complete maturity during mid July. With the potential for a high flood during mid July you need to make the best decision or you will waste time, money and resources.

Question: Given the current detail on the variable levels of flood, and the seasonal flood forecast what is the most appropriate decision?

Before you do the exercise, list the following:

Your location:

____

What is the normal river flow depth during mid-July?

____

What is the lowest river flow level in mid-July?

____

What is the highest river flow level in mid-July?

____

What is the river flow depth in your location during mid-July in a wetter than normal year?

____
____
____

What is the river flow depth in your location during mid-July in a drier than normal year?

____
____
____

What is the threshold river flow level above which it causes flood and inundation so that harvest is affected?

____
____
____

How many times has your Aus rice crop been affected due to flood at the time of harvest?

____
____
____

How often has the Aus crop harvest in mid-July been affected by high flood?

____

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____

What is the chance of above average (threshold to cause damage) flow during July from the long-range forecast given in May?

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____

Refer to the medium range empirical forecast and find out whether the level predicted is above the danger level.

____

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____

What is the probability of getting above average flow in your location during the next five days as given by the short range forecast?

____

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What is your decision based on the above information?

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Note : By writing the above information, the decision maker will be confident to make a better decision to prepare himself against flood risk.

Notes:

Exercise 8.2
T.Aman planting decision: Whether to plant in July or wait until August?

Situation: It is mid July, and you are preparing to plant transplanted Aman in a medium low land. Any potential high flood will affect the seedling establishment and subsequent crop failure. Delaying planting of this crop after mid-August will lead to reduced yield and leave no land for subsequent Boro rice crop. With the potential for a high flood during July you need to make the best decision or you will waste money and resources.

Question: Given the current detail on the variable levels of flood, and the seasonal flood forecast what is the most appropriate decision?

Before you do the exercise, list the following:

Your location: ______________________________

What is the normal river flow level?
July ______________ August _______________

What is the lowest river flow level?
July ______________ August _______________

What is the highest river flow level?
July ______________ August _______________

What is the river flow depth in your location during wetter than normal years?
July ______________ August _______________

What is river flow depth in your location during drier than normal years?
July ______________ August _______________

What is the threshold river flow level above which it causes flood and inundation so that transplanting is affected in July?

____
____
____

How many times has your T.Aman rice planting been affected due to flood?

____
____
____

How often has the T. Aman planting in July been affected by high flood?

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____
____

What is the chance of above-average (threshold to cause damage) flow during July from the long range forecast (1- 6 months) given in May?

____
____
____

Refer to the medium range (20 – 25 days) forecast and find out whether the level predicted is above the danger level.

____
____
____

What is the probability of getting above average flow in your location during the next five days as given by the short-range (1- 6 days) forecast?

____
____
____

Based on your experience and your own judgment in understanding probabilistic forecasts, what is the chance of high flood exceeding the threshold level that may cause damage to T. Aman at its early stages?

Explain your choice. Discuss this as a group.

Decision Making

Looking at the flood level probability in conjunction with flood forecasts, make an appropriate decision to manage your cropping system against flood and drought risks. Analyze the situation given the conditions based on the forecast. It is essential to consider the economic value of deciding to harvest now or after the crop attained full maturity

Which of these is your choice?

1. Plant T.Aman as usual in July and follow the *T.Aman – Boro* rice cropping system
2. Skip T.Aman and plan for short duration vegetables in late September – October/November, and plan for Boro rice in late November
3. Plant T. Aman in late August and plan for Boro rice in late December

Table 8.1: A simple decision outcome matrix with possible cropping systems

Decision	Outcome	T.Aman	Boro rice
Planting T.Aman in July	July flood	Submergence of seedlings	Boro rice possible
	No July flood	T.Aman possible	Boro rice possible
Delayed planting of T.Aman in August	Drought during critical stages	T.Aman yield reduced	Boro rice will be affected due to drought and risk of early flooding in April/May during harvest
	Adequate moisture during November	T.Aman will be successful	Boro rice will be affected due to drought and risk of early flooding in April/May during harvest
Skipping T.Aman	High flood during July	T. Aman not planted	A short duration vegetable during Sep-Nov and boro rice in early December
	No high flood during July		

What if I am wrong?

While your choice maybe the best decision considering the odds, there will be times when climate does not come as expected. What will you do when this happens, after you have implemented your decision?

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Using the Monthly Rainfall Records

Rainfall records are best used to jog one's memory and assess the risks of a decision. Fill-in the table below using rainfall values recorded for the wettest and driest years on record.

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	M ay	Jun
Wettest												
Driest												
Median												
Average												

What contingency practices have you adopted to cope with high flood during July?

___

___

___

How much rainfall do you require in each month: for successful vegetable cultivation? Boro rice cultivation? What is the chance of getting the required amount of rainfall?

___

___

___

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Mean rainfall (mm)								
Required rainfall (mm)								
Chance for getting the required amount (%)								

Notes:

- end of module 8 -

module 9: economic value of applying climate and flood forecasts

This module aims to demonstrate the economic value of applying climate and flood forecasts for disaster preparedness in agriculture.

At the end this module, participants should be able to:

1. Quantify the economic value of farm level decision making based on forecasts
2. Prepare a simple decision outcome matrix

The following example provides a simple assessment of the economic value of flood forecasts in farm level decision making.

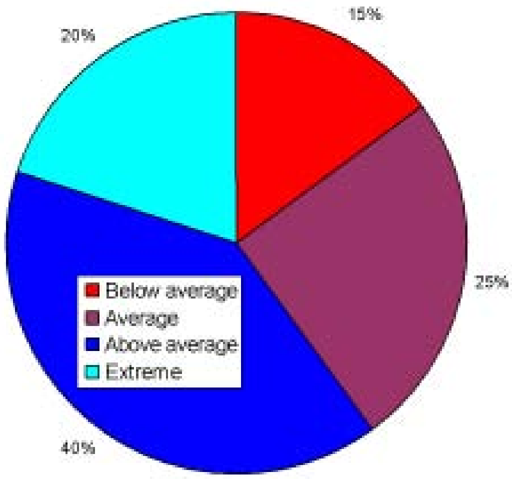


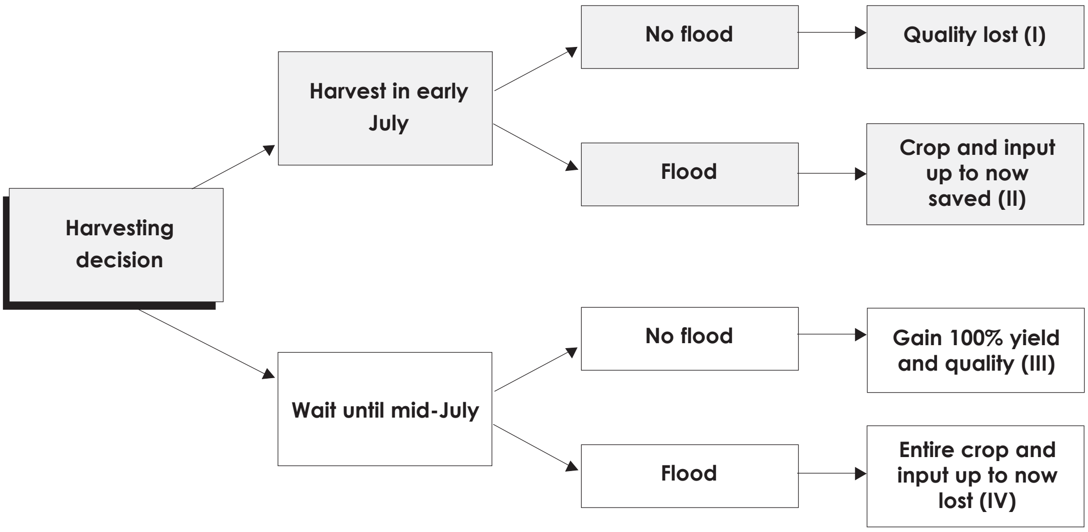
Figure 9.1: Probability of various intensities of river discharge into Bangladesh for a single day

Exercise 9.1

Refer to the short-range forecast given in Fig. 9.1. The forecast, updated daily, provides information for the next six days. The probability of exceeding threshold flood levels (extreme and above average) that can cause crop damage is 60%, the chance of flood levels not exceeding the threshold is 40%.

Situation: The crop is in 80% maturity stage and nearing physiological maturity during early July. It requires additional 10 days to reach complete maturity. The forecast indicates higher possibility of above average flow during mid-July that may cause inundation of paddy fields so that harvest would be affected substantially. Inundation during harvesting stage may lead to complete loss of produce and the entire investment. A decision needs to be taken during early July whether to harvest before full crop maturity, or wait until mid-July to ensure good crop quality.

The following decision outcome tree gives an idea about the possible outcomes:



The economic value of this forecast, considering the above possible decision and outcome scenarios, may be calculated as follows:

Economic components	Decision I	Decision II	Decision III	Decision IV
Added costs	-5%[a]	-5%[a]	-5%[b]	-5%[b]
Added returns	-	-	-	-
Reduced costs	5%	5%	-	-
Reduced returns	-25%	-30%	-	-65%
Net value	75%	70%	95%	30%

[a.)] additional cost for drying the crop as they will be harvested early; [b.)] additional cost for maintaining the crop for another 10 days

For example, the farmer decides to harvest the crop within six days, compromising crop quality by about 30%. If it is harvested early, the produce can be sold in the market for only 70% of the normal price. If the same decision (B) is taken for 10 years, in six years the decision yields better results. In four remaining years the decision yields about 25% less income.

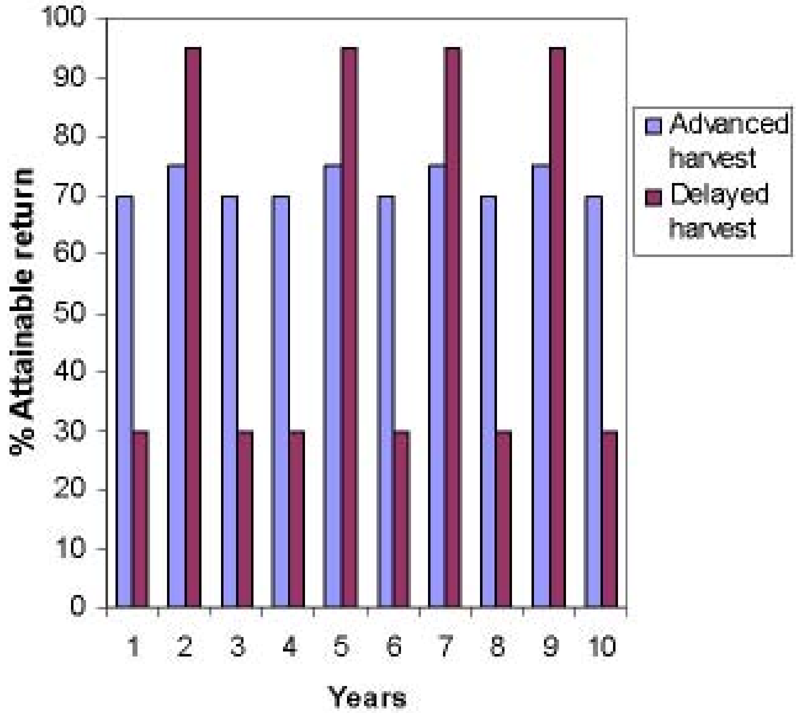


Figure 9.2. Percent attainable return from two decisions based on a probabilistic short and medium range forecasts

Analysis of Fig.9.2 indicates that the average attainable income from an early harvest decision is 72%, compared to 56% from the usual delayed harvest not using flood forecasts.

List the most important items you feel are very useful for decision making based on the above exercise.

reference 1: sources of climate and flood information

National Level Organizations

Bangladesh Agricultural Development Corporation
49-51 Dilkusha C/A, Dhaka
Bangladesh
Tel : 9556080-89
Fax: 880-2-9564357

Bangladesh Water Development Board
WAPDA Building
Motijheel C/A, Dhaka.
Bangladesh
Tel : PABX : 9562245-49, 9562251-59
Fax: 880-2-9564763
www.bwdb-bd.org/

Bangladesh Meteorological Department
Abhawa Bhaban, Agargaon
Dhaka-1207 Bangladesh
Tel : (88-02)-8116634, 8119832, 8113071, 9118448
Fax : (88-02)-8118230
E-mail : bmdswc@bdonline.com, bmddhaka@bttb.net
www.bangladeshonline.com/bmd/

Department of Agricultural Extension
Ministry of Agriculture
Middle Building Khamarbari
Farmgate, Dhaka 1215
Fax: 8111884

Flood Forecasting and Warning Centre
Bangladesh Water Development Board , 8th Floor
WAPDA Building Dhaka,BANGLADESH
Tel : 880 - 2 - 9553118 , 9550755
Fax - 880 - 2 - 9557386
www.ffwc.net/

Regional/International Organizations

Asian Disaster Prepardness Center
www.adpc.net

Programme in Atmospheric and Oceanic Sciences,
University of Colorado, Boulder
paos.colorado.edu/

Worldwide Disaster Aid and Information
www.disasterrelief.org/Disasters/
011119bangladeshflood/

Climate Forecast Application in Bangladesh
(CFAB),USAID/NSF
http://cfab.eas.gatech.edu/cfab/forecasts.html

Summary of Hydrological & Hydrometereological
Stations' Data Availability
http://www.warpo.org/NWRD/HydStn.html

Cowater International Inc.,
http://www.cowater.com/sampleprojects.html

Hazard Specific Information Services

Floods

Federal Emergency Management Agency (FEMA)
www.fema.gov

Flood warning information on technologies,
organizations and vendors
www.alertsystems.org

Flood warning information related to flood recovery
and restoration
www.gov.mb.ca/flood

Flood plain management
nwp.usace.army.mil/ec/h/fpm_home

National Association of Flood and stromwater
Management Agencies
ngdc.noaa.gov/seg/hazard/resource/soc/prflood2

Flood Risk Management and the American River
Basin
nap.edu/readingroom/records/030905334X.html

Drought

National Drought Mitigation Center, 4 USA
www.enso.unl/edu/ndmc

www.drought.noaa.gov
NOAA'a drought information center

www.meteo.go.ke/dmc
Drought monitoring center for eastern and sourthern Africa

srh.noaa.gov/ftproot/lch/drought.htm
Detailed definition of drought management

twdb.state.tx.us/rio/hydro/drought.html
General information on definition and classification of drought

cas.psu.edu/docs/cashome/droughtDrought-releated document and web site links.

agnic.org/agdb/ntldrght.html
Causes, prevention and mitigation of drought

penpages.psu.edu/univ_drought.html
Institutional and university drought sites

www.epa.gov/ow/you/drought.html
General drought management components

Cyclone

www.nhc.noaa.gov/aboutlinkcarchv.html
Provides Tropical Product Center's tropical cyclone forecast

www.seip.gso.uri.edu/tropcyc.html
Provides numerical modelling of tropical cyclone-Ocean interaction

www.info.gov.hk/hko/wxinfo/currwx/tcswarn.htm
Provides tropical cyclone warning related information for shipping issued by Hong Kong

http://www.ceos.noaa.gov/tropical.html
Provides information on Tropical Cyclone Management.

reference 2: glossary

Acceptable risk is the level of loss a society or community considers acceptable given existing social, economic, political, cultural, technical and environmental conditions.

Adaptability is the ability, competency or capacity of a system to adapt to climate stimuli.

Adaptability refers to the degree to which adjustments are possible in practices, processes, structures of systems to projected or actual changes of climate. Adaptation can be spontaneous, or planned, and can be carried out in response to or in anticipation of changes in conditions.

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

Adaptive capacity is the potential or capability of a system to adjust, via changes in its characteristics or behavior, so as to cope better with existing climate variability and change.

Analog years are years when oceanic and atmospheric conditions were the same or similar as for the current year or season.

Anti-cyclones are cells of high pressure associated with dry air, resulting in mainly cloud-free skies and little or no rainfall.

Capacity is a combination of all the strengths and resources available within a community, society or organization that can reduce the level of risk, or the effects of a disaster.

Capacity building aims to develop human skills or societal infrastructures within a community or organization needed to reduce the level of risk.

Categorical forecast is a forecast in which one of a discrete number of categories of events are forecast. Categories can be either nominal (no natural ordering, for example, clear, cloudy, rain) or ordinal (the order matters, for example, cold, normal, warm). Categorical forecasts can be either deterministic (a particular category, for example, rain or no rain tomorrow) or probabilistic (probabilities for each category, for example, probability of 0.3 of rain and 0.7 for no rain tomorrow).

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

Coping capacity is the tendency by which people or organizations use available resources and abilities to face adverse consequences that could lead to a disaster.

Crisis management is an approach for dealing with drought where responses and actions are made during the event with no prior planning, sometimes leading to ineffective, poorly coordinated, and untimely initiatives by individuals or governments.

Cyclones are depressions, or areas of low pressure, associated with rising warm air and anticlockwise air circulation in northern hemisphere (clockwise in southern hemisphere). A tropical cyclone is an intense depression fed by very warm (over 28°C) water, and by latent heat energy release in condensation. The wind is given its swirl by the Coriolis Effect.

Deterministic forecasts are non-probabilistic forecasts of either a specific category or particular value for either a discrete or continuous variable. Deterministic forecasts of continuous variables are also known as point forecasts. Deterministic forecasts fail to provide any estimates of possible uncertainty, and this leads to less optimal decision making than can be obtained using probabilistic forecasts. Deterministic forecasts are often interpreted as probabilistic forecasts having only probabilities of 0 and 1 (that is, no uncertainty), yet it is more realistic to interpret them as probabilistic forecasts in which the uncertainty is not provided (that is, unknown uncertainty). Sometimes (confusingly) referred to as categorical forecasts in the earlier literature.

Disaster is a serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources.

Disaster mitigation includes measures taken in advance of a disaster aimed at reducing its adverse impact on the community, society and the environment.

Disaster preparedness covers activities to enhance the ability to predict, respond to and cope with the effect of a disaster. It includes actions that assume an event will be disastrous and prepare people to react appropriately during and following the event.

Disaster prevention covers measures to provide permanent protection from disasters or reduce the intensity/frequency of a hazardous event so that it does not become a disaster.

Disaster risk management is the systematic process of using administrative decisions, organization, operational skills and capacities to implement policies, strategies and coping capacities of the society and communities to lessen the impacts of natural hazards and related environmental and technological disasters. This comprises all forms of activities, including structural and non-structural measures to avoid (prevention) or to limit (mitigation and preparedness) adverse effects of hazards.

Disaster risk reduction is the conceptual framework of elements considered with the possibilities to minimize vulnerabilities and disaster risks throughout a society, to avoid (prevention) or to limit (mitigation and preparedness) the adverse impacts of hazards, within the broad context of sustainable development.

Drought contingency plan identifies specific actions that can be taken before, during and after a drought to mitigate some of the impacts and conflicts that result. Frequently these actions are triggered by a monitoring system.

Drought impacts are specific effects of drought. People also tend to refer to impacts as “consequences” or “outcomes”. Impacts are symptoms of vulnerability.

Drought impact assessment is the process of looking at the magnitude and distribution of a drought’s effects.

Early warning is the provision of timely and effective information, through identified institutions, that allows individuals exposed to a hazard to take action to avoid or reduce their risk and prepare for effective response.

El Niño Southern Oscillation is a complex interaction of the tropical Pacific Ocean and the global atmosphere that results in irregularly occurring episodes of changed ocean and weather patterns in many parts of the world, often with significant impacts, such as altered marine habitats, rainfall changes, floods, droughts, and changes in storm patterns.

Forecast reliability is a reflection of whether the forecast probability is a true estimate of the forecaster’s level of confidence (consistency), and that the forecaster’s level of confidence is appropriate. If a forecast is reliable and consistent, then the probability that the event will occur is the same as the forecast probability.

Forecast skill is the accuracy of one set of forecasts compared to that of another set. Often the comparison is with a simple forecast strategy such as climatology, persistence, perpetual, or random forecasts.

Hazard is a potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation.

Hydrometeorological hazards are natural processes or phenomena of atmospheric, hydrological or oceanographic nature, which may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation.

Normal rainfall is the rainfall amount closer to long-term average or median rainfall.

Preparedness refers to activities and measures taken in advance to ensure effective response to the impact of hazards, including the issuance of timely and effective early warnings and the temporary evacuation of people and property from threatened locations.

Prevention refers to activities that provide outright avoidance of the adverse impact of hazards and means to minimize related environmental, technological and biological disasters.

Probabilistic forecast is a forecast that specifies the future probability of one or more events occurring. The set of events can be discrete (categorical) or continuous.

Probability defines the likelihood of an event or outcome occurring. Probability can range from being qualitative, using word descriptions such as likely or highly confident, to quantified ranges and single estimates, depending on the level of understanding of the causes of events, historical time series and future conditions.

Public awareness is the process of informing the general population, increasing levels of consciousness about risks and how people can act to reduce their exposure to hazards. This is particularly important for public officials in fulfilling their responsibilities to save lives and property in the event of a disaster.

Recovery refers to decisions and actions taken after a disaster with a view to restoring or improving the pre-disaster living conditions of the stricken community, while encouraging and facilitating necessary adjustments to reduce disaster risk.

Relief/ Response is the provision of assistance or intervention during or immediately after a disaster to meet the life preservation and basic subsistence needs of those people affected. It can be of an immediate, short-term, or protracted duration.

Resilience/ resilient is the capacity of a system, community or society potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organizing itself to increase its capacity for learning from past disasters for better future protection and to improve risk reduction measures.

Risk is the result of the interaction of physically defined hazards with properties of the exposed systems i.e., their sensitivity or (social) vulnerability. Risk can also be considered as the combination of an event, its likelihood, and its consequences- i.e., risk equals the probability of climate hazard multiplied by a given system's vulnerability.

Risk assessment/ analysis is the probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions.

Strategy is a broad plan of action that is implemented through policies and measures. Strategies can be comprehensive (i.e. focusing on national, cross sectional levels) or targeted (i.e. focusing on specific sectors regions or measures). Uncertainty is an expression of the degree to which a value (e.g. the future state of the climate system) is unknown.

Vulnerability refers to conditions determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards.

Safer communities and sustainable development through disaster reduction

Asian Disaster Preparedness Center

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