# CHAPTER 4

# ASSESSING CURRENT VULNERABILITY AND CLIMATE RISKS

## 4.1 Natural resources context

The surface geology of the pilot area comprises mainly alluvial sand of the active Ganges floodplain in the south and alluvial silt and clay in the north. The northeastern part of the fault-bounded Barind Tract has been uplifted some 50 m relative to the neighboring alluvium. The clay surface of the Barind Tract is composed of around 30 m of fine-grain deposits, mainly red-brown structure but also fine silt and clay with less abundant sand.

The clay is underlain by red-brown silty sands, sands and gravels and aquifers that are the groundwater source in the northeastern part of the study area. Sediments in the top 26 m of the profile have 5 000-year-old radiocarbon dates. The surface is thought to be the top erosion surface of the Barind clay and underlying sediments are therefore considered much older Barind sediments. The geological properties in the Barind Tract posses multiple problems related to water-holding capacity and recurring drought (Brammer, 2000).

### *4.1.1 Rainfall*

The average annual rainfall of the regions varies from 1400 mm to 1600 mm. The rainfall pattern is a uni-model that peaks in July (Fig. 8). Rainfall exceeds the potential evapotranspiration in monsoon months (June to September) but is less than evapotranspiration in the remaining months.

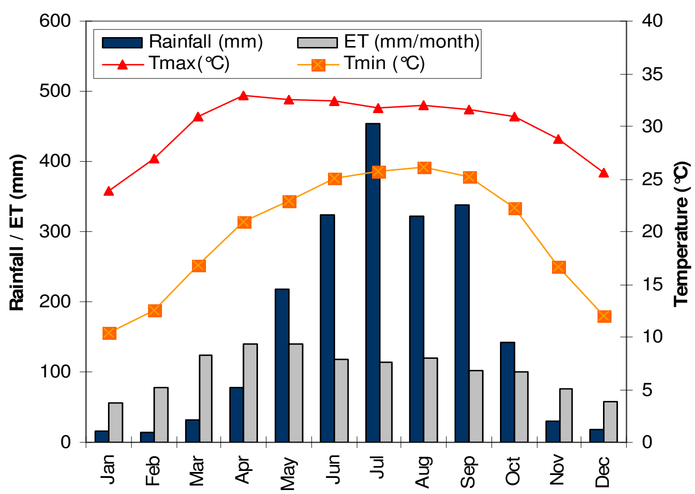



**Fig. 8**. Mean monthly rainfall, evapotranspiration and temperature in the pilot region

Highest maximum temperature occurs in April, and the highest minimum temperature occurs in June and July. Groundwater levels are at or near ground levels from August through October, and much lower in April and May. Groundwater rises as a result of recharge from

May and usually reaches its highest level in late July. Between July and October, groundwater levels are constant and maintain a balance between surface water levels and the fully recharged aquifers. Groundwater levels begin to fall in October, in response to rapid drainage of surface water. The rate of fall is highest in October and November but equally large changes may take place after January when withdrawal of groundwater for irrigation starts through deep tubewells. During the dry season, most of the minor rivers are sustained by groundwater outflows. However, many rivers in the region are dry and adequate water is not available to support growing demands of crop intensification.

### *4.1.2 Water supply situation*

Traditionally, before and during the early era of tubewell installation, rural water supply was largely from protected ponds and dug wells. About 17 percent of these ponds have been abandoned and probably dry up in the dry season.

The biological quality of water in these ponds is extremely poor due to unsanitary practices. Some traditional ponds are chemically and bio-chemically contaminated from aquaculture. The availability of surface water in the dry season (November through May) constrains development of dependable small- and large-scale surface water treatment plants for water supply. Groundwater is the most important water supply source in the pilot area. The depth of aquifers varies from zero to 54 m below ground surface. Groundwater is mainly extracted by installation of wells for the development of water supply systems. Sufficient water replenishment takes place during monsoon season in normal years. However, the continuous high pumping of groundwater leads to over exploitation during drought years.

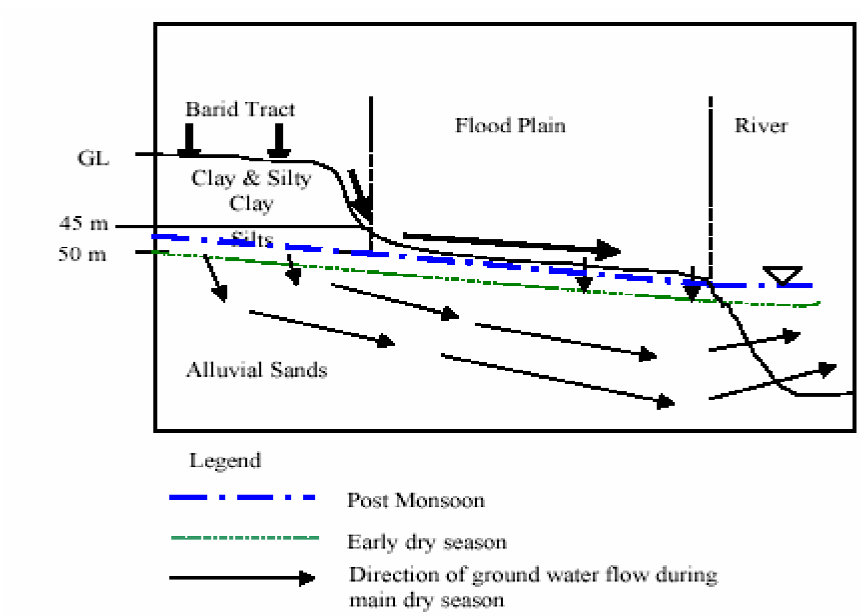



**Fig.9**. Water flow patterns and water level change following end of monsoon and early dry season

The aquifer is mostly stratified and formed by alluvial deposits of sand and silt with occasional clay. The main constituent of the aquifer materials is the medium-grained sand deposited at the lower reach by the Ganges. In this case, a shallow aquifer, considered the main aquifer, lies within 150 m of the surface with an overlying clay/silt blanket less than 2 m thick. A conceptual model showing water flow patterns and water level change following the end of the monsoon season and during the early dry season is shown in Fig. 9.

In the shallow aquifer, groundwater flows from north to south with localized outflow into the major rivers. Although the aquifer has high transmissibility, the horizontal flow of groundwater is very slow because of the low groundwater gradient. Though aquifer characteristics are uniform throughout the Barind Tract, the high Barind lacks adequate water and hence many villages have had shallow or deep tubewells installed. These villages are predominantly rainfed and face frequent drought due to high rainfall variability.

Groundwater in the region is mostly extracted from shallow depths (<60 m) in either the alluvial sediments or, in the east, from the aquifer confined beneath the Barind clay. Most drinking water supplies are extracted with suction hand pumps but as groundwater levels have a tendency to be deeper, a greater portion of water (around 20 percent) is extracted with pumps. A greater proportion of irrigation water (30 percent) is also derived from deep tube wells. Groundwater is relied upon heavily for irrigation in the dry season especially for *boro* rice, which requires very high levels of water. A few hand-dug wells are present in the region, extending to around 10 m depth, but these have been largely superseded by hand-pump tubewells. Hand-dug wells also exist in the Barind Tract, but they are seldom used and re-excavated. In recent years, over exploitation has led to rapid fall in the groundwater table (Fig.10). Future climate change combined with socio-economic and population pressure may aggravate the situation.

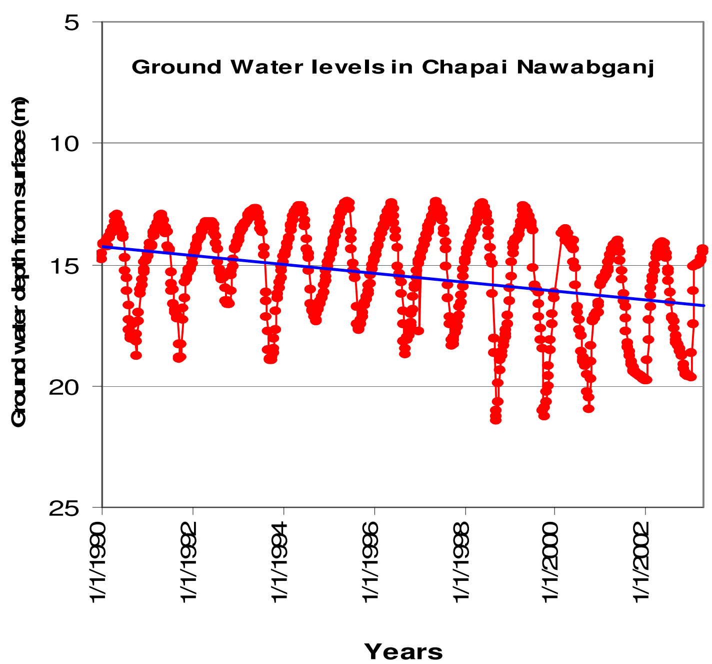



**Fig.10**. Groundwater levels in Chapai Nawabganj district from 1990 to 2002.

Water scarcity during dry season (November through May) affects the region's higher land. Because of lack of rainwater or surface water as an alternative resource, transplanting of *aman* rice is often delayed or withheld. Farmers are at a loss, as the situation is unusual and unexpected in many years.

There are often severe drought situations in Rajshahi, Naogaon and Chapai Nawabganj districts where monsoon rains fail frequently leaving farmers unable to transplant their *aman* seedling. To wet their fields artificially, they have sought alternative means of pumping water from ponds and water bodies that do not dry out. However, most of them are leased to culture fisheries and the lessees often refuse to offer them as an interim supply of water for irrigation even though they could earn extra money. On the other hand, the deep tubewells of the Barind Multipurpose Development Authority (BMDA) are often idle because there is no need for deep tubewell irrigation during and after the rainy season until the late flood season. Farmers who are included in the BMDA can rely on deep tubewells to facilitate *T. aman* cultivation, but farmers in most of those districts, including eight of the 12 villages selected for the projects, have no access to BMDA groundwater supply.

Shallow tubewells are no help. The water table in the region has been going down steadily because of upstream diversion of water from common rivers. The rainy season recharge of groundwater falls significantly short of the amount of water diverted upstream in the lean season. The problem is acute and demands immediate attention through community-based adaptation practices. The dejected farmers receive advice from the Department of Agricultural Extension (DAE) about how to meet unexpected droughts, but they do not have the means to mobilize alternative methods of irrigation and resources.

## 4.2 Socio-economic context

### *4.2.1 Agriculture*

Bangladesh has an agro-based economy with agriculture accounting for 35 percent of its GDP and employing 63 percent of its labour force. The majority of rural people in the drought-prone pilot region depend on agriculture for their livelihoods, though many do so indirectly though employment in small-scale rural enterprises, providing goods and services for farm families or in agro-based industries or trades.

Agricultural performance has a major direct impact on important macro-economic objectives, such as employment generation, poverty alleviation, human resource development and food security. The region's economy mostly depends on food production. Great success has been achieved in terms of increasing foodgrain production by converting sizable area to *boro* cultivation. The region has almost doubled its foodgrain production during the last two decades through large-scale adoption of modern rice varieties. Pests and diseases cause about 10 to 15 percent loss of rice yield. Loss of food and cash crops due to frequent droughts and other natural calamities seriously disrupts the total economy.

Land degradation, serious health hazards and degradation of aquatic resources are caused by excessive use of chemical fertilizers, pesticides and lack of crop diversification (mono-cropping of rice) during *boro* season. At the same time, over exploitation of groundwater for irrigation is causing a reduction of the groundwater aquifer in the Barind Tract. These factors will create serious problems for the environment and agricultural production in the future especially when combined with climate change.

**Table 1**. Land use pattern in Natchole Upazilla of Chapai Nawabganj district

| Categories | Area in hectares |
|---|---|
| Total land area | 28 409.8 |
| Barind Tract | 25 791.0 |
| High Ganges flood plan | 2 618.8 |
| Total cultivable area | 26 311.8 |
| Total waste/fallow | 41.8 |
| Total non-cultivable area | 2 098.0 |
| Total net cropped area | 2 6270 |
| Single cropped area | 17 105.0 |
| Double cropped area | 6 625.0 |
| Triple cropped area | 2 540.0 |
| Total cropped area | 37 975.0 |
| Total irrigated area | 7 584.0 |
| Total non-irrigated area | 16 782.0 |

Looking at land use patterns, the Barind Tract is dominated by agriculture (90.2 percent) especially under single crop rice (*T. aman*) during monsoon season. An example of land use pattern is given in Table 1. High cropping intensity, about 144.6 percent, is possible due to provision of deep tubewells, which benefits the *boro* season rice crop.

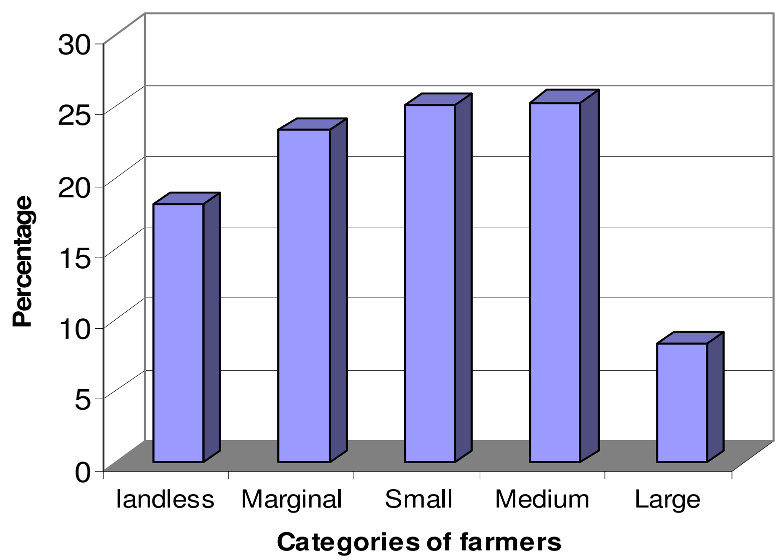



**Fig. 11**. Categories of farmers in the pilot drought-prone region in Barind tract

Most of the family farms in the pilot upazillas are small and marginal, making up almost 50 percent of the total farms (Fig.11). Although 18.1 percent of the families are landless, they still depend directly on agriculture and allied enterprises. Marginal, small and medium farms are 23.3, 25.1 and 25.3 percent, respectively and some 8.3 percent of farms are large. These groups, most vulnerable to climate change-related impacts, make up almost 91.8 percent of the population. Only 7 percent would be considered large farmers.

#### *4.2.2 Fisheries*

The Barind Tract has a diverse inland aquatic resource base with more than 300 species of fresh-water fish inhabiting the wetlands. Around 25 percent of the families are engaged in seasonal fishing, especially in low Barind Tracts, traditional canals and lowlands. Even in extremely drought-prone areas, some parts of the population (~2 percent) fish during monsoon season. The fisheries sub-sector contributes 10 percent to the agricultural GDP and 3 percent to total GDP in the country. Fish is second to rice as a source of food.

#### *4.2.3 Livestock*

The livestock population of Bangladesh includes 22.3 million cattle/buffalos, 14.6 million sheep/goats, and 126.7 million poultry. In rural areas of the Barind region, the majority of households involved in farming have livestock. In the past, cattle rearing was part of farming because cattle were used for ploughing. A significant quantity of dung is produced annually with half used as manure and the rest as fuel. Lack of grazing facilities constrains the mass rearing of cattle and goats. Poultry rearing is part of farming enterprises in drought-prone areas especially at household level. Although commercial poultry is not common in this tract compared to other areas, there is potential for future opportunities. On average, every farm family possesses three or four animals. Such animal integration in farming is unique to this region.

#### *4.2.4 Forestry*

During the last two decades, BMDA has initiated many programmes to improve the forest cover in the region. It has undertaken a roadside reforestation programme and initiated a social forestry programme for people living along roadsides and on fallow lands. Bamboo, traditionally grown in homestead areas, can support alternate livelihood activities during moderate to severe drought.

#### *4.2.5 Energy*

Traditional fuels such as tree leaves, branches and cow dung supply about 55 percent of energy used. In rural areas of Barind, tract animal waste and crop residues are major sources of energy. Many biogas schemes have been initiated in Bangladesh, but little impact has been seen in this region. However, there is lot of potential for developing community biogas production to meet household requirements. Farmers depend on diesel for pumping water and every year, during dry spells of the monsoon season and during *boro* (dry season), they find it very difficult to meet their diesel requirement. Lack of electricity and diesel fuel is an issue that leads to social unrest, with some of the government institutions being blamed by the farmers.

#### *4.2.6 Industries*

Few industries concentrate on processing agricultural raw materials and the ones that exist concentrate on food processing. As mango cultivation becomes more widespread, there is ample scope for development of new industries. Cottage industries exist but are not adequately supported by the institutional system.

## 4.3 Socio-cultural context

### *4.3.1 Livelihood strategies/portfolio*

Households in the drought-prone areas undertake various activities to gain and maintain their livelihoods (Table 2, Fig.12). The nature of these activities depends on the availability of assets, resources, labour, skills, education and social capital.

**Table 2**. Main sources of household income (%) in pilot districts (Urban + Rural) (BBS, 2005a,b)

| Sources of household income | Gometsapur | Natchole | Porsha | Sapahar |
|---|---|---|---|---|
| Cropping, livestock | 28.12 | 34.65 | 45.50 | 49.10 |
| Fishing | 1.15 | 0.29 | 0.17 | 0.18 |
| Agriculture labour | 33.18 | 38.35 | 35.77 | 29.85 |
| Business and hawking | 16.87 | 9.38 | 5.39 | 7.46 |
| Non-agricultural labour | 4.75 | 4.91 | 3.16 | 2.23 |
| Weaving, industry and construction | 2.77 | 0.96 | 0.25 | 0.37 |
| Employment | 3.45 | 3.54 | 3.34 | 3.76 |
| Transport and communication | 1.33 | 1.25 | 0.93 | 1.32 |
| Rent, remittance, religious, other | 8.39 | 6.67 | 5.49 | 5.83 |

There are also gender considerations, as household members perform activities in accordance with their culturally defined gender roles and ages. Men are mostly involved in agriculture, while women are involved in household activities. However, in Porsha and Sapahar bordering West Bengal, women are also involved in farming activities, especially farm operations such as weeding.

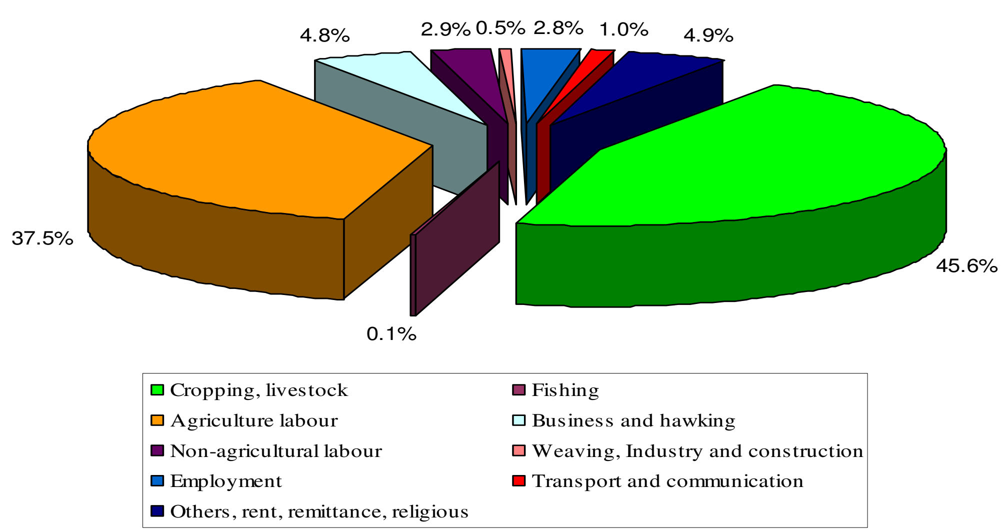



**Fig. 12**. Main sources of household income (%) in Porsha Upazilla of Naogaon district

The focus group discussions in the pilot upazillas indicated that about 45.6 percent of households are involved in farming (crop and livestock) and that in 37.5 percent of the households, members are involved in work such as farm labour. In total, almost 83.1 percent of rural households are directly involved in farming. The last decade has seen livelihood (income) diversification into non-farm activities and new activities related to farming, especially cultivation of high value crops such as mango. Also during the last decade, an increasing number of people have become involved in non-farm labour activities such as rickshaw and van pulling, which have grown with the development of road networks, small businesses and local trade. These alternative sources of income are crucial in averting vulnerability and attaining livelihood security during drought.

### *4.3.2 Farming*

Farming is the key to food security as well as livelihood security. Rice is the main produce in the area followed by vegetables, mustard, pulse and, more recently in some areas, maize. High-yield varieties of BRRI rice (mostly BR11 and BR 29) and local varieties are cultivated in the pilot upazillas. People usually cultivate their own land, but there are many sharecroppers cultivating land of rich landowners. Cultivation in rented out lands also is very common in the area. Almost 60 percent of the farmers in non-irrigated villages are tenants.

There are three types of farmers who cultivate their own land: i) rich farmers who leave the cultivating to supervisors and hired labourers, ii) farmers who do their own cultivating but also hire additional labourers, and iii) small-scale farmers who do not have the ability to hire paid labour. The average land holding in some of the pilot upazillas is about 3 *bhiga* (a *bhiga* equals one third of an acre). However, about 20 percent of the households are landless and another 30 percent possess less than 3 *bhiga.* Thus, it is not possible for these households to rely solely on their own production.

In sharecropping, the landowner shares the cost of water and fertilizer with the sharecropper and they divide the produce evenly. If a third party is involved in irrigation, the owner, sharecropper and the pump owner get equal shares. If the crops are fruits and vegetables, the landowner shares the cost of fertilizer and pesticides and receives half of the produce. However, in many villages the owners do not spend on inputs, but still expect half of the produce (with the farmers having to transport the produce to the owner's house which may be in a nearby town).

During severe droughts, farmers mortgage their land to meet family and household expenses. The person who makes the loan cultivates the land until the farmer repays the money. Occasionally, only a portion of land is mortgaged, based on the requirement. This socio-economic pressure leaves small farmers quite vulnerable.

Land, the main asset for the people in the study area, is an indicator of livelihood security and well-being. Most houses have thatched roofs with walls of bamboo sticks and mud. Liquid assets such as livestock and poultry still play a part in risk management by providing a source of livelihood security. Because of good marketing opportunities, livestock rearing is increasing. Poultry and goats are reared at household level, mainly by women and children, especially young boys.

#### *4.3.3 Credit institutions*

Loans are taken to maintain the family, meet family expenses and cover crop cultivation expenditures. The pilot area has several money-lending systems but the two main ones are: i) individuals who loan money to a person they know, and ii) microfinancing. Microfinancing is informal money lending through organized groups of individuals who save money weekly and build a fund that is used to provide loans to group members as well as non-members who live in the same village. Most of the major NGOs in Bangladesh operate in these villages and microfinancing is very common.

Commercial banks provide loans on the basis of collateral which is usually land. These banks cater to the middle class and rich. Bangladesh Krishi (Agricultural) Bank provides loans to people ranging from the lower middle class to wealthy, using land documents as collateral. The Agrani Bank has begun providing loans for purchase of goats through a special government initiative.

#### *4.3.4 Migration*

Although people usually avoid migration because it entails leaving home and community, two forms of migration occur in the study area: seasonal and urban. Seasonal migration is predominant among the poor, urban migration is predominant among all classes. Seasonal migration is a crucial way of achieving and maintaining livelihood, as well as a way to cope with drought. Many household members in the area tend to migrate in groups for short periods, mostly during April, to harvest summer crops in the nearby upazillas to sustain their livelihoods.

The food obtained through seasonal migration is for household consumption, so migrant labourers remain dependent on cash for commodities other than food. Alternate livelihood activities are required to manage seasonal migration during drought. Urban migration is dominant with young people, while the older population prefers to stay in rural villages. Urban migration takes place in drought-prone areas to meet the growing labour requirement in the construction industry.

### 4.4 Current climate risks

#### *4.4.1 Spatio-temporal extent of drought*

Bangladesh has a distinct dry season (November to May) and monsoon season (June to October) and these seasonal influences need to be part of delineating dry regions. Bangladesh, a land of 5.46 million ha, has a long dry spell accompanied by moderate to severe droughts. The value of the ratio of annual rainfall (R) to potential evapotranspiration ($ET_0$) for Northwest Bangladesh is often less than the 0.65 threshold value (Brammer, 2000). The shorter dry spells within the season have larger significance with respect to yield loss and livelihood patterns.

Considering the agro-ecological zone (AEZ) database and land resources inventory map, BARC has identified and mapped drought-prone areas of Bangladesh for pre-*kharif, kharif* and *rabi* seasons (Fig.13-14). The maps define classes of drought severity as slight (15 to 20 percent yield losses), moderate (20 to 35 percent), severe (35 to 45 percent) and very severe (45 to 70 percent) for different crops. A yield loss of more than 10 percent has a huge impact on rural livelihoods, as large proportions of farmers in this region are tenants who pay 50 percent of their production to land owners.

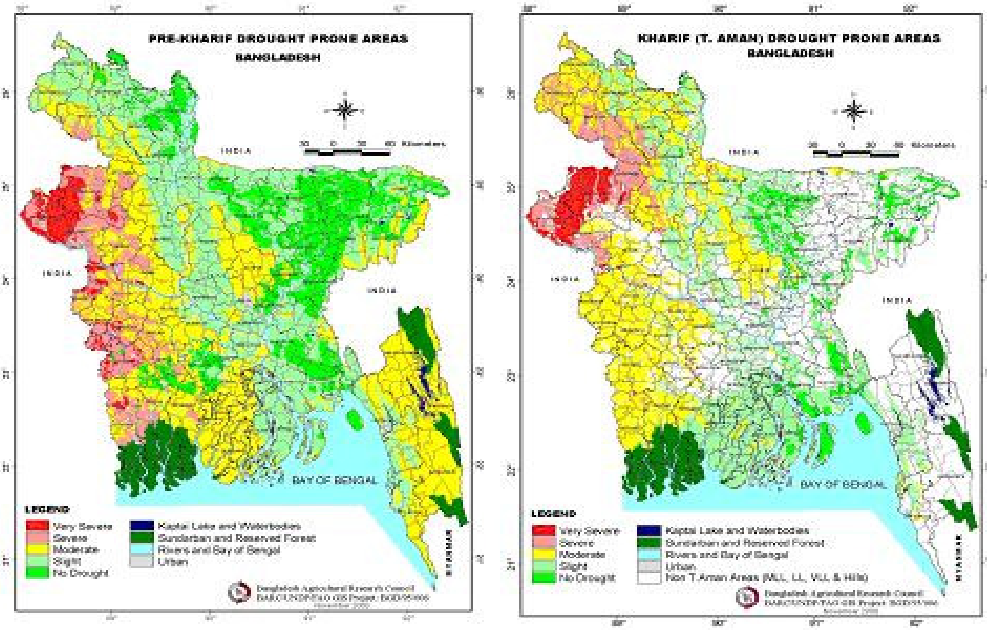



**Fig.13.** Drought severity maps for pre-*kharif* and *kharif* seasons in Bangladesh

Considering distribution of rainfall, evapotranspiration regimes and drought conditions, it has been proposed to define dry regions as having: i) annual rainfall less than 2 000 mm; ii) more than 400 mm difference between evapotranspiration and rainfall in dry season (November to May); and iii) less than 0.65 dry season R/ETo ratio value.

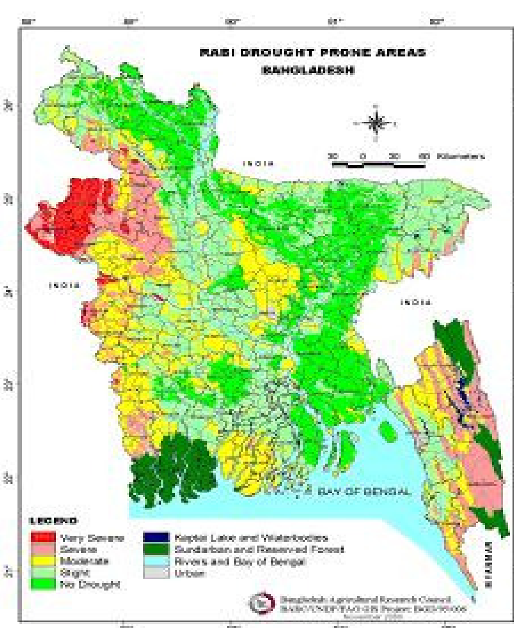



**Fig.14**. Drought-prone areas of Bangladesh in *rabi* season

Applying this assumption to the rainfall and evapotranspiration data available for the agro-ecological zones of Bangladesh, the northwest can be considered a dry region of the country. The map shows that the dry zones extend over 6.44 million ha. In this case, vulnerability is related to rice dependence. A huge population depends on single season rice (T. aman), so even a slight negative deviation in production could affect livelihoods

### *4.4.2 Drought impacts*

A historical analysis shows that drought incidence is not confined to northwestern Bangladesh alone (Table 3), although the frequency of drought is higher in the districts characterized by Barind tracts. Records also show there were only five devastating droughts from 1791 to 1900 and that the frequency increased significantly after 1951. Since 1981, four major droughts have affected the agriculture sector, mostly concentrated in northwestern Bangladesh.

**Table 3**. Chronology of major drought events in Bangladesh

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

Although droughts were not continuous, they did affect the low rainfall zones of the country. Droughts are associated with the late arrival or early withdrawal of monsoon rains and with intermittent dry spells coinciding with critical stages of *T. aman* rice. Droughts in May and June destroy broadcast *aman*, *aus* and jute. Inadequate rains in July delay transplantation of *aman* in high Barind areas, while droughts in September and October reduce yields of transplanted *aman* and delay the sowing of pulses and potatoes. *Boro*, wheat and other crops grown in the dry season are also periodically affected by drought. The consecutive droughts of 1978 and 1979 directly affected 42 percent of cultivated land. Rice production losses due to drought in 1982 were about 50 percent more than losses due to floods in the same year. The 1997 drought caused a reduction of around 1 million tonnes of foodgrain, of which about 0.6 million tonnes was transplanted *aman*, entailing a loss of around US$500 million.

The droughts of 1994-95 in northwestern Bangladesh led to a shortfall of rice production of 3.5 million tonnes (Paul, 1998). Similarly, the area (ha) under cultivation and productivity (tonnes/ha) was significantly reduced in the pilot upazillas (Fig. 15). Though the area under rice and productivity varies marginally over the years, high dependence on rice has led to food insecurity problems. The two critical dry periods, *rabi* and pre-*kharif* drought (January–May), are distinguished by: i) the cumulative effect of dry days, ii) higher temperatures during pre-*kharif* (> 40 degrees Celsius in March–May), and iii) low soil moisture.

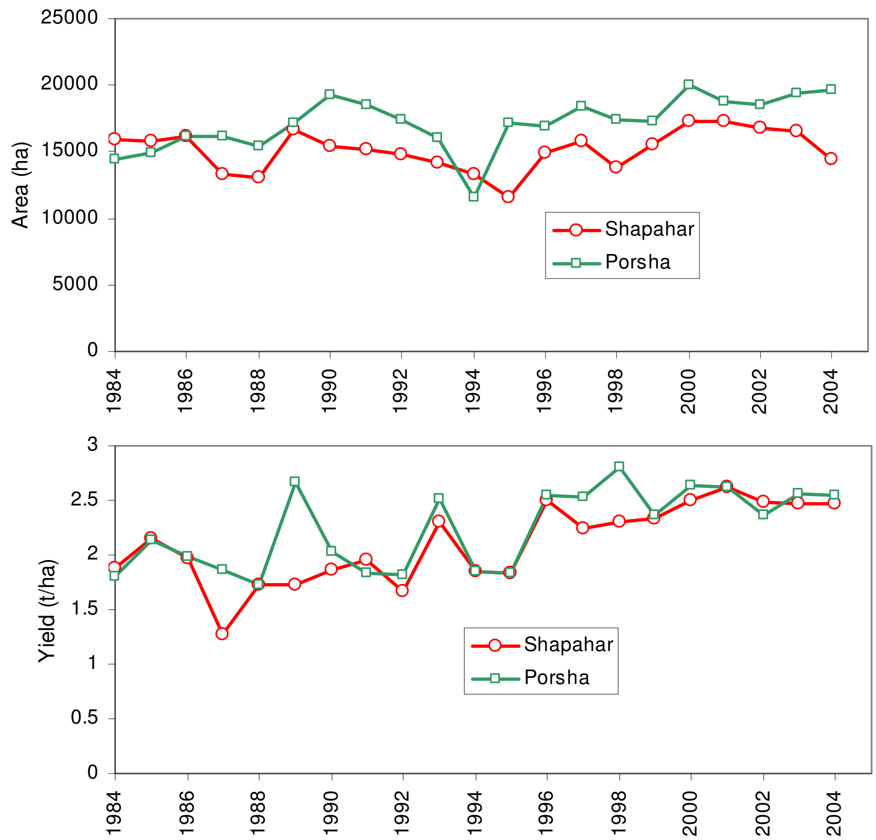



**Fig. 15**. Inter-annual variability of net area (ha) under rice and rice productivity (t/ha) in Shapahar and Porsha Upazilla of Naogoan district in Bangladesh.

Rice, jute and other crops suffered severely due to the drought. Jute suffered additionally from lack of water for retting. Livestock suffered from lack of fodder, and many farmers had to sell their cattle at distress prices for this reason and because of their need for cash to buy food at high prices. The human distress resulting from reduced crop yields, reduced employment and incomes, and increased food prices was widespread and considerable.

### *4.4.3 Climate variability*

Inter-annual and intra-seasonal climate variability is one of the major factors influencing bio-physical systems and eventually the rural livelihoods in the drought-prone areas. As climate variability directly affects the agricultural systems and subsequent yield reduction, it also affects the entire 63 percent of the population that depends on agriculture and its allied sectors. The annual rainfall and seasonal rainfall in the Barind Tract are closely related because more than 70 percent of the rainfall comes during monsoon season (Fig.16). The annual mean rainfall in this region, around 1 450 mm, is only 450 mm higher than the seasonal average (1000 mm).

In irrigated areas, groundwater is exploited to meet dry season water requirements. However, groundwater levels also are associated with the rainfall. Thus, over exploitation of groundwater and highly variable rainfall patterns can lead to problems. The fact that rainfall declined significantly during monsoon season in major drought years indicates the homogeneity of the entire northwestern drought-prone area in terms of rainfall pattern and drought.

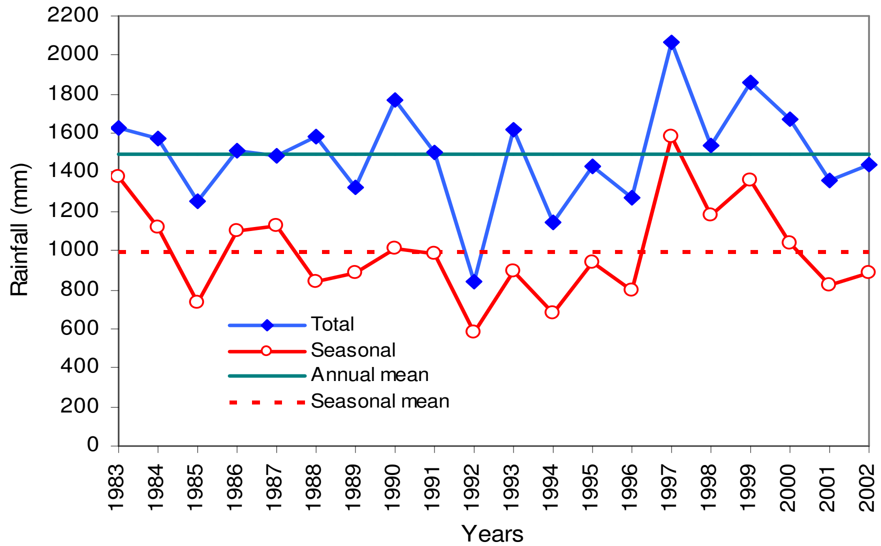



**Fig.16**. Inter-annual rainfall variability in the Barind Tract (1983-2002)

The rainfall pattern for the Barind Tract (Fig. 16) shows lower than normal monsoon season rainfall in 1985, 1988, 1989, 1992, 1993, 1994, 1995, 1996, 2001 and 2002. Below normal rainfall, associated with long dry spells through the season, is critical, as climate change may bring more intermittent dry spells during the growing season.

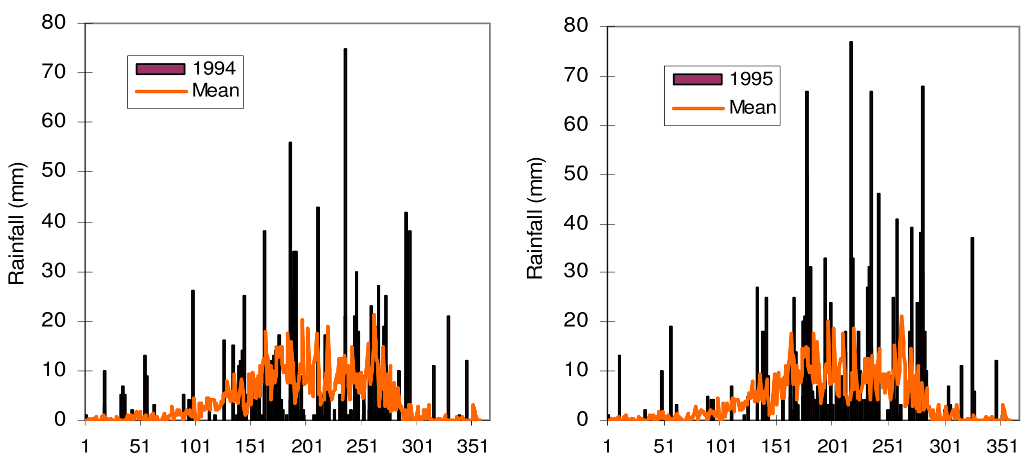



**Fig.17**. Daily rainfall distribution during 1994 and 1995 in Rajshahi, Bangladesh

Daily rainfall in the pilot regions during 1994 and 1995, presented in Fig. 17, shows that though the rainfall did not deviate significantly from the normal, intra-seasonal dry spells, they led to an overall seasonal deficit. The most critical dry spell in 1994 was in July, while in 1995 it was in August. In both the years, the main rice crop T.*aman* was affected because its critical growth period coincided with drought. To reduce the drought impacts during intermittent dry spells, the surface water stored from the previous rainfall needs to be used before the rice maturity stage.

The length of a growing period is directly related to the time of the onset and end of monsoon rainfall. In the past, there were significant variations in the onset of monsoon. When early onset coincided with early dry spells, it required extra labour and expenditure to grow additional seedlings as a contingency measure. Most farmers must depend on external financing to cover them if they need to replant after an early season drought. Most rainfall ends in September, but the T.*aman* varieties are harvested only in November/December and exposure to mild-to-severe drought during grain-filling stage can cause substantial yield reduction (Jensen et al., 1993).

The current cropping patterns in the Barind Tract have evolved to manage the intermittent dry spells. However, farmers often face three different kinds of dry spells in one year: early season, mid season and terminal season. Early season dry spells affect the seedling stage. Although there is some possibility for replanting, if the crop is re-planted late, the terminal season drought coincides with maturity stage, which is more critical in terms of yield reduction. The possibility of introducing other crops during monsoon season is also limited due to the sticky nature of the soil. Extended water stagnation could also influence crops such as pulses and maize.

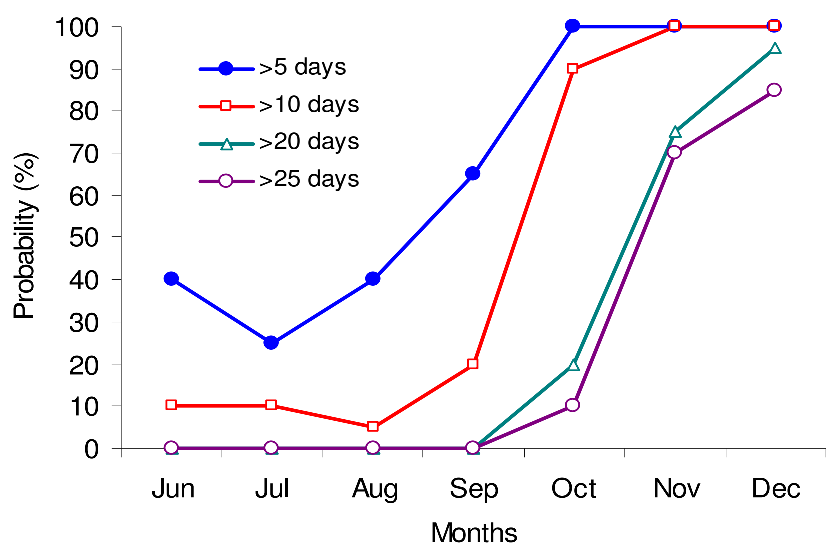



**Fig. 18.** Probability of receiving various amount of rainfall during the cropping season

Figure 18 illustrates the probability of the length of dry spells. In the early rainy season, rainfall is comparatively assured. The chance of a dry spell exceeding five days is about 30 to 40 percent in the first three months, while the chance of it exceeding 10 days during the same period is only 10 percent. The results of the probability analysis indicated that relatively assured, however still timely, onset of rainfall is critical.

The chances of extended dry spells increase after September. The chance of a dry spell of more than five days is 65 percent and more than ten days is 20 percent. The dry spell length exceeds five to ten days in almost every year from October to December. The dry spell exceeds 20 days in about 20 percent of years during October, when the crop is in its reproductive stage. In November, the dry spell length exceeds 25 days in 80 percent of the years, indicating the seriousness of terminal drought during *kharif* II season.

#### *4.4.4 Soil variability*

Deep loamy soils store more water, making them the most suitable for rainfed crops. Shallow soils, sandy soils and clay soils become dry more quickly than loamy soils, unless they have a water table close to the surface. Rainfed *rabi* crops and broadcast *aus* usually are quickly affected by drought in soils that are also used for transplanted rice (especially *aman*). That is because the puddled top soil and strong plough pan in such soils store very little moisture, and the plough pan prevents roots from reaching moisture stored in the subsoil. For transplanted rice, the easily puddle silty and clay soils can hold water on and in the topsoil longer than sandy, loamy and some cracking clay soils that do not puddle easily. Soils subject to periodic flooding with saline water and those with a saline groundwater table from which moisture can be drawn to the soil surface by capillary attraction are liable to be more strongly affected by salinity during a drought than in normal conditions. Though this factor is a serious problem for future climate change, further probing would be out of the scope of this study.

**Box 1: Critical dry periods in Bangladesh**

There are two critical dry periods in Bangladesh.

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

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

(Karim, *et al.,* 1990)

#### *4.4.5 Cropping systems*

Agricultural crops are grown during three distinct seasons (Fig.19) – *kharif*-I (March 15 to June 30), *kharif*-II (July to September/October) and *rabi* (November to March). Transplanted *aus* is the first rice grown between March and June, followed by fine rice. Transplanted *aman* is the second crop grown between July and November followed by *boro* rice during winter. Among the four rice crops, the wet season second rice crop of transplanted *aman* rice is grown in about 70 percent of the rice area in the study region. *Rabi* crops, wheat, vegetables, pulses (chick pea) and mustard, are grown from mid-October to March.

In dry years, the *T. aman* crop suffers from high-yield reduction due to inadequate rainfall (drought) during the transplanting period as well as during critical growing periods such as flowering and maturity. In non-irrigated villages, farmers do not practice supplemental irrigation during drought as it requires substantial investment in excavation of water storage structures and water transport devices. Delayed transplanting of *aman* rice reduces the yield and leaves no land to grow short-duration vegetables, oil seeds (mustard) and pulses (chick pea) before *boro* rice cultivation. Delayed transplanted *aman* also has a subsequent effect on recently evolved short-duration crops and also the *boro* (summer) rice.

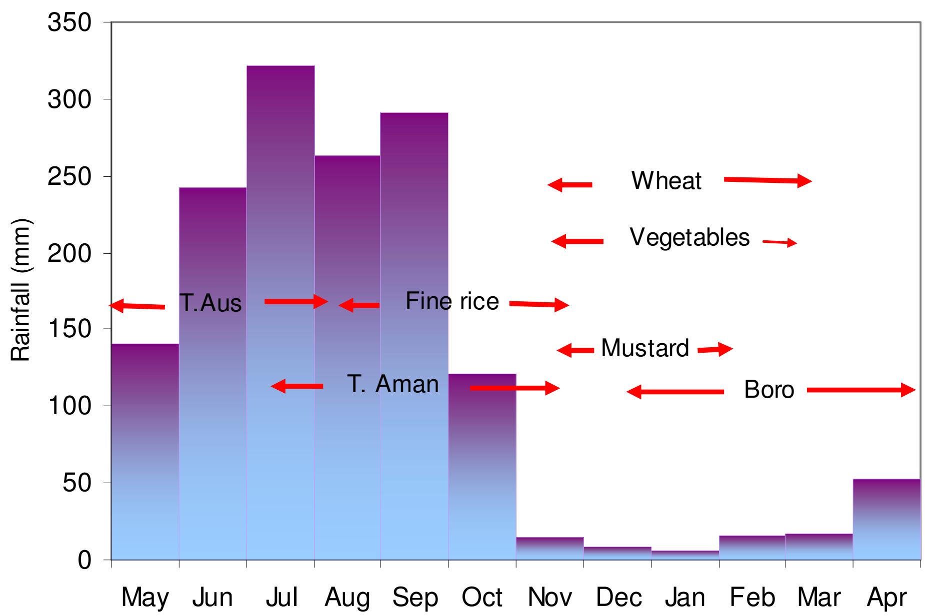



**Fig.19**. Crops and cropping pattern of drought-prone Barind tracts

Wheat is grown during the dry season (November to March), usually after the *aman* harvest, in competition with other crops such as dry season *boro* rice. Among the physical factors, the climate is responsible for high instability of wheat yield because sowing may be delayed due to the late planting of *aman* or use of long-duration *aman* cultivars. This increases the risk of exposing the wheat crop to high temperature during the grain-filling stage in March/April, which reduces grain yield. Therefore, the productivity of transplanted *aman* rice and wheat in a rice-wheat rotation depends on timely establishment of transplanted *aman* and availability of water. The area under wheat in the pilot region is very limited although wheat cultivation is practiced in some rainfed areas.

In irrigated areas, *boro* rice is highly preferred to wheat. However, drought can affect *boro* rice as well. Other non-climatic factors such as non-availability of electricity for pumping groundwater also influence the *boro* yield.

## 4.5 Local perception on climate risks

Local perception of the impact of climate hazards in the drought-prone Barind Tract is discussed in this section. In participatory focus group discussions held in the pilot village, participants stated their perceptions that the current climate in the region is behaving differently than in the past with i) more frequent droughts, ii) changes in seasonal rainfall patterns, iii) un-seasonal rainfall, and iv) long dry spells. In addition, the participants perceived that the temperature has increased over the years and the duration of winter has been shortened, affecting the potential growing period with the wheat crop frequently affected by high temperature during the grain-filling period and an increased occurrence of pests and disease.

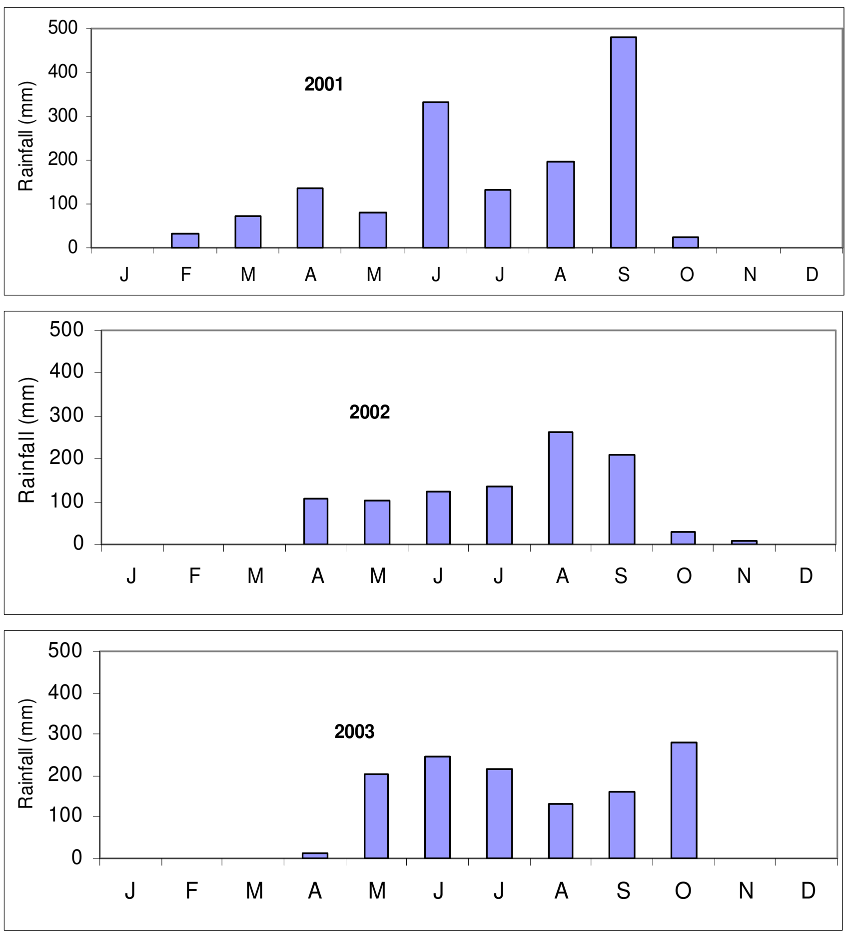



**Fig. 20**. Monthly rainfall distribution in 2001, 2002 and 2003

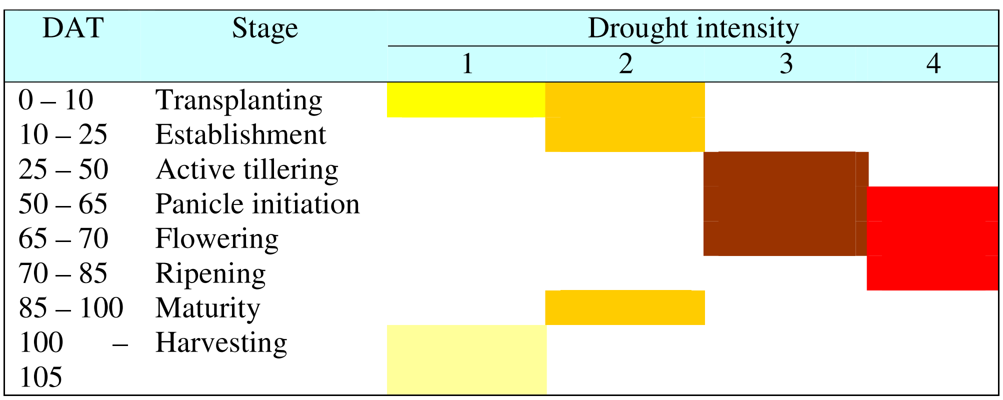
Local communities were of the opinion that the high-yielding modern varieties are more susceptible to pests and diseases than traditional varieties. They pointed out three major reasons for increased pest and disease population: i) the modern varieties are not resistant to pests and diseases, ii) change in management practices and iii) change in climate parameters such as rainfall and temperature.

The also perceived that the practice of fishing for livelihoods has been reduced substantially because i) there is insufficient water in the traditional ponds and ii) there is no accessibility to community ponds by the local people as they are leased out. In addition to crop loss, households also perceived other potential changes such as extreme heat and lack of moisture damaging banana, mango, bamboo and jackfruit. Many respondents reported damage to livestock and poultry and that dried up pond beds caused loss of fish.

### *4.5.1 Intensity of drought*

Local populations understood that rainfall distribution is more important than seasonal rainfall totals. Though the 2001 seasonal rainfall was the highest in three years (Fig.20), mid-season drought in July/August and terminal drought in October/November were perceived as devastating and, in some areas, reduced the T.*aman* yield from 30 to 50 percent. Similarly, in 2002, both early season drought and terminal drought affected the crop. Lack of sufficient water for timely transplanting led to late harvest of T.*aman* and had a cascading effect on subsequent crops.

With regard to transplanted *aman* rice, it was perceived that transplanting and establishment stages were affected by mild drought, the active tillering stage was affected by moderate drought, and the panicle initiation, flowering and ripening stages were affected by severe drought. Generally it was perceived that severe drought during flowering and ripening stages reduced the grain yield up to 70 percent. They also perceived the maturity stage was affected by mild to moderate drought (Fig. 21).




Days after transplanting (DAT): 1-slight water scarcity; 2-mild drought; 3-moderate drought; 4-severe drought

**Fig.21**. Local perception about drought for T.*aman* rice in Barind tract

Farmers are very much concerned about drought at various stages of crop growth during T.*aman*. The problem ranking the farmers gave to T.*aman* crop was considered most informed because 100 percent of the farmers grew this crop in all their available land (Table 4), indicating that T.*aman*, a crop often affected by drought, is an essential part of the agricultural system in the rainfed Barind Tract. Wheat ranks second to monsoon season rice, grown by about 80 percent of the farmers on about 20 percent of their land. Since wheat is suitable only for *rabi* season, non-availability of irrigation water in that season limits its cultivation. Transplanted *aus*, ranked third, is grown in areas where there are early spells of rain.

**Table 4**. Farmers' perception of climate-related problems in different crop cultivation

| Crop | Problem rank | % of farmers growing the crop | % area allotted |
|---|---|---|---|
| *T. aman* | 1 | 100 | 100 |
| Wheat | 2 | 80 | 20 |
| T.Aus | 7 | 30 | 30 |
| Mustard | 8 | 5 | 5 |
| Potato | 3 | 50 | 6 |
| Tomato | 9 | 10 | 3 |
| Water melon | 4 | 5 | 1 |
| Vegetables | 5 | 80 | 3 |
| Onion | 6 | 20 | 5 |

### *4.5.2 Local rules of thumb*

In describing drought thresholds based on their experience, farmers indicated their perception that: a dry spell exceeding 12 days in the high Barind Tract could trigger drought, while in the level Barind Tract, a dry spell of more than 14 days could trigger drought at early stages of rice crop (Table 5). However, in later stages, especially in the flowering stage, the perceived threshold number of days to trigger drought declines sharply to seven days in the high Barind Tract and to nine or ten days in the level Barind Tract. Farmers respond to the drought in different Barind Tracts based on this threshold dry spell length and visual observations.

**Table 5**. Threshold number of dry days to trigger drought onset at various stages of the T. *aman* rice crop

| Stage of the crop | Barind tract | Days |
|---|---|---|
| Early stage | High | 12 |
| | Level | 14-16 |
| Flowering | High | 7 |
| | Level | 9-10 |

Dry spell thresholds also were identified for various stages of the crop. In high Barind areas, the perceptions of the threshold dry spell lengths (consecutive non-rainy days) varied considerably with respect to stages of growth (Table 6). ). On average, a dry spell length of five to seven days was considered mild drought at seedling and flowering stages, while dry spell length of seven to eight days was considered mild drought in flowering stage. At flowering stage, a rainless period of more than 12 days was considered a severe drought that could reduce crop yield up to 40 percent. This perception about drought by the farmers of the region is consistent with the climate data analysis presented in the previous section.

Most farmers perceived that a rainless period longer than 12 days during flowering stage is not tolerable. However, the perception varies across the Barind Tract. In low Barind Tracts, a dry spell of 14 to16 days in early stages and nine to ten days in flowering stages is tolerable without significant yield reduction. Understanding the local rules of thumb and local perceptions is necessary to identify a suitable adaptation practice that fits within the rules.

**Table 6**. Farmers' perception of drought, based on the length of dry spells and crop phonological stages in high Barind Tracts.

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

### *4.5.3 Perception about soil dryness*

Status of soil dryness also decides the severity of drought in Barind areas. If the soil is very dry and cracked, 75 mm of water is required to break the drought. About 50 mm of water is required to soak the soil and close the cracks formed in extended dry spells, while another 25 mm of water can stand above the surface:

- 25 mm – closes the soil crack partially,
- 50 mm – closes the soil crack fully, but no standing water,
- 75 mm – closes the soil crack fully and standing water to a depth of 2.5 cm.

Dry spell length of more than 12 days can lead to soil cracks. This indicates that selection of adaptation practices and new drought tolerant varieties also should depend on the soil properties.

### *4.5.4 Fisherman's perception on climate impacts*

Extended dry spells can limit the groundwater recharge and surface water storage in the Barind Tract. As local inland fisheries depend on the water storage of traditional ponds and *khari* canals, surface water storage was considered very important. They recognized that any level of negative deviation from the mean adversely affected fishing activities in the pilot villages. Even in the irrigated villages, traditional water bodies are not filled with deep tubewell water and, hence, fish cultivation depends entirely on rainfall during monsoon season.

Fishermen believes that change in rainfall pattern or delayed onset of monsoon rain has large socio-economic consequences at household level. Delayed rains often affect intercultural fishing and farm operations. As 25 percent of the farm families also are involved in seasonal fishing, fishing is considered one of the important household economic activity. Normal rainfall onset provides an opportunity to distribute household labour among the available livelihood portfolios.

## 4.6 Local capacities and coping strategies

In order to cope with the adverse effects of drought, the households practiced various adjustments at the household and community levels and also received support from both formal and informal sources including local/national institutions. The coping strategies followed by local people during droughts were identified through participatory rural appraisal methods (ADPC, 2005) and from a review of previous studies.

### *4.6.1 Household level agricultural strategies*

Over the years, local communities in the Barind Tract have developed a range of risk management strategies, usually crop adjustments, to combat drought. Very few farmers have practiced agricultural adjustments to reduce crop loss due to drought, mainly because of financial and other socio-economic constraints. However, those farmers who practiced agricultural adjustments to drought adopted a crop replacement strategy of cultivating wheat, onion and other vegetables instead of rice (Paul, 1998).

Other strategies mentioned were irrigation, gapfilling and inter-culture of wheat. Gap-filling is practiced in fields where germination of an earlier crop has been poor or patches of seedlings have died. Crop adjustments generally depend on the stage at which drought occurs. Early season drought triggers crop change due to shortened growing periods. These strategic crop adjustments are efficient and economical if timely climate forecast information is available.

Re-planting is an adjustment usually practiced if drought occurs after *aus* and *aman* have been sown when the young plants may die due to lack of moisture. In such a situation, farmers re-plant *aus* in May and *aman* in July. This practice is not considered viable if drought occurs during the later stage of the crop growth. Agricultural adjustments to drought are not confined to the drought period. To compensate for loss of crop production, farmers can devote more land to crops in the post-drought period if irrigation sources are available, but this depends on whether water was stored in the ponds during the late monsoon period.

Traditionally, farmers practiced adjustment during early *kharif* drought (March/April) by conserving the soil moisture provided by occasional showers. After each shower, farmers said they quickly ploughed or hand weeded their fields in order to i) reduce moisture losses caused by evaporation and evapotranspiration, and ii) prepare the soil to absorb the next shower quickly and deeply. This practice is carried out if the farmers are not employed in other off-farm activities.

Very few households practice agricultural adjustments to drought. An analysis found this was mainly because middle and large landholding categories were in a better position to practice agricultural adjustment compared to small and marginal farmers. Re-planting or irrigating crops requires additional money, which many households, particularly the poor ones, could ill afford during the drought period. DAE has introduced a project to support the farmers by providing plastic pipes to transport water from the traditional ponds and miniponds. Many farmers found this useful to save their crops.

There are two sources of irrigation for crop fields in the pilot area: i) accessing water from nearby sources, such as tanks or hand pump tubewells, and ii) installing a deep or shallow tubewell in the crop field. The former requires additional labour while the latter demands a large capital investment. Even if villagers are financially able to invest capital in a well or could get institutional financing to sink a well, there is no certainty the well will have water because of the decrease in the water table. Farmers felt that lack of water was the principal reason for non-adoption of agricultural adjustment. BMDA has supported installation of deep tubewells in certain villages, however the rainfed villages still suffer from drought impacts.

### *4.6.2 Household level non-agricultural adjustments*

Household and personal assets are not disposed of under normal circumstances. However, with onset and intensification of drought, when domestic food stocks become exhausted or very low, the need to raise cash through the sale of assets increases. Some 88 percent of households had disposed of belongings to cope with severe drought conditions during monsoon season, by selling their livestock or land or by leasing out their land. Many households had sold other belongings such as poultry and housing structures during drought although very few had leased their livestock. Although migration of family members is very rare in this area, seasonal migration takes place for want of employment and to meet the household expenditure. Very few farmers spent savings or sold valuables such as jewelry to cope with the drought and the vast majority deferred the purchases of clothing and luxury items during drought periods.

Villagers usually sell or lease out land only in extreme drought circumstances. All farmers who practiced agricultural adjustments also practiced non-agricultural adjustments. This suggests that they were the group most affected by the drought because they were compelled to make both types of individual-level adjustments in order to ensure survival from the effects of the drought.

Farmers were more likely to make adjustments at the individual level compared to businessmen and input suppliers. Because of their educations and access to government and other resources, businessmen and service holders were in a better position compared to the farmers to receive support from various sources. For this reason, they seemed less willing to make individual adjustments to cope with drought.

### *4.6.3 Individual level adjustments*

Adoption of individual-level adjustments to drought differed significantly according to landholding size and tenancy status of the sample households. The small and middle farmers made adjustments in relatively greater proportion compared to the large farmers. Most of the tenant farmers made individual-level adjustments. In the pilot villages, more than two thirds of the tenant farmers were also small farmers, which might explain why they practiced individual-level adjustments in larger numbers than their counterparts.

Illiterate farmers make individual-level drought adjustments in larger proportion than literate farmers. Illiterate farmers have the least access to resources supporting drought victims and, therefore, are compelled to make individual-level adjustments to mitigate the effects of the hazard. The current status of individual-level adjustments has shown some change over the past (Table 7).