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CASE STUDY

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CASE STUDY

Livelihood adaptation to climate variability and change in drought-prone areas of Bangladesh

Developing institutions and options

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Implemented under the project
Improved Adaptive Capacity to Climate Change for Sustainable Livelihoods in the Agriculture Sector – DP9/1-BGD/01/004/01/99

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EXECUTIVE SUMMARY

The impacts of climate variability and change are global concerns, but in Bangladesh, where large parts of the population are chronically exposed and vulnerable to a range of natural hazards, they are particularly critical. In fact, between 1991 and 2000 93 major disasters were recorded, resulting in nearly 200 000 deaths and causing US$5.9 billion in damage with high losses in agriculture.

Agriculture is the largest sector of the Bangladesh economy, accounting for some 35 percent of the GDP and 63 percent of the labour force. Agricultural production is already under pressure from increasing demands for food and the parallel problem of depletion land and water resources caused by overuse and contamination. Impacts of climate variability and change cause an additional risk for agriculture.

Global circulation model (GCM) results predict an average temperature increase in Bangladesh due to climate change of 1.0ºC by 2030 and 1.4ºC by 2050. Though monsoon precipitation is likely to increase by 6.8 percent by 2050, the distribution patterns of precipitation during the growing season, high temperature and higher rates of evapotranspiration will create further water stress conditions and a decline in agricultural production in the drought-prone areas. A continued trend of more frequent and intense droughts, as a result of further climate variability and climate change, is expected to have significant impacts on the agricultural sector.

Within this context, FAO and the Asian Disaster Preparedness Centre (ADPC) are guiding an assessment of livelihood adaptation to climate variability and change in the drought- prone areas of Northwest Bangladesh. The project, implemented under the Comprehensive Disaster Risk Management Programme (CDMP) and in close collaboration with the Ministry of Agriculture Department of Agricultural Extension (DAE), specifically looks at: characterization of livelihood systems; profiling of vulnerable groups; assessment of past and current climate impacts; and understanding of local perceptions of climate impacts, local coping capacities and existing adaptation strategies. It also is developing a good practice adaptation option menu, evaluating and field testing locally selected options, and introducing long-lead climate forecasting, capacity building and training of DAE extension staff and community representatives.

Pilot areas are located in Chapai Nawabganj (Gomastapur and Nachole Upazillas) and Naogoan (Porsha and Sapahar Upazillas), districts mainly covering the Barind Tract and the Punarbhava and Ganges river floodplain. Average annual rainfall in the study area ranges between 1400–1500 mm, with 80 percent occurring during monsoon season (June–September). During the dry months, water deficits range from 400–500 mm. The surface water flow of the Mohananda and the Punarbhava rivers tends to decrease in the dry season. The rate of depletion of groundwater has been increasing since tubewell irrigation and crop intensification began in the early 1980s.

Within the pilot areas, the main rural livelihood groups identified were: crop and livestock farming (39.3 percent), fishing (0.4 percent), agriculture labour (34.3 percent), small business and hawking (9.8 percent), non-agricultural labour (3.7 percent), small enterprises such as

weaving, industry and construction (3.5 percent), transport and communication (1.2 percent) and other sources of income such as rentals, remittances and religious activities (6.5 percent).

Local informants indicated recent shifts in both coping strategies and livelihood portfolios of rural men and women due to institutional interference, economic motivation and employment opportunities. Traditional risk management practices such as sharecropping, goat rearing, craft making are less common. Farmers perceive that limited access to deep tubewell water in the non-irrigated areas is a cause of their current vulnerability, along with several other external factors such as electrical failures and high prices of agricultural inputs.

People in the study area perceive that today's climate is different from the past – the seasonal cycle and rainfall pattern have changed, droughts have become more frequent, pest and disease incidences have increased and the average temperature has increased in the summer while winter has shortened. Local people also feel that their production of *boro* and *aus* rice, winter vegetables and fruit including several varieties of mangoes have been affected by increased variations in rainfall, dry spells, temperature and drought occurrences. Focus group discussion with farmers showed they have developed rules-of-thumb to monitor dry spells and their likely impact on crop production, livestock and fisheries.

Household coping strategies in agriculture in the pilot areas for managing climate variability and drought occurrences can be categorized as: i) traditional, locally managed practices such as pond excavation, retention of rainwater in *khari* canals and moisture conservation, ii) government-supported practices such as deep tubewell facilitated irrigation, supplemental irrigation and miniponds, iii) alternative and innovative automatic adaptation practices such as adoption of mango farming, integrated crop-livestock farming systems, and iv) technology-driven efforts such as new short-duration and drought-tolerant crop varieties, cropping systems and homestead gardening.

Households also make non-agricultural adjustments such as i) disposing of productive assets and mortgaging lands, and ii) institutional-support activities including support from the government, NGOs and community-based organizations (CBOs). However, these strategies are insufficient for proper adjustment to future climate variability and change-related threats. Identification of additional good practices and broader replication and exchange of good practices needs promotion.

Several institutions including government agencies, NGOs, social, informal and private institutions and farmers' water-user groups are operating in the area. Their roles, capacities and expertise for dealing with climatic risks vary widely. The Barind Multipurpose Development Agency (BMDA), with its formal mandate to provide deep tubewell irrigation, plays a lead role but does not focus on areas where groundwater is not accessible. Local disaster management committees exist, but their capacities for advocating adaptation practices are limited. Coordination among NGOs and government agencies at local level appears weak. Efforts are already in place, through this project, to improve the technical capacities of the DAE and local disaster management committees as well as the coordination among them.

Climatic conditions and anthropogenic factors mutually reinforce the chronic vulnerability of livelihoods in drought-prone areas. Droughts strike regularly, but it is the limited local capacities and capabilities and the lack of access to various forms of assets that make peoples' livelihoods increasingly vulnerable.

Successful local adaptation to climate variability and change requires multiple pathways with well planned, interrelated short- and long-term measures, including:

- adopting physical adaptive measures – such as excavation, re-excavation of canals, miniponds, irrigation, storage facilities for retaining rain water;
- adjusting existing agricultural practices – such as adjustment of cropping patterns, selection of drought-tolerant crop varieties; better storage of seeds and fodder; dry seedbeds; or adopting alternative, cash crops such as mango and jujube (*Ziziphus jujuba*);
- adjusting socio-economic activities – such as livelihood diversification, market facilitation, small-scale cottage industries, integration of traditional knowledge;
- strengthening local institutions – such as self-help programmes, capacity building and awareness raising for local institutions;
- strengthening formal institutional structures – such as local disaster management committees and financial institutions;
- formulating policy to catalyze enhancement of adaptive livelihood opportunities;
- creating awareness and advocacy on climate change and adaptation issues;
- supporting better research – such as on-farm links to new or improved crops including drought-tolerant varieties, and other conducive and adaptive technologies.

Setting and selecting among these livelihood options for respective "geo-physical settings" and "livelihoods systems" requires stretching the limits and coordination of current local adaptive responses and research and technology development. In the first project phase, local adaptation practices were identified by involving the community in participatory dialogue. The practices identified included: dry seedbed, improved short-duration crop varieties, supplemental irrigation, closing of soil cracks, homestead gardening with fruit trees, re-excavation of *khari* canals and miniponds, and strengthening of field bunds. The next step was working with farmers to test various options, followed by a sound economic and marketing analysis of the successfully tested options. Dissemination and extension strategies being considered include: demonstrations, orientation meetings, field days, farmer field schools, and demonstration farmer or community rallies.

For medium- and long-term sustainability of any kind of intervention, the linkages between climate change adaptation and mainstream development need to be ensured, and an enabling institutional environment must be established. The fundamental prerequisite of long-term livelihood adaptation is coordination of agency planning, communication and field operations activities, as well as the activities of government line agencies and departments, NGOs, GO agencies and farmers.

CONTENTS

ACRONYMS

ADPC	Asian Disaster Preparedness Center
ADB	Asian Development Bank
AEZ	Agro-Ecological Zone
ASSP	Agriculture Support Service Project
BADC	Bangladesh Agricultural Development Corporation
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BEMAP	Barind Environment Management Action Plan
BIADP	Barind Integrated Area Development Project
BLB	Bacterial Leaf Blight
BMD	Bangladesh Meteorological Department
BMDA	Barind Multipurpose Development Authority
BRAC	Bangladesh Rural Advancement Committee
BRRI	Bangladesh Rice Research Institute
BSB	Bangladesh Sericulture Board
BSRTI	Bangladesh Sericulture Research and Training Institute
CARE	Cooperative for Assistance and Relief Everywhere
CBO	Community-Based Organization
CCS	Climate Change Scenario
CCC	Climate Change Cell
CDMP	Comprehensive Disaster Risk Management Programme
DAE	Department of Agricultural Extension
DANIDA	Danish International Development Agency
DAT	Days After Transplanting
DFID	Department for International Development
DMB	Disaster Management Bureau
DMC	Disaster Management Committee
DOE	Department of Environment
DOF	Department of Fisheries
DOL	Department of Livestock
DOR	Department of Relief
DRR	Directorate of Relief and Rehabilitation
DSR	Direct Seeded Rice
DTW	Deep Tube Well
FAO	Food and Agriculture Organization of UN
FAO-BD	Food and Agriculture Organization of UN-Bangladesh
FAO-SDAR	FAO- Rural Institutions and Participation Service
FFS	Farmer Field School
GCM	General Circulation Model
GDP	Gross Domestic Product
GFDL	Geophysical Fluid Dynamics Laboratory
GHG	Green House Gas
GO	Government Organization
GOB	Government of Bangladesh
HYV	High-Yielding Variety
IDA	International Development Association
IDB	Islamic Development Bank
IFAD	International Fund for Agricultural Development
IMDMCC	Inter-Ministerial Committee

IPM	Integrated Pest Management
LGED	Local Government Engineering Department
MAGICC	Model for Assessment of Greenhouse-gas Induced Climate Change
MoA	Ministry of Agriculture
MoEF	Ministry of Environment and Forests
MoFDM	Ministry of Food and Disaster Management
NARS	National Agricultural Research System
NDMAC	National Disaster Management Advisory Council
NDMC	National Disaster Management Council
NEMAP	National Environment Management Action Plan
NGO	Non-Government Organisation
NTIWG	National-level Technical Implementation Working Groups
PMU	Programme Management Unit
PRA	Participatory Rural Appraisal
PRECIS	Providing Regional Climates for Impact Studies
RCM	Regional Climate Model
SAAO	Sub-Assistant Agricultural Officer
SCENGEN	Scenario Gnerator
SCM	Sub-Component Mnager
SEMP	Sustainable Environment Management Programme
SIA	Sub-Implementing Agencies
SOD	Standing Order on Disasters
SPARSO	Space Research and Remote Sensing Organization
SRI	System of Rice Intensification
TMSS	Thengamara Mohila Sabuj Sangha (NGO)
TPR	Transplanted Rice
UAO	Upazilla Agricultural Officer
UNDP	United Nations Development Programme
UNFCC	United Nations Framework Convention on Climate Change
UTIWG	Upazilla Technical Implementation Working Groups

BANGLA TERMS/CROP NAMES

aus	rice crop coinciding with late dry and early monsoon season
baid	lowlands
beel	naturally depressed body of water remains throughout the year
bhiga	one third of an acre
boro	dry season rice that grows between December and April
chalas	uplands
khari	traditional irrigation canals
kharif I	early *kharif* season, typically from March to June
kharif II	a second part of *kharif* season, typically from July to October
kodal	hand-held hoe
monga	seasonal famine condition
pre-kharif	a season before kharif II typically from March to June
rabi	dry season, typically from November to February
shika	hanging shelves
taka	Bangladesh currency
thana	subdistrict
t. aman	transplanted aman rice typically from July to October
t. aus	transplated aus
upazilla	subdistrict

CHAPTER 1

INTRODUCTION

Devastating and recurrent droughts caused by varying rainfall patterns occur frequently in many parts of Bangladesh, causing substantial damage and loss to agriculture and allied sectors. Drought impact, associated with late or early monsoon rains or even complete failure of monsoon, spreads over a large geographical area – much larger than areas affected by other natural hazards. Bangladesh experienced major droughts in 1973, 1978-79, 1981-82, 1989, 1992 and 1994-95.

The foodgrain production lost in the 1978-79 drought was probably 50 to 100 percent more than was lost in the great flood of 1974, showing that drought can be as devastating as a major flood or cyclone (Paul, 1998). Foodgrain off-take through the ration and relief systems averaged 227 000 tonnes per month in June to November 1979, compared to 169 000 tonnes per month from June to November 1974. Rice, jute and other crops were greatly affected although jute suffered the most because of lack of water for retting. Livestock also suffered, with many farmers having to sell their cattle at distress prices because they lacked fodder or needed cash to buy food which had increased in price because of scarcity. The widespread human distress resulting from reduced crops, reduced employment and incomes, and increased food prices was considerable. The droughts of 1994-95 in the northwestern districts of Bangladesh led to a 3.5 million tonnes shortfall of rice and wheat production.

Drought can affect the rice crop in three different seasons, which accounts for more than 80 percent of the total cultivated area in the country. Droughts in March and April prevent timely land preparation and ploughing, delaying planting of crops during monsoon season. Inadequate rains in July and August delay transplantation of *aman* in highland areas, while droughts in September and October reduce yields of both broadcast and transplanted *aman* and delay sowing of pulses and potatoes. *Boro*, wheat and other crops grown in the dry season (summer) are also periodically affected by drought.

Increased climate variability means additional threats to drought-prone environments and is considered a major crop production risk factor. It forces farmers to depend on low-input and low-risk technologies, leaving them unable to adopt new technologies that would allow them to derive maximum gains during favorable seasons and less able to recover quickly after disasters. Increasing climate risks undermine development and poverty reduction efforts in drought-prone areas. Future climate variability and change will aggravate these problems even more in drought-prone environments.

The impact of climate variability and change on agricultural production is a global concern. However, the impact is particularly important in Bangladesh where agriculture is the largest sector of economy, accounting for some 35 percent of GDP and 63 percent of the labour force. Agriculture in Bangladesh is already under pressure from increasing demands for food and the parallel problems of depletion of agricultural land and water resources from overuse and contamination. Climate variability and projected global climate change makes the issue particularly urgent.

Adaptation to climate change is one of the approaches considered likely to reduce the impacts of long-term changes in climate variables. Adaptation is a process by which strategies to moderate and cope with the consequences of climate change, including climate variability, can be enhanced, developed and implemented (UNDP, 2004). Obviously, many countries already are adapting to current climatic events at national, provincial, state, district and local levels in short-, medium- and long-term time frames.

However, in the past, many structural, physical and institutional adaptation mechanisms, implemented through conventional top-down approaches, lacked community participation and livelihood focus. Appropriate adaptation strategies also require balancing the need to reduce climate change impact with any constraints in national policy-making processes.

In order to increase resilience at all levels and reduce damage and losses from natural disasters, in 2003, the Government of Bangladesh approved the Comprehensive Disaster Management Programme (CDMP) as a key strategy to advance government and agency risk reduction efforts in the country. The CDMP follows a strategic institutional and programming approach to address risks associated with climate variability and change.

CDMP is designed to optimize the reduction of long-term risk and to strengthen the operational capacities for responding to, and recovering from, emergencies and disasters. Efforts to reduce vulnerability to long-term climate change have included livelihood adaptation strategies in the agricultural and allied sectors, particularly for women and poor communities with the lowest capacities to adapt.

Within the broader framework of climate change adaptation, this report looks at past drought impacts, local perceptions of droughts, anticipated climate change and its related impacts, and viable adaptation options for drought-prone areas of Bangladesh. This includes assessment of current vulnerability, coping strategies and future climate-related risks and adaptation strategies.

Considering this framework for action, the Food and Agricultural Organization (FAO) of United Nations is assisting the Government of Bangladesh and other key stakeholders in designing and promoting livelihood adaptation strategies in the agricultural sector that may help reduce vulnerability to climate change, particularly among women and poor communities. ADPC has conducted a climate change impact assessment and adaptation study that also demonstrates viable adaptation practices to improve the adaptive capacity of the rural livelihoods. The outputs and deliverables of this effort include:

- survey of climate impacts and local perceptions of climate hazards including assessment and analysis of capacities and coping strategies;
- increased understanding of the effect of drought on agriculture and allied sectors;
- analysis of climate analogues and climate change model outputs;
- documentation of viable adaptation practices and options for livelihood adaptation; and
- development of extension materials and awareness-raising methods.

This report is based on detailed interaction with all project partners and stakeholders at all levels and an extensive literature review. It is meant to serve as a basis for understanding drought impacts and to demonstrate viable adaptation options in the drought-prone areas of Northwest Bangladesh.

CHAPTER 2

DESCRIPTION OF STUDY AREA

A study on assessment of climate change impacts and livelihood adaptation in drought-prone areas was conducted in two pilot districts of Northwest Bangladesh. This chapter presents a brief description of the pilot *zillas* and *upazillas* (districts and sub districts).

The pilot locations, situated in Northwest Bangladesh, include the drought-prone districts of Chapai Nawabganj (Fig.1) and Naogaon (Fig. 2). The western part of Bangladesh borders West Bengal, India.

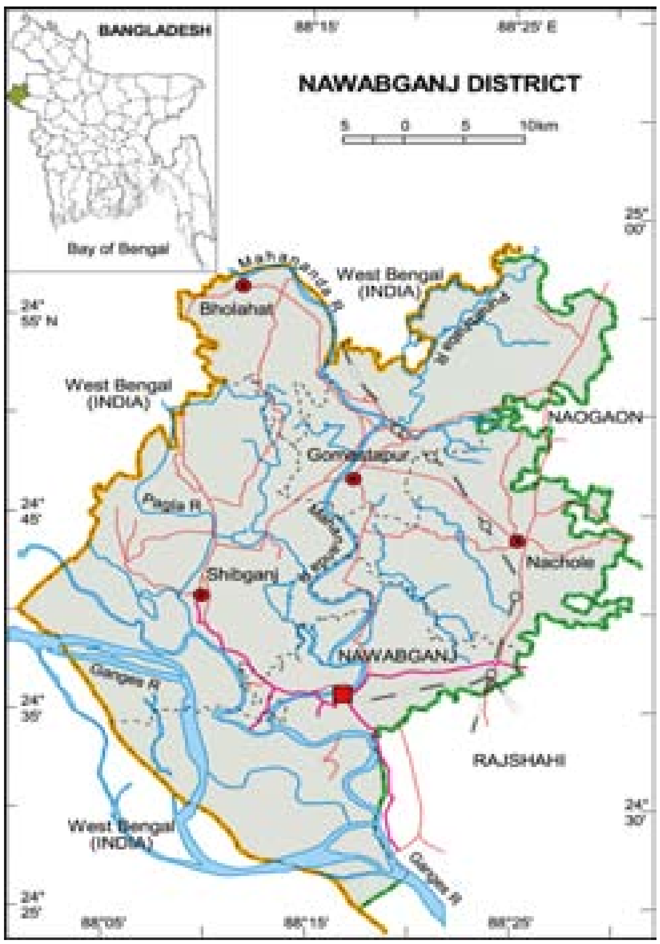

Fig.1. Location map of Chapai Nawabganj district in Northwest Bangladesh

2.1 Chapai Nawabganj District

Chapai Nawabganj district (Fig.1) has an area of 1 744.3 km^2 and a population of 1.42 million (50.1 percent male and 49.9 percent female). Located in the Barind Tract, its main rivers are the Ganges, Mahannda, Pagla, Moraganga and Punarbhaba. Average literacy rate is 35.9 percent and the main occupations are farming, commerce, service, agricultural labour, wage labour and construction. Among the farmers, 35 percent are landless, 34 percent marginal, 27 percent medium and 4 percent are big. Main crops of the district are paddy, jute, sugarcane, wheat, betel leaf, oil seed and pulses. Main fruits are mango, jackfruit, litchi, blackberry and palm. The manufacturing industries include a silk mill, textile mill and cold storage operation. Cottage industries include silk, weaving, copper, bell-metal and brass works; decorated *shika* (hanging rope shelves); pottery; hand fans; bamboo and cane works (BBS, 2005a).

2.1.1 Gomastapur Upazilla

Gomestapur Upazilla of Chapai Nawabganj district has an area of 318.1 km^2 and population of 240 123 (50.6 percent male, 49.4 percent female). Noted rivers are Mahananda and Punarbhaba. Main occupations are farming, fishing, agricultural labour, wage labour, weaving, commerce, service and others. Main crops are paddy, potato, wheat, tomato, corn, onion and garlic. Main fruits are mango and jackfruit with the nation's largest mango market located at Rohanpur. Fisheries, dairies and poultry units are also present. There are bakeries and an ice factory as well as cottage industries for weaving, bamboo working, goldsmithing, blacksmithing, pottery, woodworking, manual oil grinding and welding. NGOs operating in the area include CARITAS, PROSHIKA, BRAC and the Grameen Bank. The three villages selected for the project implementation include Baradapur and Malpur (non-irrigated) and Prosadpur (irrigated).

2.1.2 Nachole Upazilla

Nachole Upazilla in Chapai Nawabganj district has an area of 283.7 km^2 and a population of 132 308. Its main rivers are Mahananda, Lakshmikol, Aisha, Itail and Hazardighi. Main occupations are farming, agricultural labour, wage labour, commerce, service and others. Main crops are paddy, wheat, pulses and vegetables. Main fruits are mango, jackfruit, litchi, blackberry and palm. Fisheries, dairies and poultry units are present as are cottage industries for pottery and bamboo work. NGOs operating in the area include BRAC, PROSHIKA, CARITAS and Bangladesh Islamic Youth Society. The three villages selected for the project implementation include Azoir, Basbaria (non-irrigated) and Shiala (irrigated).

2.2 Naogaon District

Naogaon district (Fig.2) has an area of 3 435.67 km^2 and a population of 2.39 million (50.7 percent male and 49.3 percent female). Its main rivers are Atrai, Punarbhaba, little Jamuna, Nagar, Chiri and Tulsi Ganga. Guta, Mansur and Dighali *beels* are notable. Main occupations include agriculture, fishing, agricultural labour, wage labour, commerce, service and others. Main crops are paddy, potato, watermelon, oil seeds and pulses. Fruit production is dominated by mango, jackfruit, banana and litchi. Manufacturing activities include a rice and husking mill, ice factory, flour mill, oil mill, sawmill and welding. The cottage industries are goldsmith, pottery, bamboo and mat work and tailoring (BBS, 2005b).

2.2.1 Porsha Upazilla

Porsha Upazilla in Naogaon district has an area of 252.8 km^2 with a population of 121 809 (50.2 percent male, 49.8 percent female). Rivers are the Shiba which creates the eastern boundary and the Punarbhava. Main occupations include farming, agricultural labour, wage labour, commerce, service and others. Main crops are paddy, wheat and mustard. Main fruits are mango, jackfruit, litchi and watermelon. Manufacturing includes a rice mill and flour mill and cottage industries include bamboo work, goldsmithing, blacksmithing, pottery, woodworking, welding and sewing. Important NGOs are CARITAS, BRAC, CARE, PROSHIKA and Barendra Prakalpa. The three villages selected for project implementation are Saharandha and Chhaor (non-irrigated) and Shavapur (irrigated).

Fig.2. Location of map of Naogaon district in northwestern Bangladesh

2.2.2 Sapahar Upazilla

Sapahar Upazilla of Naogaon district has an area of 244.5 km^2 and population of 143 853. Its main river is Punarbhaba and the main occupations are farming, agricultural labour, wage labour, commerce, service and others. Main crops are paddy, wheat and mustard. Main fruits are mango, jackfruit, banana and papaya. Manufacturing includes a flour mill and rice mill, and cottage industries are bamboo work, goldsmithing, pottery, woodwork, and welding. The NGOs operating locally are BRAC, ASA, PROSHIKA, Ujjban, CARITAS and Varendra Prokalpa. The three villages selected for project implementation include Basuldanga and Bahapur (non-irrigated) and Chachahar (irrigated).

CHAPTER 3

CONCEPTUAL FRAMEWORK AND METHODOLOGY

3.1 Definition of key concepts

This section defines the concepts and terms used in climate change impact assessments and adaptation menus for drought risk management. Definitions for some terms, such as vulnerability and risk, vary among disciplines and contexts. In these cases, broad definitions are provided along with alternative definitions where applicable (IPCC, 2001; UNDP, 2004)**.**

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

Adaptation baseline: Current climate adaptations that are already in place.

Adaptive capacity: The ability of a system to adjust its characteristics or behaviour in order to expand its coping range under existing climate variability or future climatic conditions. There is a difference between "adaptive potential", which is a theoretical upper limit of responses based on expertise and anticipated developments within the planning horizon of the assessment, and "adaptive capacity," which is existing information, technology and resources of the system under consideration.

Climate change: Any change in climate over time, whether due to natural variability or human activity.

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

Climate variability: Variations in the mean state and other statistics (such as standard deviations) of the climate on all temporal and spatial scales. Variability includes more than individual weather events and may result from natural internal processes within the climate system (internal variability) or to variations in natural or anthropogenic external forces (external variability).

Coping range: The range of climates where the outcomes are beneficial or negative but tolerable. Beyond the coping range, the damages or losses are no longer tolerable and a society is said to be vulnerable.

Risk: The result of the interaction of physically defined hazards with the properties of the exposed systems, i.e. sensitivity or vulnerability. Risk can also be from the combination of an event, its likelihood and its consequences. Risk equals the probability of climate hazard multiplied by a given system's vulnerability.

Scenario: A plausible and often simplified description of how the future may develop based on a coherent and internally consistent set of assumptions about driving forces and key relationships. Scenarios may be derived from projections, but are often based on additional information from other sources, sometimes combined with a narrative storyline.

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

Stakeholders: Those who have interest in a particular decision, either as individuals or as representatives of a group. This includes people who influence a decision as well as those affected by it.

Vulnerability: The degree to which a unit is susceptible to harm due to exposure to a perturbation or stress, and the ability of the exposure unit to cope, recover or fundamentally adapt. It can also be considered the underlying exposure to damaging shocks, perturbations or stresses, rather than the probability or projected incidence of those shocks themselves.

3.2 Conceptual framework

3.2.1 Adaptive Capacity for climate variability and change in drought-prone areas

Future climate variability and change may increase the frequency of drought and thus reduce the coping range and adaptive capacity of the vulnerable population in drought-prone areas of Bangladesh. Figure 3, a hypothetical example, illustrates how a coping range is breached under climate change if the ability to cope is held constant. If that range is represented in terms of rainfall, the upper wet (Y1) baseline or reference threshold is exceeded less frequently, while exceeding of the lower threshold (or dry conditions) increases over time (Selvaraju, 2003). Vulnerability will increase to extreme levels for the dry threshold over time. Rainfall during the baseline climate that is experienced now is more or less stable with the mean (Y). With changing climate, however, rainfall tends to reduce gradually and frequency of drought (below Y2) increases.

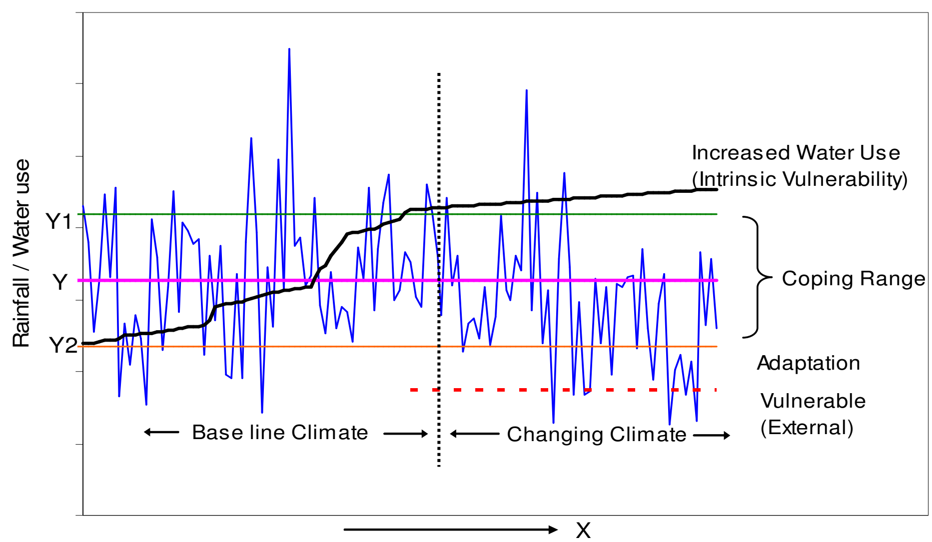

Fig. 3. A hypothetical diagram focusing on social pressure and bio-physical system performance describing the relationship among climate change, coping range, vulnerability and adaptation in drought-prone areas.

Applying this to Bangladesh, the fact that cropping intensity is also increasing in the drought-prone Barind Tract indicates there may be increased water requirements in the future. There are two factors contributing to increased vulnerability: i) higher frequency of droughts and dry spells that may affect the agriculture sector negatively, and ii) higher water requirements in the agricultural system as a whole due to increased cropping intensity. That means low rainfall and increased evapotranspiration may further aggravate the current situation in a region that is already drought prone.

The rainfall amount often exceeds the lower (dry) threshold and thus breaches the existing coping range. Once the coping range is breached, a vulnerable population has difficulty adjusting to that low level of rainfall. However, it is possible to expand the coping range through introducing novel and stable adaptation practices that could improve the adaptive capacity of the rural livelihoods in drought-prone areas. Adaptation practices can reduce vulnerability of the exposed bio-physical systems in general – the rural population in particular – with a consequent reduction in vulnerability. The nature of adaptation required depends on the planning horizon under assessment and the likelihood of exceeding given criteria over that planning horizon.

The coping range can also be used to explore how climate and coping ability may interact over time. For example, an agricultural assessment that projects growth in technology, yield and income would broaden the coping range and also could determine whether these changes would be adequate to cope with projected climate changes.

3.2.2 Climate variability and change and livelihoods

Based on the theoretical insights discussed above, a model was developed to implement adaptation to climate variability and change with an overall aim to improve the adaptive capacity of the rural livelihoods in agriculture sector (Fig.4).

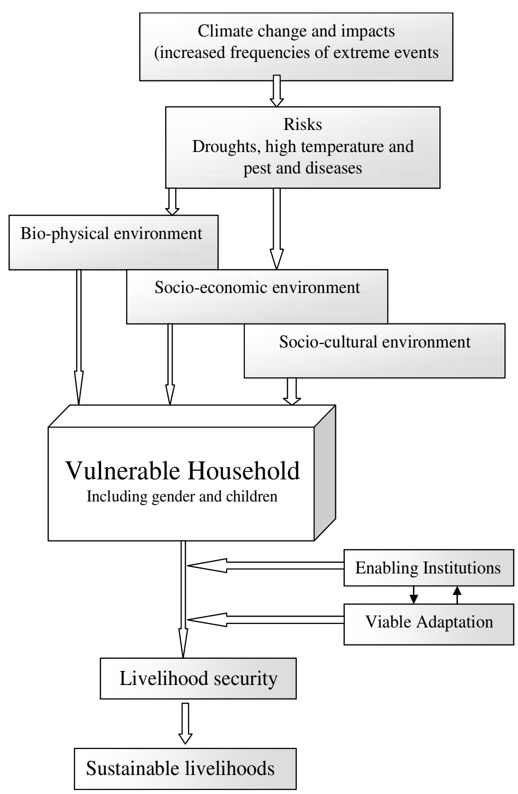

Fig.4. Conceptual framework for improving livelihood security and sustainable livelihoods through adaptation to climate change

Figure 4 shows how different environmental factors together with risk factors influence household livelihood strategies and decision-making processes over time, taking the role of gender and other vulnerable populations into account. At the center of the model are the households, where strategies are developed and decisions taken to develop and maintain livelihoods by means of the livelihood portfolio. Looking at the model from a systems perspective, climate change could influence the bio-physical (agriculture), socio-cultural and socio-economic environments of households, impacting resources and assets, including social capital. The resource management strategies and decision-making potential of the local population is also affected. The fact that coping range drops significantly under climate change is one of the reasons that improving adaptive capacity to maintain or improve livelihood security is one of the core aims of this effort.

3.2.3 Components of climate change adaptation

Designing and implementing livelihood adaptation to climate change in drought-prone areas is well within the policy of the Government of Bangladesh. The Comprehensive Disaster Management Programme (CDMP) recognizes the risks associated with climate variability and change. It seeks to establish an integrated approach to manage climate risks at the national and local levels and implement activities to promote adaptation and reduce livelihood vulnerability, particularly among women and poor communities that have the lowest capacity to adapt. In terms of the national policies related to climate change adaptation, the following strategy elements, to be read from the bottom upwards but not implemented in a rigid time sequence, can be used to form an overall strategy implementation plan (Fig.5)

(i) Assessing current vulnerability – involves responding to several questions, such as: Where does this society stand today with respect to vulnerability to climate risks? What factors determine this society's current vulnerability? How successful are the efforts to adapt to current climate risks? The major steps to address these questions are:

- assess natural, socio-economic conditions,
- assess current climate risks,
- assess local perceptions about climate risks and impacts,
- document livelihood profiles in the pilot sites,
- assess institutional frameworks.

(ii) Assessing future climate risks – focuses on developing scenarios of future climate, vulnerability and environmental trends as a basis for considering future climate risks. The major processes involved are:

- Climate impact assessment & outlooks on agriculture
- Local agro-meteorological data collection and monitoring
- Downscaling climate change scenarios

(iii) Testing adaptation options - involves the identification and selection of viable adaptation options and the further formulation of these options into farmer-friendly adaptation menus; thereafter the testing and evaluating, with the goal of improving the adaptation options identified through stakeholder consultations. The major steps of this component are:

- Institutional and technical capacity building
- Developing adaptation options & extension strategy
- Validation and selection of adaptation options
- Community mobilization and local awareness raising

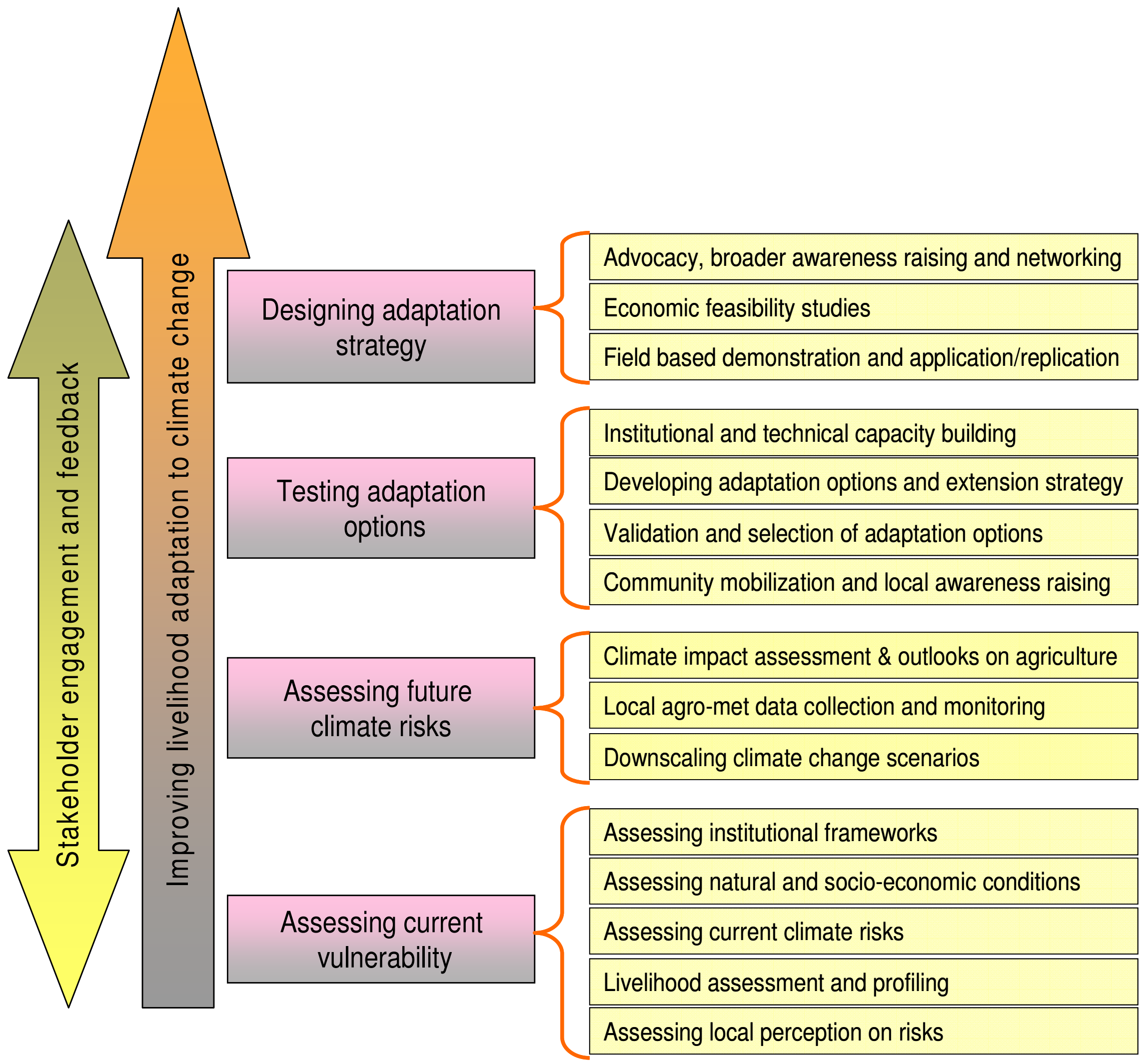

Fig.5. Operationalizing strategy and processes for livelihood adaptation to climate variability and change in drought-prone areas of Bangladesh.

(iv) Design adaptation strategy – prepares for broader dissemination and replication of successful field testing of adaptation options to current vulnerability and future climate risks. The key steps followed under this section are:

- Advocacy, broader awareness raising and networking
- Economic feasibility studies
- Field-based demonstration & application/replication

3.3. Development of an adaptation options menu

An adaptation options menu can identify viable options for managing climate risks (in this case drought-related). It synthesizes adaptation practices that could catalyze long-term adaptation processes. The four major steps for developing the tool, presented in Figure 6, are:

i) identify locally available and new research based on improved adaptation options,
ii) analyse above adaptation options based on their constraints and opportunities,
iii) validate and prioritize adaptation options against a set of key criteria, and
iv) consolidate the most suitable options into an adaptation options menu.

These steps fall well within the overall adaptation policy framework proposed for the country as a whole. Determining the viable adaptation options actually creates a menu of adaptation options with recommendations for the development planning process and its potential integration into the existing institutional agenda. The adaptation option menu provides input and catalysts for field-level demonstrations of viable adaptation options with the potential to improve the adaptive capacity of rural livelihoods to climate change.

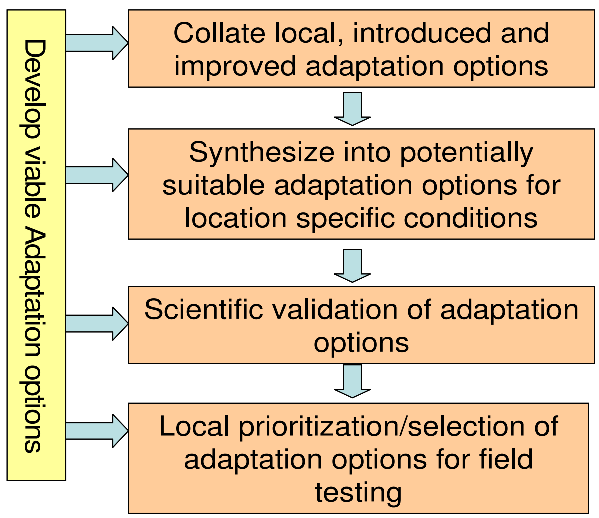

Fig.6. Sequential tasks in designing viable adaptation options for drought-prone areas

The strategy for adapting to climate variability and change impacts and awareness raising has been categorized as:

- recognition of local knowledge and existing adaptation strategies,
- establishment of an institutional framework through which local adaptation strategies can be reviewed, verified and integrated into the mainstream of resource management,
- documentation of all coping and adaptation strategies to provide a basis for the future,
- creation of mass awareness of climate variability at grassroots level, through government and non-governmental intervention and provision of essential support such as information, technology, technical know-how, alternative sources of income and employment, credit facilities, health facilities and markets information, and
- dissemination of all awareness messages in local language.

3.4 Methodology

3.4.1 General approaches

A three-stage methodology was used for assessing climate variability and change in the agriculture sector with special emphasis on livelihoods at the selected pilot study locations. The stages include the following:

1. Document local perceptions of impacts. This stage employed participatory methodology to collect perceptive information from various village-level stakeholders.
2. Analyse past climate data to understand the risks in relation to rainfall variation and dry and wet spells. At this stage, analogues of extremes and magnitudes matched with secondary data collected from other sources (including DAE) provided understanding of the magnitude of past impacts.
3. Employ a climate modeling approach to understand the future climate change scenario for the pilot study locations. This stage looked at the climatic parameters most relevant to the agriculture sector such as rainfall and temperature. Downscaling procedures were followed to develop climate change model outputs and scenarios. This allowed estimates of potential climate impacts to be based on both the model scenarios and local understanding.

Documentation of local agricultural adaptation practices, defined through participatory approaches, was integrated into documentation of local perceptions from similar areas in the region (as identified in Stage 1) and then evaluated in collaboration with other relevant national institutions identified by the project. The national institutions were encouraged to organize field demonstrations that would show the potential effectiveness of the adaptation practices.

Guidance and collaboration were provided to the national research and extension institutions to develop technically viable agricultural practice menus based on local conditions such as climatic and non-climatic risks. Guidance was also given to transform potentially viable adaptation options into farmer-friendly extension tools and messages for dissemination through small workshops, leaflets and other mass media.

The approach has been institutionalized by maintaining the collaboration and involvement of various international, national and local institutions through constant input to the Sub-Component Manager (SCM) attached to the DAE. Strong linkages with cooperating partners such as the Department of Environment (DoE) and the United Nations Development Programme (UNDP) have been maintained throughout the project. Regular exchange of ideas took place with the Climate Change Cell at DoE and other related CDMP components.

3.4.2 Methods and tools

The approaches outlined above required a well established methodology to assess the impact of past and current climate hazards[1] in the agriculture sector. The most convenient method used for documenting information from the farmers was focus group discussions[2] in 12

[1] Climate hazard is a potentially damaging physical event or phenomenon (hydrometeorological) that may cause loss of life or injury, property damage, social and economic disruption or environmental degradation.
[2] Focus group discussion is a powerful tool to explore a focused issue through well facilitated discussions – a topic is introduced and participants are asked to discuss the issue.

selected villages. A time-line analysis[3] and trend analysis[4] were also followed when necessary to understand the past impacts of climate variability.

The methodology aims at a holistic analysis of the causes and impacts of climate variability and the local perceptions[5] of climate-related hazards. The local adaptation practices the community followed to minimize the impact of drought were documented through participatory rural appraisal methods. Also, seasonal diagramming[6] was used to identify which and when crops are exposed to climate-related hazards.

A desktop analysis looked for possible trends and patterns in the long-term climate data collected from the Bangladesh Meteorological Department (BMD). Climate-related risks in agriculture are associated with the length of the growing period, dry and wet spells at various stages of crop growth (initial, development and reproductive). Simple tools explaining water balance[7] for major crops were used to assess the risks, and climate model[8] outputs derived from General Circulation Models (GCMs) were used to identify possible climate change scenarios. The climate change scenarios were developed from consultation with national research institutions and national focal points such as the CDMP Climate Change Cell and other CDMP components within Bangladesh.

The drought-prone pilot locations were ultimately identified based on a field trip to Chapai Nawobgonj and Naogaon districts in northwestern Bangladesh. The pilot study areas were chosen because they were:

- primarily drought prone[9] (moderate to severe) and
- subsistence small-scale agriculture is a major livelihood activity.

Two upazillas were selected in each of the identified districts – Gomestapur and Natchole in Chapai Nowobganj, Porsha and Sapahar in Naogaon (refer chapter 2) – and then three villages were identified in each of the four selected upazillas. This pilot location selection was based on the first-hand information of the local DAE staff. Of three villages chosen in each upazilla, one was irrigated and two were non-irrigated (rainfed). The irrigation for these villages comes from deep tubewells installed by the Barind Multi-purpose Development Authority (BMDA).

The adaptation practices followed locally and introduced by national development, research and extension organizations were collected from the respective organizations and evaluated at different levels (Fig.7).

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[3] Time line analysis provides a historical perspective of the major events that have occurred in the village and their impact upon the lives of the community.
[4] Trend analysis is a profile of the changes that a community is able to recognize in its midst.
[5] Local perceptions indicate the local understanding of farmers about a particular climate hazard with respect to their exposed infrastructure and properties.
[6] Seasonality diagramming shows farmers' seasonal concerns, including crop cycles and seasonal weather issues.
[7] Water balance represents the water input and output relationships from a medium (usually soil) on a specified time period.
[8] Climate model indicates physical representation of atmospheric system components used to describe the behaviour or state of the atmosphere at a specific time.
[9] The term "drought prone" is often used loosely and ambiguously. In Bangladesh it is sometimes used to refer to the driest parts of the country – the "dry zone" – where the mean annual rainfall and short length of rainy season impose restrictions on agricultural production which are not experienced in wetter parts of the country. It is also used to refer to areas that have soils with low capacity to store moisture and, therefore, dry quickly during the period when rainfall is below average and stay dry for a long period during the dry season.

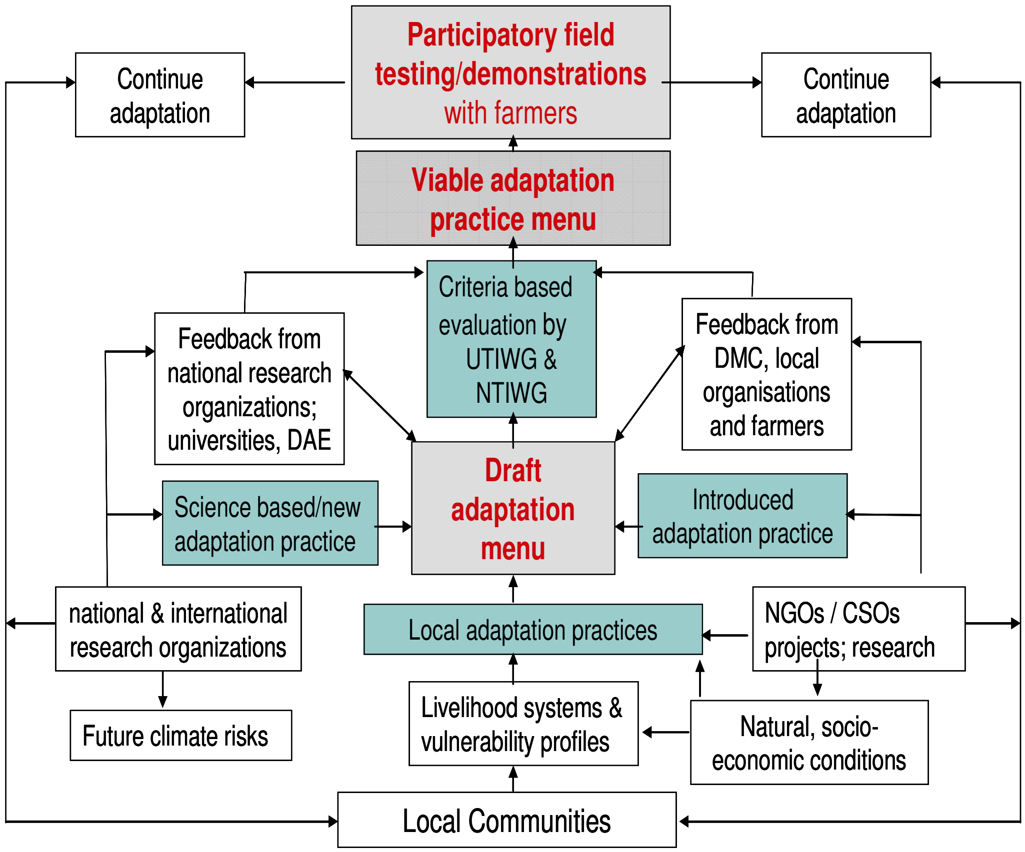

Fig 7. Overall framework and institutional structure describing activities and process of selection, evaluation and prioritization of adaptation practices for drought-prone areas in Bangladesh

3.4.3 Selection of viable adaptation practice

Viable adaptation options were selected through a sequence of evaluation processes at different levels starting from upazilla-level DMC members, Upazilla-level Technical Implementation Groups (UTIWG) and National-level Technical Implementation Working Groups (NTIWG). Consultative meetings and brief feedback workshops were also organized with the local research institutions Bangladesh Agricultural Research Institute (BARI) and Bangladesh Rice Research Institute (BRRI) and developmental organizations.

Selecting viable adaptation options requires criteria that include the type of problem and future expectations. Initially, environmental friendliness and cost effectiveness were the only two criteria considered for documenting a draft menu of adaptation practice. However, in view of the diversity of climate change adaptation options, more than one method is required to review all of the choices. Thus, they were prioritized according to:

- environmental friendliness and qualitative cost-benefit analysis;
- evaluation of adaptation options for their technical suitability;
- multi-criteria analysis;
- expert judgment.

The adaptation options were evaluated with the UTIWG and NTIWG for their technical suitability in drought-prone areas. The outcome of the stakeholder evaluation was integrated into the multi-criteria analysis. The criteria used were:

- drought mitigation – potential to reduce drought impact in terms of resources and economics,
- climate change scenarios – suitability under high temperature, frequent dry spells, high evaporation, etc.,
- environmental friendliness – less impact on the environment in terms of deteriorating quality of resources and its secondary impacts,
- economic viability – cost effectiveness and cost–benefit ratio,
- increased productivity – capacity to improve the overall productivity per unit area,
- sustainability – long-term effectiveness and capability of continuance after the project,
- social acceptability – preference of the community in all sections,
- gender integration – capacity to give larger role to women due to the particular adaptation practice,
- household income – capacity to increase household income on a continuous basis,
- employment opportunity – year-round employment opportunity for family members,
- relevance to vulnerable community – effect on small farmers, wage labourers and small businessman,
- applicability to multiple sectors – use for sectors such as agriculture, livestock, fisheries, forestry and water resource management,
- seasonal relevance – use of the adaptation practice during drought-prone *kharif* II season,
- immediate need – matching the adaptation practice to local community needs,
- institutional support – government policy and local institutions take up a particular adaptation practice,
- expert acceptance – feedback from the evaluation workshop organized at upazilla and national level.

Once potential adaptation measures were identified, they were used in discussions with key stakeholders from each sector to determine their relative feasibility based on their:

- effectiveness in reducing key risks,
- potential in technical terms as well as costs, social acceptance and manageability,
- current state of implementation and requirements of improvements, i.e. how they are being practiced in the country with or without consideration of climate change.

3.5 Details of activities

In relation to the above approaches and methodologies, the overall work programme followed the:

- inception of project and identification of pilot sites,
- assessment of climate impacts and local perception,
- analysis of climate change model outputs and scenario development,
- documentation of local and introduced adaptation practices,
- development of extension tools and awareness-raising strategies,
- provision of technical advice and coordination support.

3.5.1 Project inception and identification of pilot sites

The project inception was based on discussions of the project outline and proposed activities with FAO-SDAR, FAO-BGD, National Sub-Component Manager (SCM) and other project partners including local NGOs identified for the livelihood profiling study. The initial implementation phase was completed in May 2005, and a detailed work plan with the project partners was completed in early June 2005.

3.5.2 Assessing bio-physical and socio-economic conditions

Small focus groups with open discussions led by a skilled moderator explored issues of concern in the community – local problems, climate impacts, needs perceptions, socio-economic conditions, social capital, activity calendars, adaptation practices and institutional interventions – to elicit the group's reaction on these vital issues. Focus group meetings were conducted in all 12 pilot villages and were usually followed by a brief field by both the project team and the focus group participants.

3.5.3 Assessment of climate impacts and local perception

The past and present impacts of climate were assessed with hazard risk assessment tools[10] and problem analysis.[11] Secondary data, collected from various national organizations, were used to analyze the past impacts. The output was used to develop a hazard risk calendar for the pilot study locations with special emphasis on the agriculture sector. The assessment also included the coping strategies used by local people against climate-related hazards. The deliverable was a climate change impact analysis and perception document.

3.5.4 Analyzing climate change model outputs and scenario development

The work plan involved these major activities:

- review and develop climate change scenarios using GCMs for pilot study areas,
- analyze climate data on the frequency of past extreme events that might be expected in future (linking with climate change model outputs).

The development of climate change scenarios using GCM outputs was part of the desktop study. The DoE Climate Change Cell was contacted to create a liaison to share results of climate change model outputs. The historical climate data pertaining to rainfall and maximum and minimum temperature were collected from the Bangladesh Meteorological Department (BMD) and analyzed. The historical data sets for the pilot study area were analyzed to assess the past and current impacts on agriculture in general and livelihood in particular. Climate change scenarios were developed based on the desktop analysis of past climate analogues and future climate change as well as the local perceptions of climate impacts. These scenarios looked at the possible future state of the climate in the pilot study locations.

3.5.5 Documentation of local and introduced adaptation practices

Descriptions of the adaptation practices employed locally to minimize the impact of climate hazards were collected from farmers and local community. Adaptation practices introduced by national development, research and extension organizations were collected from the

[10] Hazard risk assessment tools include participatory rural appraisal methods described under section 3.4.2.
[11] Problem analysis provides an understanding of the climate related problems faced by the community.

respective organizations and these practices were evaluated with the farmers. The procedure involved the following activities:

- collection of local adaptation practices from farmers, using PRA,
- coordination with the national institutions to document introduced adaptation practices,
- documentation of drought adaptation practices used in neighboring regions.

3.5.6 Extension tool development and awareness-raising strategies

The impacts of climate hazards were translated into a menu of good practices in order to test their feasibility at pilot study locations. This required:

- understanding the impact of anticipated climate change on the agriculture sector of the pilot study locations through analysis of trends and awareness of local perceptions,
- developing a technically viable agricultural practice menu in collaboration with national research institutions,
- monitoring pilot testing by farmers in cooperation with agricultural extension staff,
- translating adaptation options into farmer-friendly extension tools, and
- raising awareness through demonstrating identified livelihood adaptation practices with farmers in the pilot sites.

The extension tools will include written and explanatory pamphlets, brochures and pictures of good practices. The printed materials will contain good practice menus with cost benefit analysis.

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.

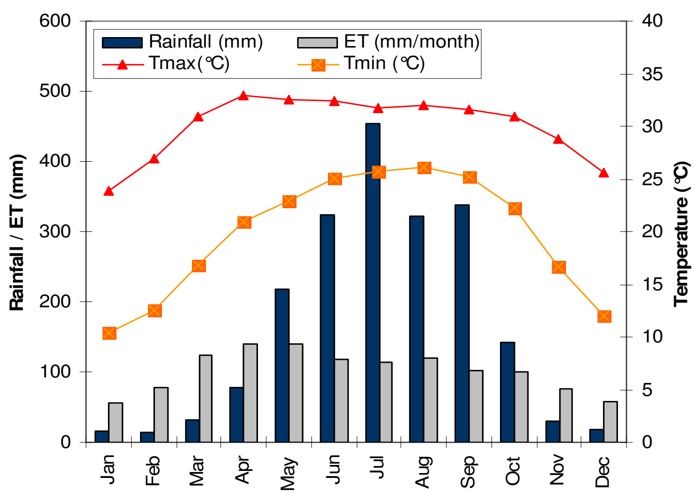

Fig. 8. Mean monthly rainfall, evapotranspiration and temperature in the pilot region

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.

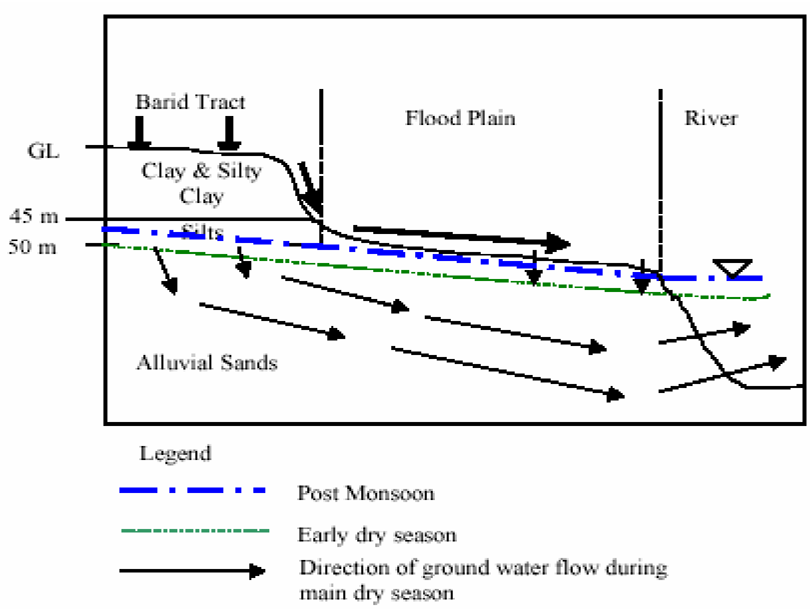

Fig.9. Water flow patterns and water level change following end of monsoon and early dry season

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.

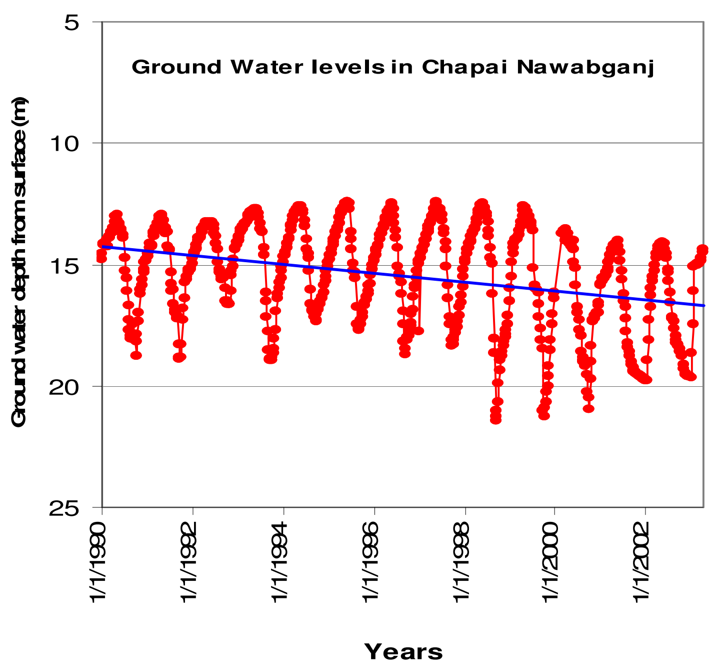

Fig.10. Groundwater levels in Chapai Nawabganj district from 1990 to 2002.

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.

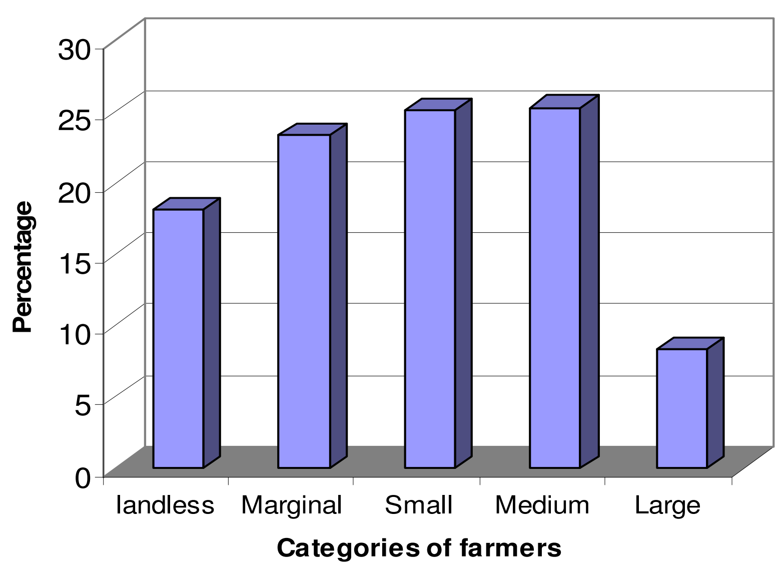

Fig. 11. Categories of farmers in the pilot drought-prone region in Barind tract

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.

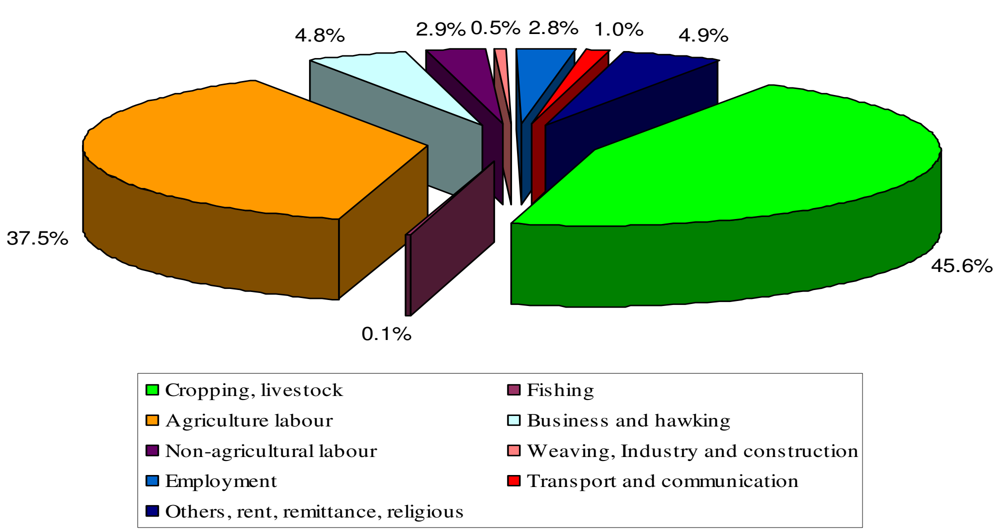

Fig. 12. Main sources of household income (%) in Porsha Upazilla of Naogaon district

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.

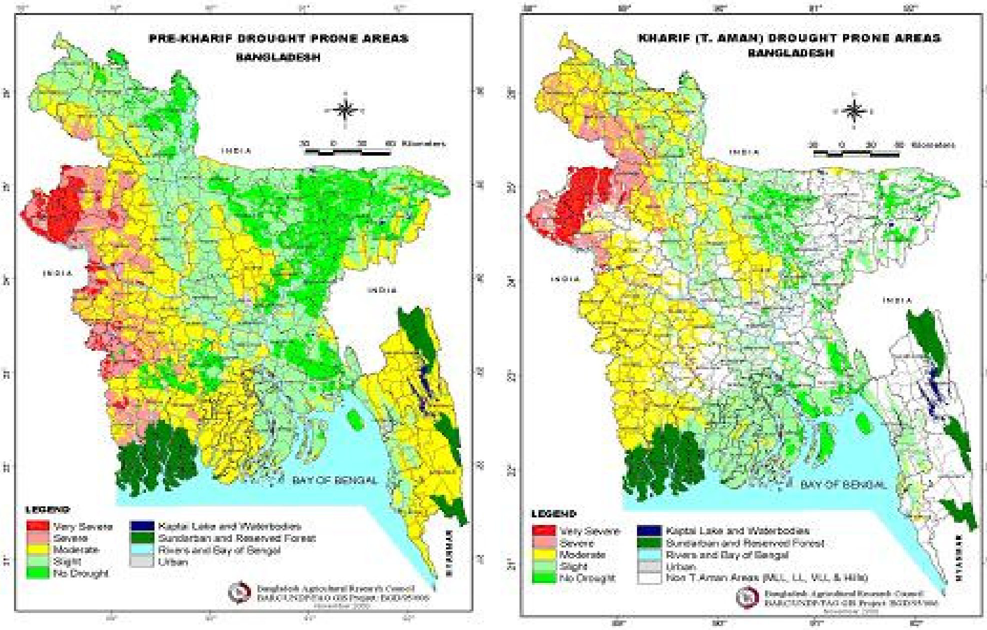

Fig.13. Drought severity maps for pre-*kharif* and *kharif* seasons in Bangladesh

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.

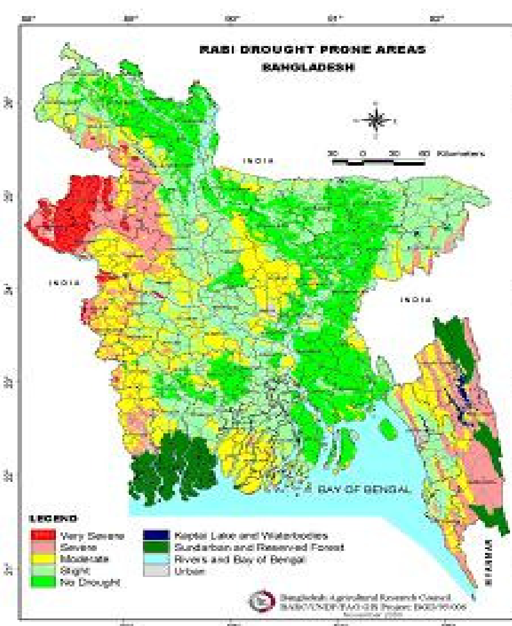

Fig.14. Drought-prone areas of Bangladesh in *rabi* season

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.

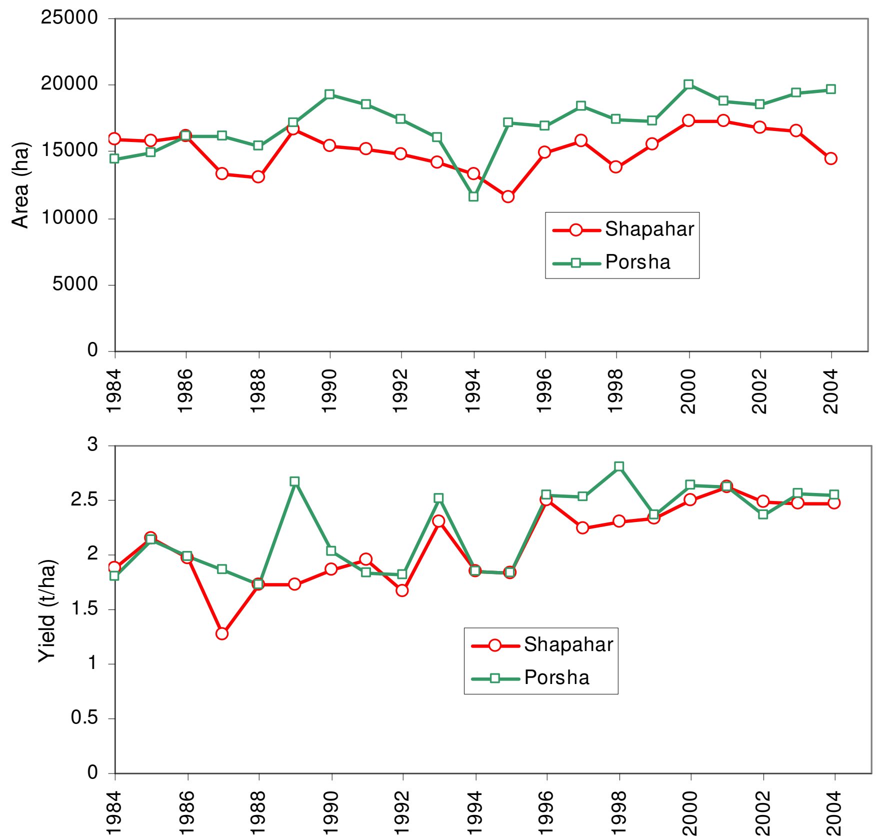

Fig. 15. Inter-annual variability of net area (ha) under rice and rice productivity (t/ha) in Shapahar and Porsha Upazilla of Naogoan district in Bangladesh.

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.

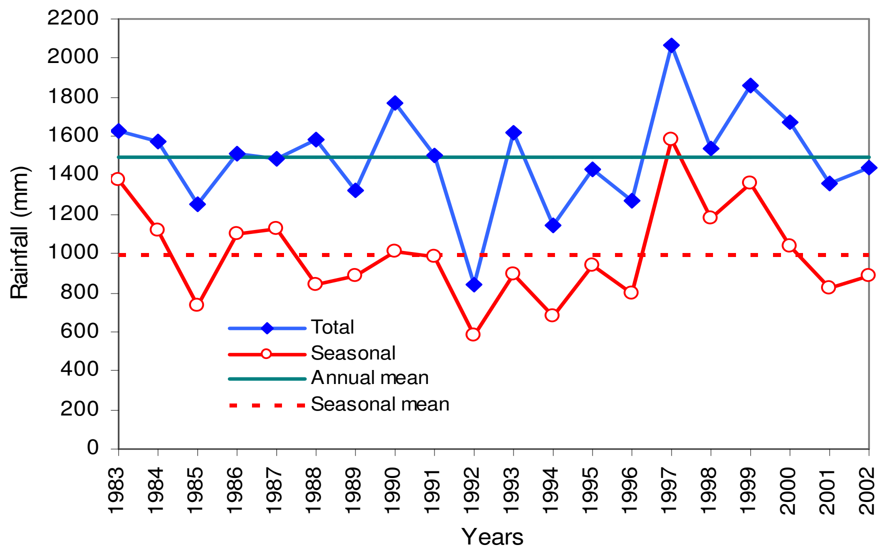

Fig.16. Inter-annual rainfall variability in the Barind Tract (1983-2002)

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.

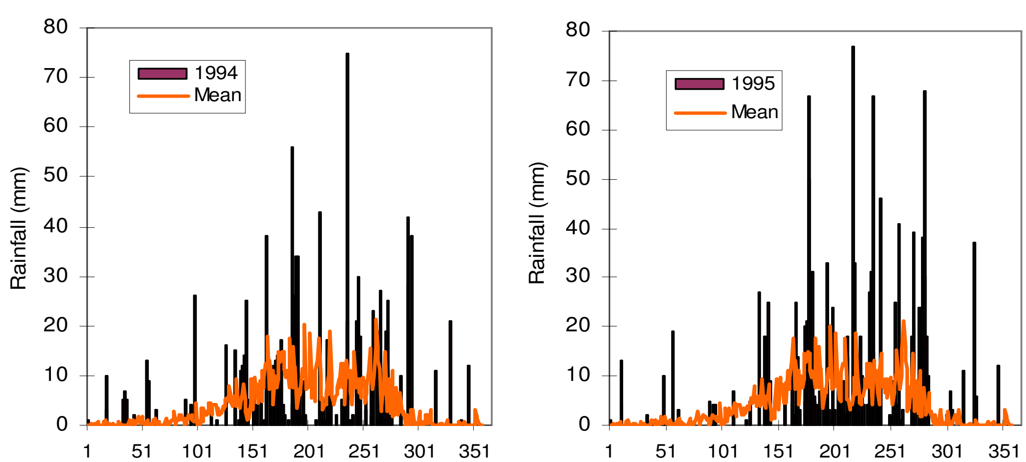

Fig.17. Daily rainfall distribution during 1994 and 1995 in Rajshahi, Bangladesh

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.

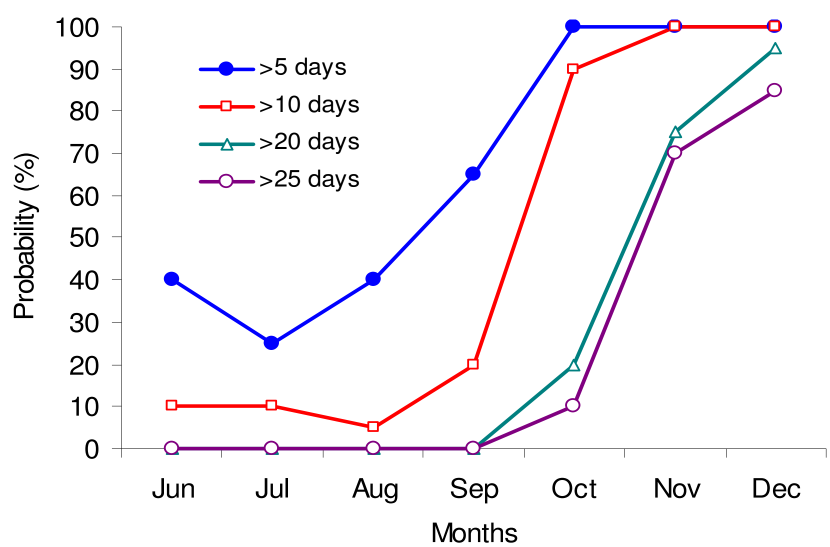

Fig. 18. Probability of receiving various amount of rainfall during the cropping season

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.

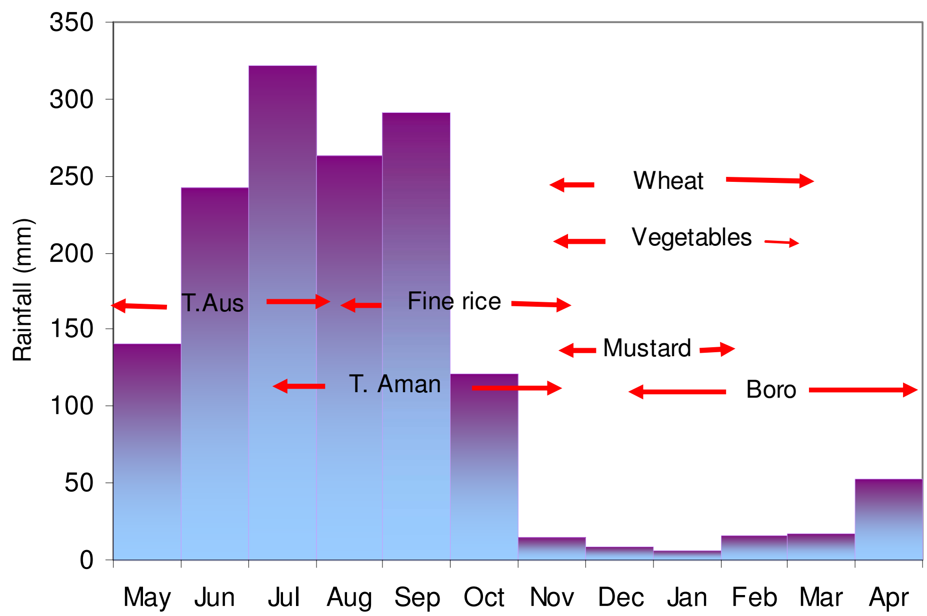

Fig.19. Crops and cropping pattern of drought-prone Barind tracts

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.

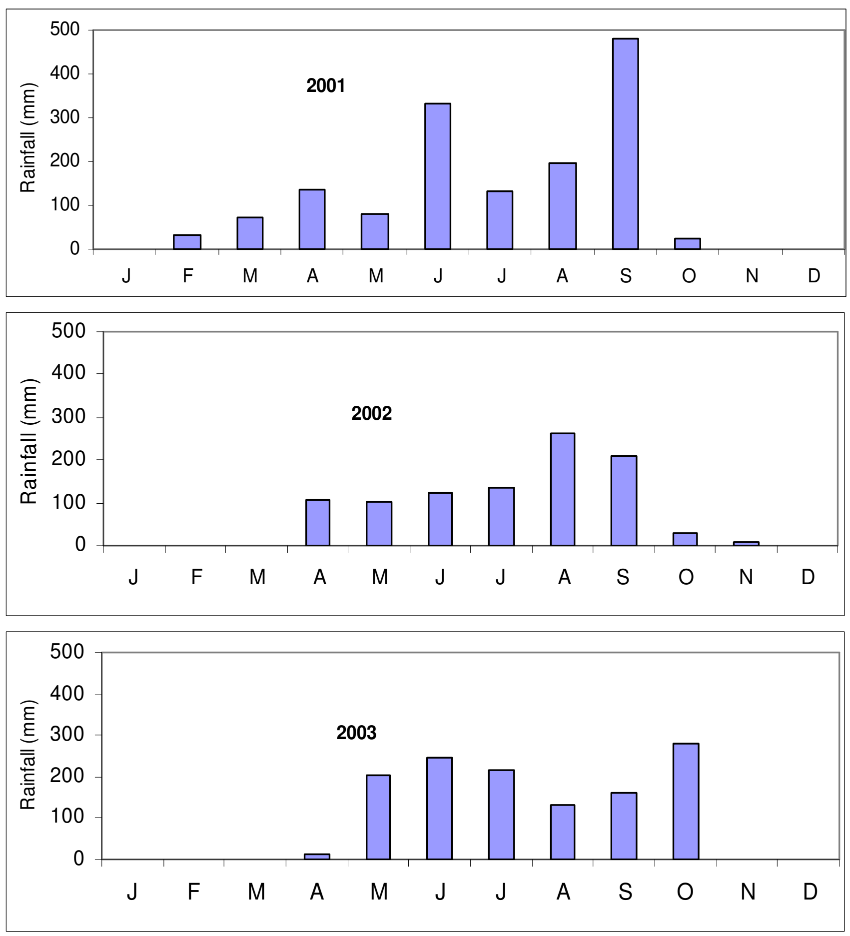

Fig. 20. Monthly rainfall distribution in 2001, 2002 and 2003

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).

DAT	Stage	Drought intensity			
		1	2	3	4
0 – 10	Transplanting				
10 – 25	Establishment				
25 – 50	Active tillering				
50 – 65	Panicle initiation				
65 – 70	Flowering				
70 – 85	Ripening				
85 – 100	Maturity				
100 – 105	Harvesting				

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).

Table 7. Trends of local coping strategies to drought in non-irrigated areas

S.n.	**Coping storategies**	In the past	At present
1.	**Household-level agricultural strategies**		
	Change of crops	Common	Less common
	Re-sowing/re-planting	Less common	Less common
	Soil moisture conservation	Common	Less common
	Development of irrigation surface sources	Common	Less common
2.	**Household-level non-agricultural adjustments**		
	Disposing of productive assets	Common	Less common
	Mortgaging land	Common	Less common
3.	**Individual-level adjustments**		
	Reducing food intake	Common	Less common
	Reducing personal expenditure	Common	Common
4.	**External and institutional support**		
	Government institution support	Less common	Common
	NGO support	Less common	Common
	Large farmers	Common	Common
	Community-based organizations	Common	Common

4.6.4 External and institutional supports

Drought-affected households received support from sources inside and beyond their communities. However, these sources provided support to a relatively small number of households. The households received financial and other forms of support from various government and non-governmental sources, mainly from the national government which provided cash loans to drought victims through public banks such as Janata, Sonali, and Krishi. Other sources of formal and informal support were relatives, friends, NGOs, other villagers and local governments. Assistance from informal sources during times of droughts was expected and were forthcoming. BRAC, PROSHIKA, TMSS and TRINOMUL were the NGOs actively involved in many pilot villages.

The items of assistance received from the above sources included cash loans, food, seeds and fertilizer. Similar to the national government, NGOs were limited to provision of cash loans to the victims. The amount of loans provided by friends, relatives and other villages was much lower than those provided by the formal sources. Local governments, friends, relatives and other villagers were the sources for other items offered to the drought victims such as food and seeds.

Support from governmental and non-governmental sources differed significantly according to the victim's occupation, land ownership, tenancy and education. Contrary to expectations, farmers, businessmen and service holders had no difference in terms of receiving support from different sources. However, when only governmental sources were considered, businessman and service holders were over represented. As indicated earlier, members of these two groups are more educated and own more land than their counterpart groups. Additionally, they are acquainted with local- and sub-district-level government officers and have regular contact or personal relationships with the officers, bank managers and other key officials involved in providing support to mitigate loss. Because of their connections and influence, they not only were over represented in receiving government support, they received larger amounts of support compared to small and marginal farmers.

Since the respondents owning moderate and large landholdings were more influential than their counterparts, they were better represented in receiving supports beyond the household level. Participatory interaction indicated that a considerable number of middle and large landowners rented some of their lands to tenant farmers. Additionally, some educated respondents who were employed in non-agricultural sectors also rented lands to tenant farmers. Big land owners who leased their land to small and marginal farmers also helped them get loans for crop cultivation during subsequent seasons.

In terms of ability to secure support from various sources, the respondent households that were members of institutionalized groups did better than their counterpart non-members. Members of institutional organizations received support from various government and non-government sources. Development of social institutional networks was found effective in lessening hazard impacts.

4.7 Institutional responses to mitigate drought

In the event of drought, the government undertakes relief measures by providing drinking water, foodgrains and food subsidies to special groups and through food-for-work programmes. The Disaster Management Bureau (DMB) coordinates drought relief work with local governments. DMB also has activities in human resource development, database and information services, and documentation on disaster management**.** The rural works programme of the GoB provides employment to the population affected by drought and helps mitigate the drought severity. The role of various formal institutions of the country in responding to drought and scarcity is discussed in this chapter.

4.7.1 Department of Agricultural Extension (DAE)

DAE has a well organized structure reaching out to local people and villagers (Fig.22).

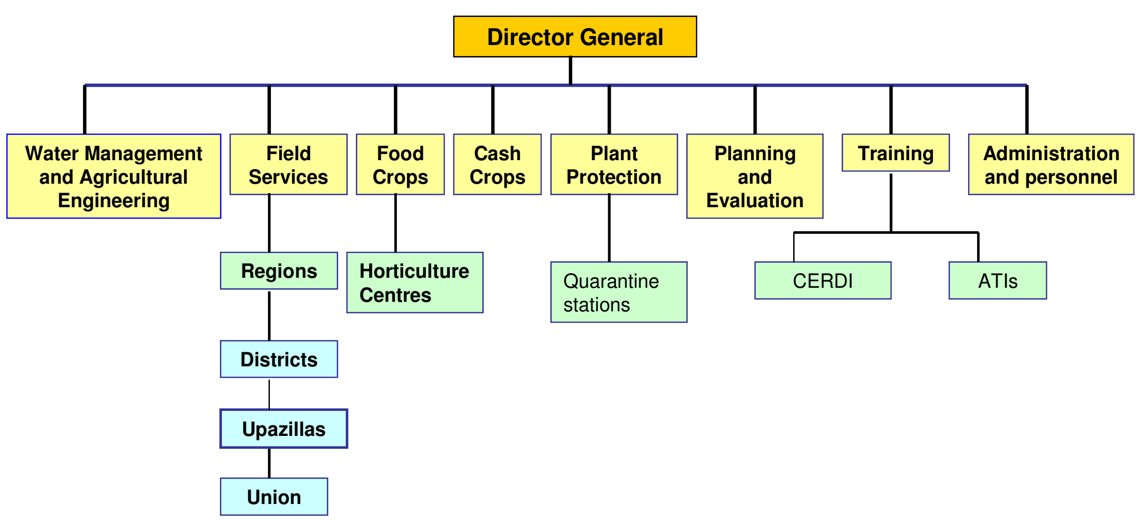

Fig.22 Organizational structure of Department of Agricultural Extension (DAE) in Bangladesh.

It has initiated a few programmes that directly or indirectly help manage drought- and climate-related impacts such as crop diversification and supplemental irrigation to T. *aman* rice in drought-prone areas. The major objective of the crop diversification programme is to assist in improving national, household and individual food security on an economically sustainable basis and to contribute to equity and poverty alleviation by i) rapidly increasing food production and productivity, ii) reducing year-to-year variations in production and iii) improving access to food. Some projects are related to climate change mitigation although they do not specifically address this issue, such as agroforestry development projects and production and use of biogas and organic fertilizer for maintaining environmental balance. A list of projects and their brief objectives is provided in Table 8.

Table 8. List of programmes and projects – implemented through Department of Agricultural Extension (DAE) in Bangladesh – with the potential to improve adaptive capacity of rural livelihoods against climate risks.

S. no	Project Subject	Area Covered (Districts)	Funding Source	Objectives of the Project	Project Period
1	Agricultural diversification and intensification	Tangail Gazipur Narsinghdi Kishoregonj	IFAD GoB	To improve the livelihoods of approximately 85 000 farm families in the project area by: • enabling landless and marginal families to increase their income and improve their nutrition through (i) poultry and fish enterprise (ii) agro-processing and other income-generating activities and (iii) homestead gardening, and • enabling small farmers to intensify and diversify crop production as well as to pursue other rural enterprises.	1997 - 2004
2	Production and use of biogas and organic fertilizer for maintaining environmental balance	All over Bangladesh	GoB	To maintain environmental balance through establishment of biogas plant and expansion of organic manure use.	1997 - 2003
3	Construction of 10 rubber dams in small and medium rivers	10 rivers selected in 6 districts	GoB	To develop surface water storage facilities after rainy season. To increase surface water use for irrigation in *rabi* and *boro* crops in the project area.	1999 - 2004
4	Marginal and small farm development	Kurigram Nilphamari Lalmonirhat Gaibandha Ranjpur	IDB GoB	To increase and secure income of small and marginal farmers through: • strengthening of the extension services to the marginal and small farmers, introduction of on-farm and off-farm income generation activities.	2001 - 2006
5	Agricultural services innovation & reform	All over Bangladesh	DFID IDA FAO GoB	To sustain improvements already achieved under ASSP and gradual improvement of management technical capabilities of DAE. To strengthen the collaborative extension activities between GO/NGOs and private sector.	1999 - 2004

S. no	Project Subject	Area Covered (Districts)	Funding Source	Objectives of the Project	Project Period
6	Integrated soil fertility and fertilizer management	328 upazillas of all districts	DANIDA GoB	To increase food production through updating technology on soil fertility and fertilizer management practices for major cropping pattern through on-farm testing based on farmers' socio-economic condition over varied agro-ecological zones.	1999 - 2004
7	Supplementary irrigation for drought- affected *T. aman*	254 selected upazillas of 46 districts	GoB	To maintain sustainability of *T. aman* crop production in drought. To expand supplementary irrigation through motivation of farmers.	1998 - 2004
8	Mushroom cultivation in Chittagong hill tracts	Rangamati district	GoB	To motivate farmers to produce mushrooms through provision of training.	1999 - 2004
9	Production, storage and distribution of quality seeds at farm level.	Throughout Bangladesh	GoB	To help fulfill HYV rice and wheat seeds needs for producing 25 million tonnes of foodgrain.	1999 - 2005
10	Northwest crop diversification	60 selected upazillas of 16 northern districts	ADB GoB	To increase regional and farm income in the project area through increased production of high-value crops and more efficient marketing. To build sustainable partnerships and capacities among small farmers, participating NGOs and the public sector to provide training and credit support to small farmers.	2000 - 2008
11	Production and marketing of fine rice	Throughout Bangladesh	GoB	To increase production of fine rice.	2001 - 2006
12.	Strengthening plant protection services	In 200 upazillas throughout Bangladesh	DANIDA GOB	To save crops from insects, pests and diseases through strengthening IPM, plant quarantine surveillance, forecasting and early warning systems.	2002 - 2005
13	Small farmer agroforesty development project	Rangpur Kurigram Nilphamari Lalmonirhat Gaibandha Dinajpur districts	German GoB	To increase income of women and men marginal and small farmers.	2001 - 2005
14	FAO Special Programme for Food Security	21 selected upazillas of 16 districts	Japan GoB	To assist in improving national, household/individual food security on an economically sustainable basis by rapidly increasing food production and productivity, reducing year-to-year variation of production and improving access to food as contribution to equity and poverty alleviation.	2001 - 2006
15	Crop diversification	300 upazillas of 55 districts	GoB	To help improve nutritional food status and food self-sufficiency through increased production of potato, oil seeds and pulses.	1995 - 2002 - 2005

S. no	Project Subject	Area Covered (Districts)	Funding Source	Objectives of the Project	Project Period
16	Integrated maize promotion project	200 upazillas of 47 districts	GoB	To increase maize production, improve nutritional status and fulfill the demand of poultry, livestock and fish feed.	1995 - 2005
17	Horticulture development	21 selected nurseries	GoB	To increase yield per acre of horticulture crops through supply of seeds and saplings.	2000 - 2005

4.7.2 Ministry of Food and Disaster Management

Following the devastating floods in 1988 and the cyclone of 1991, Bangladesh adopted an approach embracing the processes of hazard identification and mitigation, community preparedness and integrated response efforts. Relief and recovery activities are now planned within a risk management framework that seeks to enhance the capacities of at-risk communities and thereby lower their vulnerability to specific hazards. In line with the paradigm shift from relief and response to comprehensive disaster management, the former Ministry of Relief and Rehabilitation became the Ministry of Disaster Management and Relief and then, in 2003, it became the Ministry of Food and Disaster Management (MoFDM).

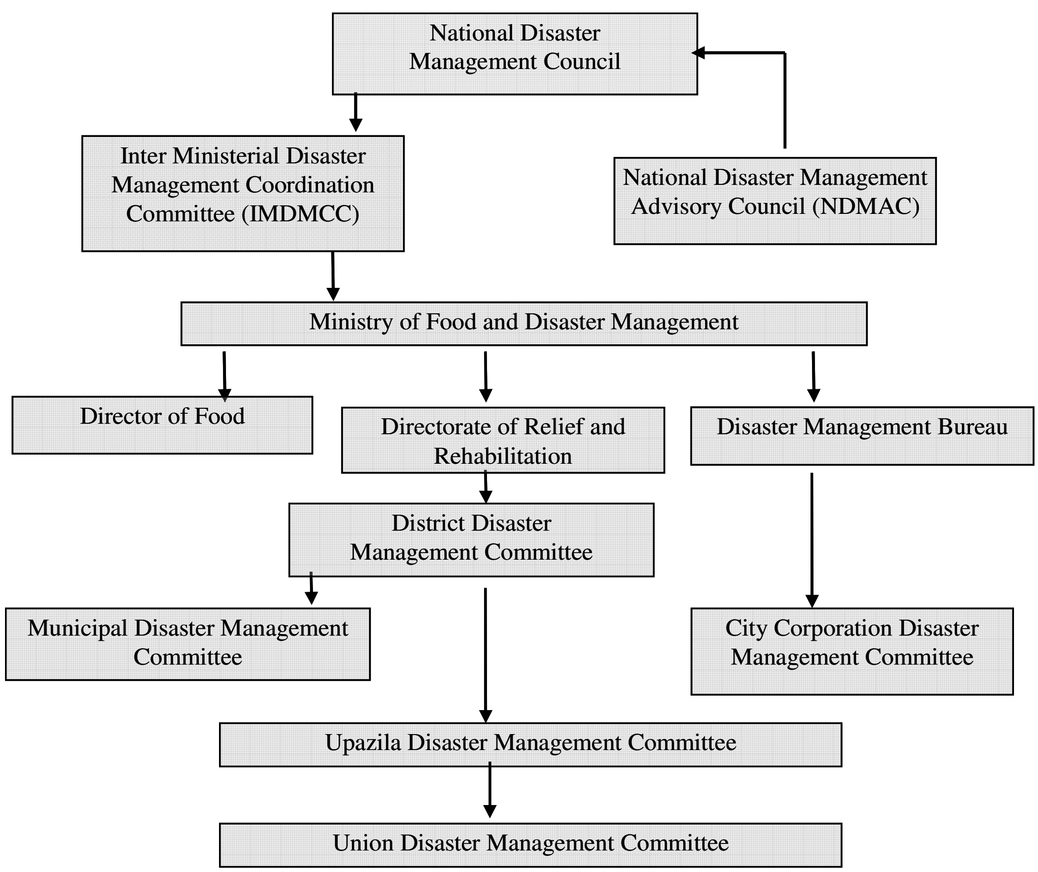

Fig.23. Disaster management systems in Bangladesh

Inter-related institutions were developed to ensure that planning and coordination of disaster episodes were performed in accordance with the Standing Order on Disasters (SoD). Specific codes developed to address climate-related impacts are applied at institutional levels, ranging from the Union Disaster Management Committee (lowest community level) to the apex institution level, the National Disaster Management Council. The development of union, *pourashava, upazilla*, district, city corporation and national disaster management strategies are all broad-based and comprehensive.

The Disaster Management Bureau (DMB), created as a professional unit at national level in 1992, was assigned specialist support functions in close collaboration with district and *thana/upazilla*-level authorities and the concerned line ministries under the overall authority of the high-level Inter-Ministerial Committee (IMDMCC). The DMB also has responsibility for creating public awareness on the severity and risks associated with natural and human-induced hazards and to formulate programmes and projects that prepare at-risk communities and public officials to mitigate their consequences. As a technical arm of the Ministry of Food and Disaster Management, DMB oversees and coordinates all activities related to disaster management from the national to the grassroots levels (Fig. 23). It is also entrusted to maintain an effective liaison with government agencies, donors and NGOs to ensure maximum cooperation and coordination in all aspects of disaster management.

The Comprehensive Disaster Management Programme (CDMP) was designed as a long-term programme of the Ministry of Food and Disaster Management with multi-agency involvement. Funded jointly by the United Nations Development Programme (UNDP) and the Department for International Development (DFID), the programme was launched in 2003 with its activities designed to be implemented in phases. One of its major activities is related to climate change adaptation in various sectors where the project has been implemented.

4.7.3 Barind Multipurpose Development Authority (BMDA)

The Barind Integrated Area Development Project (BIADP), later renamed the Barind Multipurpose Development Authority (BMDA), was established in 1985 to retain environmental balance and check the desertification of the Barind region's Rajshahi, Naogaon and Chapai Nawabganj districts. Before the project activities started, the Barind Tract was the most unfavourable agricultural section of the country where rainfed local *T. aman* was the dominant crop.

Now, the ensured supply of deep tube well (DTW) irrigation has fundamentally changed the Barind Tract's agricultural scenario. In place of a single crop, multiple crops are grown with higher agro-economic productivity. This transformation has resulted in more productive cropping patterns and increased cropping intensities. Construction of cross dams and water control structures, and re-excavation of canals and ponds has contributed to improved surface water augmentation. This is reflected in satisfactory command area development and ecological balance. The slow moving bullock cart previously was the main transport for carrying goods and passengers because of the lack of good road networks. Now, BMDA construction of feeder and rural roads has improved the rural economy and changed the status of rural livelihoods.

The Barind Multipurpose Development Authority (BMDA) has implemented needs-based development programmes aimed at improving socio-economic conditions of the people and protecting environmental balance in the Barind Tract. Between its inception in 1985 and 2004, the BMDA executed eight big projects in its command areas of 25 upazillas in Rajshahi, Naogaon and Chapainawabganj districts at a cost of US$154.6 million. Since 2004, it has implemented nine other projects with a projected cost of about US$289.9 million. As of 2006, US$50.72 million had been completed with the rest work scheduled to be finished by 2009. Initially, some projects were executed with government funds but now, the BMDA implements the projects with its own resources.

After evaluating the progress of the BMDA in the field of irrigation management, the government has given it further responsibilities – to rehabilitate all the non-functional DTWs under the Bangladesh Agricultural Development Corporation (BADC) throughout the northern region. These ongoing projects of the BMDA include:

- installation of DTWs,
- construction of irrigation canals and roads,
- electric connections for the DTWs,
- re-excavation of ponds,
- afforestation,
- drinking water supply through the DTWs and
- production of fine and aromatic rice.

Before BMDA, there were 500 DTWs and 5 000 irrigated ha. Now, there are 6 626 DTWs, of which 5 000 have electric connections, and 275 000 irrigated ha. Under the pond and canal digging programme, 2 144 ponds and 75 kilometers of canals have been re-excavated for fish culture and irrigation, 48 cross dams have been constructed to preserve surface water in the canals and more than 18 million saplings of various tree varieties have been planted in the command area to protect environmental balance and meet the growing demand for fruit and timber.

Of the 1 200 km roads not properly maintained (*kutcha*) in the three districts, 500 kilometers have been paved, with the remaining 700 km set to be paved in phases. A 5.4 million project is being implemented to facilitate safe drinking water for the Barind Tract. These projects serve the beneficiaries by offering access to civic facilities and creating employment opportunities.

4.7.4 Sustainable Environment Management Programme (SEMP)

Sustainable Environment Management Programme (SEMP), the largest UNDP programme in Bangladesh and the first follow-up activity in the implementation of the National Environment Management Action Plan (NEMAP), began in October 1998 and should conclude in December 2006. Executed by the Ministry of Environment and Forest (MoEF), SEMP is being implemented by 21 Sub-Implementing Agencies (SIAs) through a UNDP US$26 million grant.

The objectives of SEMP are to build and strengthen capacity for environmental management at:

- community level – enable the poor to have access to environmental resources,
- local level – develop capacity to project the interests of the poor, and
- national level – suggest enactment of supportive laws, polices, etc.

Along with these, SEMP also aims to:

- prevent and reverse the present trend of environmental degradation,
- promote sustainable development, and
- reduce existing poverty and improve the quality of life.

As an important component of SEMP, a programme on ecosystem management in the Barind Tract was designed to improve its dry and degraded ecosystem through community-based sustainable environmental activities. The Environment Management Action Plan for the Barind Area, designed to combat desertification and support environmental awareness, social mobilization and motivation activities, is yet to be implemented by the civil society bodies, research organizations and NGOs.

SEMP has a component of ecosystem management in the Barind Tract and BMDA has been entrusted with the responsibility of implementing the same. The main objectives of the programme are:

- ensure pilot intervention on eco-system management,
- conserve the soil and water in areas inhabited by poor and distressed people,
- combat aridity through massive afforestation with indigenous plant species,
- develop awareness among rural women of ecological activities and improved fuel use,
- introduce the eco-village concept to raise local awareness of the need to take care of ecosystems,
- prepare the Barind Environment Management Action Plan (BEMAP) to identify new, innovative activities.

Three districts of Rajshahi, Naogaon and Nawabgonj, comprising 25 upazillas of the Barind Tract, are covered under the programme. However, the activities are concentrated in the high Barind Tract. The following works were undertaken on pilot basis:

- soil conservation, afforesation and a pilot programme on soil health,
- conservation, through demonstration, of organic manuring and compost preparation.

In rural areas, the farmers usually keep their manure yards open and, as a result, the nutrient content is leached out. Thus, in a few selected villages, steel-framed manure sheds with asbestos sheet roofing were constructed on private land to demonstrate how to improve quality of the homestead manure yard. Green manure was demonstrated by supplying *dhaincha* (sesbania) seeds to model farms at no cost. There were also demonstrations of composting. Current afforestation activities of the Forestry Department, NGOs and even the BMDA are confined to fast-growing, often exotic, species. However, there is also a need for trees to provide food and shelter for the local birds. Thus, contractors have been engaged to plant the samplings. In addition, as per the procedures followed in BMDA's main programme, the project has employed local people in need, especially women, for the purpose. The maintenance period will be two to three years, depending on the growth of the saplings.

In general, the SEMP mandate is to work in these areas.

- ***Re-excavation of ponds –*** When land is identified, the new excavation will be done if the owner allows the community to use it for at least seven years. Work is undertaken in areas of extreme poverty and in villages with no ponds.

- ***Canals*** – Natural canals with potential for water conservation, irrigation, etc., have been chosen for re-excavation.
- ***Water control structures*** – Low cost water control structures of appropriate design have been built across the re-excavated canals. They conserve water that can be used for supplemental irrigation of rain fed paddy and for low water consuming crop cultivation. In addition, the water in the storage section of the canal can be leased out for cultivation of fish and ducks and for supplemental irrigation.
- ***Mini ditches:*** In 2000, a 2 m-deep mini ditch (5m x 5m) was excavated on private land as a demonstration for farmers with no source of irrigation. The mini ditch/pond can be used to harvest rainwater for use as supplemental irrigation.

Demonstrations of improved fuel use for women in rural areas and introduction of renewable energy through construction of biogas plants were also provided. In areas where the Local Government Engineering Department (LGED) constructed biogas plants, the programme covered the costs that were to be paid by the farmers, if necessary. Similarly a pilot demonstration of solar-based home lighting was given in selected villages to introduce the eco-village concept of organizing communities to develop awareness among the poor – especially poor women – of ways to fight environmental degradation.

Activities such as supplying potable water, sanitation, horticulture, manure management, biogas plants, solar lightening, homestead gardening and afforestation have been implemented. The following works also have been carried out:

- sustainable environmental initiatives,
- components of the Barind Environmental Action Plan not undertaken by BMDA,
- training in efficient fuel use and introduce renewable energy.

4.7.5 Institutions targeting livelihood development to improve adaptive capacity

Community and household assets are influenced by the institutions, organizations, policies and legislation that shape livelihoods. Policies and institutions are an important set of human-made external factors that influence the range of livelihood options. The institutions and processes operating from the household to the national level and in all spheres, from private to public, determine access to assets, livelihood strategies and vulnerability to climate change-induced droughts. The sustainable livelihood framework describing the vulnerability context (climate change), livelihood assets, transforming structures and processes, livelihood strategies and outcomes is presented in Fig. 24.

Transforming structures and processes can reduce or worsen the impact of climate change on vulnerable people. These are organizations that set and implement policy and legislation, deliver services, purchase goods and perform many other functions that affect livelihoods. They determine the way structures and individuals operate and interact through setting policies, legislation and rules that regulate access to assets, markets, and culture and power relations in society.

Livelihood strategies consist of a range and combination of activities and choices that people make in order to achieve their livelihood goals. Operating within the vulnerability context, people choose and implement livelihood strategies under the considerable influence of policies, institutions and processes. These strategies include short-term considerations such as

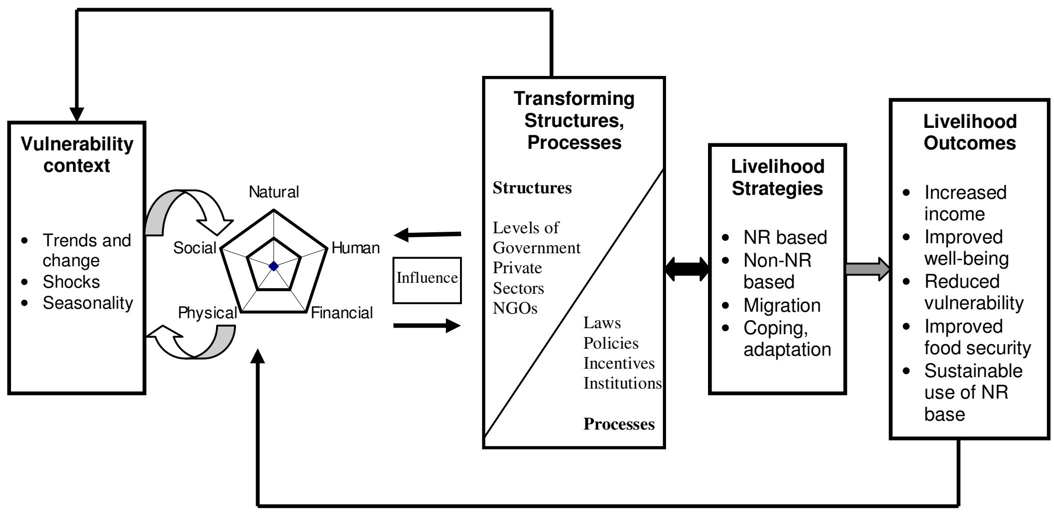

Fig. 24. Overview of the sustainable livelihoods framework (Carney, 1998)

ways of earning a living, coping with shocks and managing risk as well as aspirations for their children and for their own old age. The strategies may change rapidly in response to their vulnerability and the impact of policies and institutions. The local-level institutions, operating with a view to improve local adaptive capacity and livelihood development, are presented in Fig. 25. The figure identifies the existing institutions at local level but does not qualify their strengths and weaknesses in improving adaptive capacity. Success of these institutions in developing livelihood assets depends on needs-based development programmes and projects. Their very limited focus on climate change adaptation needs to be strengthened – through mainstreaming climate change adaptation into development.

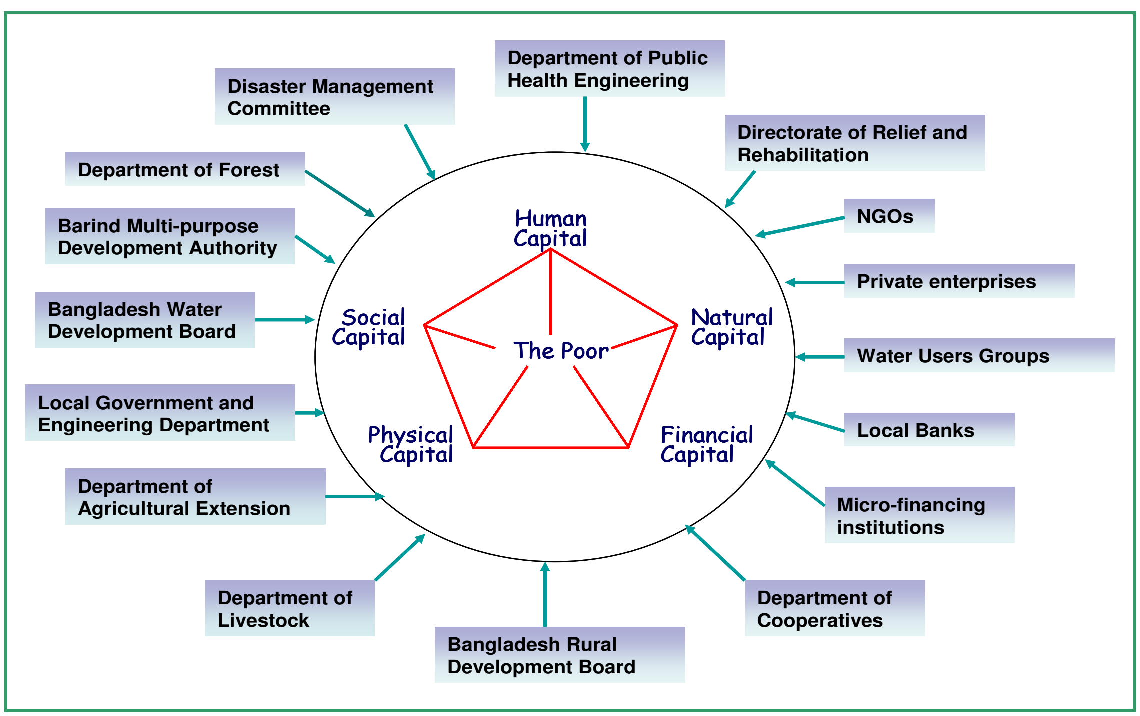

Fig. 25. Institutions targeting livelihood asset development at the local level

4.7.6 Institutional set-up promoted for local application of climate information products

Sustainable implementation of viable adaptation options depends heavily on disseminating climate information in a usable format. At national level, BMD generates weather and climate information relevant to drought risk management. Mass media plays an important role in disseminating weather and climate information to farmers, farmer groups and community associations at the local level. However, this information hardly allows the end users to make pro-active decisions, as it often is not properly packaged into easily understandable or usable formats. As for the horizontal flow of information at national level, only limited sharing of information takes place between BMD and DAE.

Available weather and climate forecast information products at national level need to be tailored to match local user's needs. The process of developing tailored products includes three sequential steps: i) translating global climate outlooks into local outlooks, ii) translating local climate outlooks into impact scenarios, and iii) communicating response options. However, because the current institutional and technical capacity within DAE is not sufficient to carry out all these tasks, a range of technical training activities were carried out by the project to improve the capacity of NTIWG and UTIWG members. A framework for climate information generation and application as introduced by the project is presented in Fig.26.

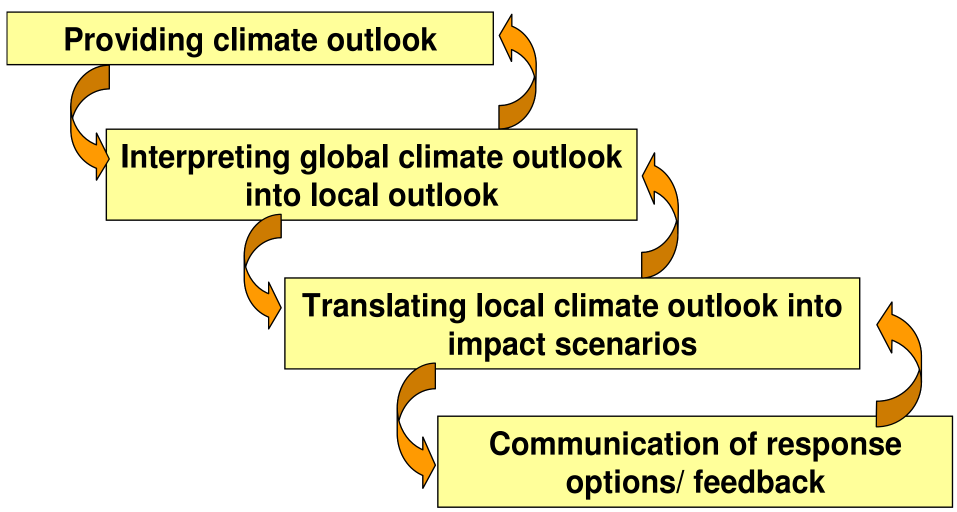

Fig.26. A framework for climate information generation and application system for climate forecast applications as promoted by the project

An institutional framework that can cater to development needs and dissemination of weather and climate information for drought risk management is set up during FAO project implementation (Fig.27). As for weather and climate forecasting, BMD would have main responsibility with input from its own monitoring networks and also from the networks available with BMD.

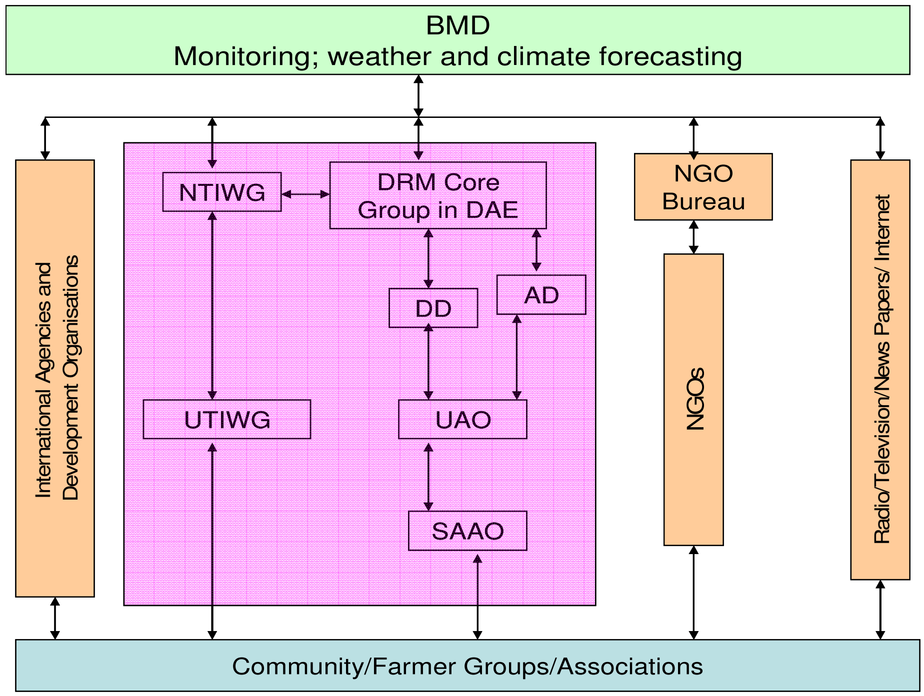

Fig.27. Institutional set-up for generation and application of weather and climate forecast products for drought risk management in Bangladesh

The capacities of the NTIWG and UTIWG have been enhanced to translate climate change modeling results into agriculture sector impacts and response options during the project period. The DRM core group within DAE consists of resource persons who can translate generic climate information into impact outlooks. Building and sustaining trust and credibility with the user is an essential element in communicating climate information. Therefore, the DMC members, SAAOs and other community representatives were introduced to climate information dissemination and application at local level. Decision support tools such as an alternative management plan can play an important role in providing context-specific information. Considerable efforts were undertaken to develop the technical capacity of working group members and DAE functionaries for interpreting and communicating climate information effectively. The training curriculum covered the following two major areas.

i) Climate risk and impact analysis:

- climate risk analysis tools and methods,
- climate change impacts, and
- local and introduced adaptation practices against climate risks.

ii) Climate forecast applications for drought management:

- introduction to probabilistic climate forecast information products,
- interpretation of climate information products with local data,
- translation of climate information into agricultural sector impacts (location specific impact outlooks),
- translation of impacts into locally relevant management options to mitigate drought impact,
- communication of forecast information to the users.

CHAPTER 5

ASSESING FUTURE VULNERABILITY AND CLIMATE RISKS

This section briefly reviews climate model projections of temperature and precipitation change in Bangladesh and addresses the major risks from climate change that Bangladesh may face in future. This is based on the significance of:

- climate change impact – a function of severity and importance of the affected resource,
- timing of impacts – likely to be (i) significant or noticeable in the first half of this century or (ii) not likely to happen until the latter half of this century, and
- certainty of impact – the relationship with climate change or the nature of the climate change itself.

Climate change scenarios were based on desktop analysis of the future climate change using GCM outputs and further developed incorporating local perceptions about climate impacts. The GCMs scenarios look at the possible future state of the atmosphere (climate) in the pilot study locations, considering major climatic parameters such as rainfall and temperature.

5.1 Developing climate change scenarios

5.1.1 Climate change scenarios based on GCMs

Scenarios of global climate change between 1990 and 2100 project an increase of 1.4-5.8° C in the average surface temperature of the earth, and a mean sea level rise of between 9-88 centimeters (IPCC, 2001a). A study conducted by SMRC (2000) on the monthly and annual mean maximum and minimum temperature in Bangladesh for a period of 30 years revealed a statistically significant increasing trend for annual mean maximum temperature, a slightly decreasing trend for annual mean temperature and slightly increasing trend of annual mean temperature. The climate change scenarios and potential effects of climate change on Bangladesh up to 2050, presented in Table 9, are based mainly on the climate change scenarios developed for 2030 and 2050 (Ahmed and Alam, 1998; World Bank, 2000) by using general circulation models (GCMs).

Table 9. Climate change scenarios for Bangladesh by 2030 and 2050 (World Bank, 2000)

Year	Sea level rise (cm)	Season	Temperature increase (ºC)	Precipitation fluctuation compared to 1990 (%)	Changes in evaporation (%)
2030	30	Monsoon	+ 0.7	+ 11	+15.8
		Winter	+1.3	- 3	- 0.9
2050	50	Monsoon	+1.1	+28	+16.7
		Winter	+1.8	-37	0

The magnitude of these climate changes may appear to be greater when these scenarios are combined with existing climate events, and could substantially increase the magnitude of disaster events and decrease their return period. For example, a 10 percent increase in precipitation could increase runoff depth by 20 percent (World Bank, 2000). Thus, within the planning horizon for development activities, it is possible that there could be a significant increase in the intensity and frequency of extreme events (both flood and drought) in Bangladesh.

An analysis carried out by Agarwala, *et al.* (2003) on changes in average temperatures and precipitation over Bangladesh based upon GCMs using MAGICC/SCENGEN is presented in Table 10. The spread in temperature and precipitation of the GCMs provides an estimate across various models for particular projections. More consistent projections across various models tend to have lower standard deviation, relative to the value of the mean. The climate models all estimate a steady increase in temperatures for Bangladesh, with little inter-model variance. More warming is estimated for winter than for summer.

Table 10. GCM estimates of temperature and precipitation changes (Agarwala, *et al.,* 2003)

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

Change in precipitation is a critical factor in estimating how climate change will affect Bangladesh, given the country's extreme vulnerability to water-related disasters. More than 80 percent of the 2 300 mm of Bangladesh's annual precipitation comes during the monsoon period. Most climate models estimate that precipitation will increase during the summer monsoon due to high summer temperature. The estimated increase in summer precipitation appears to be significant and is larger than the standard deviation across models. The climate models also show small decreases in precipitation during the winter months of December through February. The increase is not significant, and winter precipitation is just over 1 percent of annual precipitation. However, with higher temperatures increasing evapotranspiration combined with a small decrease in precipitation, dry winter conditions, even drought, are likely to be made worse.

5.1.2 Climate change scenario based on regional models

Several approaches are being used to develop regional-scale climate change scenarios at reasonable resolution. Though climate change scenarios are developed from GCMs, significant uncertainties remain when these scenarios are translated to smaller scale. Despite the capacity of the GCMs to predict climate, direct output from GCM simulations is largely inadequate for regional scale and site-specific applications. The coarse spatial resolutions employed by most GCMs filter out important sub-grid, regional-scale climate differences.

Techniques such as pattern scaling have been developed in order to overcome these difficulties and provide useful local-scale climate scenarios for impact analysis. A nested regional climate model (RCM), using boundary conditions forced by a parent GCM, has been used to increase the spatial resolution. In addition, statistical downscaling has also been used to establish empirical relationships between meso-scale variables and an observed climate–time series.

Providing Regional Climates for Impact Studies (PRECIS), the regional climate model developed by the Hadley Center in the United Kingdom, can be run on a personal computer and easily applied to any area of the globe to generate detailed climate change predictions. PRECIS has a horizontal resolution of 50 km with 19 levels in the atmosphere (from the surface to 30 km in the stratosphere), four levels in the soil, and can downscale to 25 km horizontal resolution.

In Bangladesh, PRECIS has been validated by a group of scientists coordinated by the DoE Climate Cell which is actively involved in the research, application and capacity-building component of the initiatives (DoE, 2005). The PRECIS regional model in Bangladesh was validated using the surface observational data of rainfall and temperature collected by BMD at 26 observation sites throughout the country from 1961 to 1990. Overall, PRECIS calculated about 92 percent of surface rainfall for selected locations. PRECIS can explain more than 96 percent variability in observed maximum and minimum temperature. In this scenario analysis, PRECIS results were not used for developing climate change scenarios as it required additional validation exercise.

In this study, daily outputs of HadRM2 for temperature were used to generate climate change scenarios. Two sets of HadRM2 were run: i) control (CTL) file with fixed greenhouse gas forcing of 1990 levels, and ii) perturbed with increasing GHG (1 percent compound, IS92a), corresponding to the period 2041-2060. The monthly maximum and minimum surface temperature were created for the pilot districts of northwestern Bangladesh. The scenarios for maximum January temperature indicate a possible temperature increase of about 1.5° to 2.0°C by 2050. The minimum temperature projection for January ranges from 2.8° to 3.5°C. In July, the maximum temperature is projected to increase by 1.4° to 2.0°C, while the minimum temperature would be greater by 2.5° to 2.7°C compared to control. The scenarios indicate a high level of increase for the future and that excess heat and related impacts during winter are certain.

5.2 Impact of future climate risks in drought-prone areas

In the future, it is likely that Bangladesh will suffer higher risks of drought. Geographical distribution of drought-prone areas under climate change scenarios shows that the western parts of the country will be at greater risk of drought during both pre-*kharif*, *kharif* and *rabi* seasons. Under a moderate climate change scenario, *aus* production would decline by 27 percent while wheat production would be reduced to 61 percent of its current level (Karim, *et al*., 1998). Moisture stress might force farmers to reduce the area under *boro* cultivation.

In case of severe drought, forced by a change of temperature by +2°C and a 10 percent reduction in precipitation, runoff in the Ganges, Brahmaputra, and Maghna rivers would be reduced by 32, 25 and 17 percent respectively (Mirza and Dixit, 1997). This would limit surface irrigation potential in the drought-vulnerable areas, and challenge national food security programmes. In this chapter, possible impact of climate change in drought-prone areas is reviewed and presented.

5.2.1 Agriculture

Nearly 75 percent of the Bangladesh population is directly or indirectly dependent on agriculture, with the agriculture sector contributing about 30 percent to the national GDP. Though declining, it is still the major GDP contributor and the main user of water. Agriculture's share in water demand will continue to increase with efforts to attain food security. Land, the most basic resource in Bangladesh, is the main factor in crop production. Presently, the country has about 8.5 million ha of cultivated land of which more than 7.85 million ha is under agriculture.

Foodgrain, particularly the rice crop, dominates the country's agricultural scenario with respect to both cropped area and production, claiming a 77 percent share. Thus, rice crop development has substantial impact on the sector's performance and food self-sufficiency. There has, however, been a shift in the composition of agriculture during the past few years with a gradual decline in crop agriculture and increase in non-crop agriculture (NCA), which consists of livestock, fisheries and forestry.

Of the net cultivable area, 37 percent is single cropped, 50 percent is double cropped and 13 percent triple cropped. The three cropping seasons coincide approximately with the three meteorological seasons: *kharif* I (pre-monsoon), *kharif* II (monsoon) and *rabi*. *Aus*, *aman* and *boro* are the three main rice crops. The area and production of major cereals is given in Table 11.

Aman is the leading rice crop, occupying about 56 percent of the total area under rice, followed by *boro* (27 percent), and *aus* (17 percent). The pattern of growth in crop agriculture during the past two decades has seen an increase in the area covered by dry season HYV *boro* rice (DAE, 2006).

Table 11. Crop statistics of major cereals (2004-2005)

Crop	Area ('000 ha)	Average yield (mt)	Current production ('000 tonnes)
HYV Aus	451	1.91	862
HYV *Aman*	2 906	2.30	6 693
HYV *Boro*	3 876	3.47	13 446
Other rice	3 136	1.32	4 156
Rice total	10 369	2.42	25 157
Wheat	558	1.74	976

During the last 15 years, average farm size has declined, with per capita cultivated area decreasing from 0.10 ha in the mid-1980s to only 0.06 ha in the late 1990s (BBS, 2001). Continuous utilization of land without proper replenishment, land degradation and decline in soil fertility has lowered land productivity. In spite of all these adversities and need to feed increasing populations, transformation in agricultural practice is remarkable. At present, more than 62 percent of the land is covered by high yielding varieties. The introduction of HYV rice and the expansion of irrigation have both contributed to increasing foodgrain production by more than 25 million metric tonnes, bringing Bangladesh to a level of self-sufficiency. The challenge now is to retain that self-sufficiency in spite of the risk factors in agriculture and the predicted change in climate. With climate change, food security will be further threatened, as intensification has already taken place.

Changes in both the mean and variability of climate, whether naturally forced or due to human activities, pose a threat to crop production globally (Slingo *et al*., 2005). It is clear that climate change will seriously affect total agriculture production in general and the crop subsector in particular. With the rise in the CO_2 level, positive fertilization effect will occur but the rise in temperature will suppress the yield. Thus, in order to derive the desired benefit, the interaction of CO_2 and temperature has to be synchronized with the choice of crop cultivars.

Attempts have been made to clarify the vulnerability of climate change and its impact on agriculture in terms of yield sensitivity and also in terms of agro-environmental degradation. Aggregated rice and wheat yield show positive fertilization effects with a CO_2 rise but it does not sustain – it lowers with the rise in temperature. Almost all the model results on climate change projections indicate a significant temperature increase in both monsoon season and winter. Considering that in the future, temperature increase may coincide with drought indicates that yield reduction, at least in drought-prone regions, is inevitable.

Agricultural drought refers to a condition when the moisture availability at the root zone is less than adequate. Transplanted *aman* cultivation suffers from periodic drought conditions during *kharif* II season, as the crop depends mostly on rainfall throughout the growth period. Similar conditions often affect *boro* in early pre-*kharif,* and wheat cultivation in the northeast and central-east regions of the country in *rabi*. With the change in climate, significant change in the present drought classes has been observed through model output and is shown in Table 12 (Karim and Iqbal, 1997; MoEF, 2002). It has also been found that dry season drought affects the production of wheat, potato, mustard and *aus* paddy. Drought-related impacts may be countered either by supplementary irrigation for the *kharif* or ensured irrigation for the *rabi* and pre-*kharif* crops.

Table 12. Changes in area (km^2) under different drought classes due to climate change scenarios (CCS)

Drought classes	Climate change scenarios (CCS)				
	Existing	CCS-1	%	CCS-2	%
Very severe	3 639	8 636	+ 137	12 220	+ 236
Severe	8 581	10 874	+ 27	15 303	+ 78
Moderate	32 847	30 381	- 7.5	25 465	- 22
Less Moderate	14 571	9 747	- 33.1	19 814	+ 36
Slight	43 524	43 524	+ 0	30 360	- 30

5.2.2 Water resources

In Bangladesh, the largest need for both surface and groundwater is to support irrigation in the dry months. However, the national water policy gives this sector a relatively low priority and sets the following order for water allocations during critical periods: domestic and municipal uses, non-consumptive uses (navigation, fisheries and wild life), sustenance of river regime, and other consumptive and non-consumptive uses including irrigation, industry, environment, salinity management and recreation. It has been predicted that by 2018, demand for irrigation may reach 58.6 percent of the total supply while demand for other uses is estimated to reach 40.7 percent for navigation, salinity, and fisheries, and 0.7 percent for domestic and industrial use.

Change in water supply and demand caused by climate change will be overlaid by changing water use due to growth of population and income. Currently, Bangladesh withdraws 22 500 million m^3 of water annually. The total requirement for water consumption in 2020 will be 24 370 million m^3 and supply will be 23 490 million m^3. Thus, there would be a shortage of 880 million m^3. Agriculture is estimated to constitute 58.6 percent of demand; navigation, salinity and fisheries 40.7 percent, and municipal and industrial demand 0.7 percent. It is also estimated that about 77 percent of annual water supply comes from surface water sources.

Box 2:
Climate Change and Drought

Based on climate change scenarios and projections, it can be concluded that Bangladesh will be at risk from droughts. A geographical distribution of drought-prone areas under climate change scenarios shows that the western parts of the country will be at greater risk of droughts, during pre-*kharif,* pre-*kharif* and *rabi* seasons. Moisture stress might force farmers to reduce the area for *boro* cultivation.

In case of a severe drought, forced by a temperature change of +2°C and a 10 percent reduction in precipitation, runoff in the Ganges, Brahmaputra and Meghna rivers would be reduced by 32, 25 and 17 percent respectively (Mirza and Dixit, 1997). This would limit surface irrigation potential in the drought-vulnerable areas and challenge the Bangladesh food self-sufficiency programmes.

With climate change, availability of surface water during monsoon will increase, whereas in winter, water availability will decrease and more water will be required for irrigation. Irrigation will be more dependent on groundwater withdrawal. Under that condition, it would be quite difficult to control salinity intrusion, maintain navigation and ensure environmental and ecological harmony in various places. Stream flow decrease will largely affect the river ecosystem.

5.2.3 Crop water requirement

It has been predicted that there will not be much change in crop water requirement in the future. Though the temperature projections show an increasing trend, the positive effect of CO_2 increase may offset the water use efficiency of crops. However, there are two overriding factors that will influence the crop water requirement substantially: i) increased maximum and minimum temperature and ii) reduced or highly variable surface water availability.

5.2.4 Inland capture fishery

The management and culture of brood stocks of indigenous carp, snakeheads and other important species would be difficult under climate change conditions. Introduction of alien species in the open waters should be stopped immediately as it is a futile and illogical endeavor. Food chains and food webs and their variability in the winter and summer in the aquatic ecosystems have to be elucidated and guidelines formulated for action in case of future temperature rise.

The alien carp introduced in Bangladesh are from cold water and high latitude countries and will never breed naturally in Bangladesh. In the case of only a 2°C rise in temperature, their growth would become retarded. Therefore, the support being provided these endeavors now in Bangladesh should be withdrawn as early as possible so that they vacate their niche and allow native species to occupy them, without unnecessary and unwanted competition.

Improvement of native indigenous carp stock is a must. If necessary, improved stocks from neighboring countries should be imported with sanctuaries established in rivers and *haors* (low-lying water basins) to grow brood stocks of these species. The sanctuaries should be protected properly with due vigilance. Elucidating the biology, including food chains, of small indigenous fish species should be a priority. They should be encouraged in close water culture and in open waters. They would be very suitable for ponds in drought-prone areas.

5.2.5 Livelihood strategies

Crop cultivation in the Barind Tract was once dominated by various drought tolerant crops. Crops such as wheat, sweet potato, potato, mustard, sesame, pulses such as lentils and black gram, and spices such as onion, garlic, ginger and turmeric were also grown. Today, due to the introduction of deep tubewells, rice is the main crop grown in the area. Hybrid rice varieties have been introduced, many from neighboring villages of India. The same with vegetables that traditionally were grown at the household level for household consumption. Now, with the introduction of commercial vegetable-cultivation, more people are taking up vegetable production. Poultry production was almost entirely home-based, but now commercial poultry production is beginning to be seen. In the past, fishermen fished in the rivers and in low-lying swamp areas. Now, the low-lying areas are used for *boro* rice cultivation wherever water is available and fishermen are now more involved in fish trading than fishing. Due to changes in the resource base, many activities that were most relevant to poorest of the poor are disappearing. There were many risk management non-farm activities, but now they are becoming less common. In the future, climate change may push these practices further out of context and may create unemployment-related problems. The livelihood activities followed by men in the Barind area villages are listed in Table 13.

Table 13. Change of livelihood portfolios among rural men

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

Women's economic activities depend on their socio-economic status, with women from landless households and female-headed households most likely to be engaged in economic activities. The range of economic activities undertaken by women at present and in the past are presented in Table 14. Husking, boiling and selling paddy at the local market once was a prime source of women's employment, but the introduction of rice mills ended this employment opportunity. With the introduction of commercial vegetable cultivation, women and young children who used to help harvest in return for vegetables now do so for money. After collecting the harvest, good vegetables are sold at markets while infected or bad quality vegetables are distributed among those who helped with the harvest. Similarly household-level economic activities such as pottery and cocoon rearing have disappeared in recent time. It is difficult to predict how livelihood activities will change in the future but it is certain that, based on the type of anticipated impacts in drought-prone areas, there will be a change in livelihood patterns.

Table 14. Changes in livelihood portfolios among rural women

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

CHAPTER 6

OPTION MENU FOR LIVELIHOOD ADAPTATION TO CLIMATE VARIABILITY AND CHANGE

6.1 Assessment and synthesis of adaptation options

The livelihood adaptation options to climate variability and change in drought-prone areas were identified based on the general typology of options and overall resource availability in the Barind Tract. Though the Barind Tract is drought prone and future climate change could aggravate the problems, there are many positive aspects that can be considered for selection of viable adaptation options.

Table 15. Categories of adaptation options and their sources

Sl. No	Categories	Adaptation practice	Source
1.	Agronomic management	Seedbed method for T.*Aman* rice	Farmers + experts
2.		Manures and composting	Farmers
3.		Depth of transplanting for T.*Aman*	Farmers
4.		Weed control-reduce water seepage	Farmers
5.		Manual closing of soil cracks	Farmers
6.		Strengthening field bunds (Ail lifting)	Farmers
7.	Water harvesting	Re-excavation of traditional ponds	Farmers
8.		Re-excavation of khari canals	BMDA
9.		Canals	Farmers
10.		Water control structures	BMDA
11.		Miniponds	BMDA
12.		Supplemental irrigation	Farmers/ DAE
13.	Water resources exploitation	Shallow and deep tubewells	BMDA
14.	Water use efficiency	System of rice intensification	Experts
15.		Direct sown rice (drum seeder)	Experts
16.		Drought resistant rice varieties	Multiple sources
17. a)	Crop intensification	Green Manure – T.*Aman* system	Farmers
b)		*T. Aus* – Chini atap system	Farmers
c)		*T. aman* – Mustard/linseed system	BARI/ BRRI
d)		*T. aman* – Chickpea	BARI/ BRRI
e)		*T. aman* – Mung bean	DAE
d)		Famine reserve crops	Experts
18.	Alternate enterprise	Mango cultivation	Farmers
19.		Homestead gardens	BARI
20.		Mulberry intercropping in rice	BRRI
21.		Fodder cultivation	DoL
22.		Fish cultivation in miniponds	DoF
23.		Cottage industries	Community
24.		Manufacturing industries	Community
25.	Alternative energy source	Community based biogas and tree planting	Experts
26.	Post harvest practices	Seed storage for higher viability	Farmers

Table 15 provides a list of adaptation practices, collected through community-level participative discussions with various sources, found most adaptation practices are related to agriculture and its allied sectors because that is the livelihood source of the majority of the population. The sources included farmers, villagers, community leaders, key local contacts, local institutions, and research and development organizations.

6.2 Typology of adaptation options

6.2.1 Increased crop productivity and food security

Bangladesh is highly sensitive to climate variability and change impacts on the agriculture sector. Considering its agriculture-based subsistence economy and the fact that the sector employs almost two thirds of the population, adaptation to climate change impacts will be vital to achieving sustainable development. The key risks from climate change to agriculture and allied sectors in northwestern Bangladesh are related to increased drought frequencies (*kharif* II) and inadequate availability of water for irrigation (*rabi*). Agriculture depends on freshwater resources and, thus, depends on the success of adaptations in that sector. Moreover, the agriculture sector has the difficult task of meeting the ever increasing demand for food.

The agriculture sector must have increased productivity if agriculture is to remain a source of employment and a key element of economic development. Crops need to be diversified and, thus, less vulnerable to changes in market conditions and climate. Adaptation practices related to new cropping systems involving drought resistant crops will benefit the sector as a whole. In fact, with successful adaptation, the production of major crops would not be threatened by climate change. The agronomic management practices suggested in Table 16 would improve the productivity of crops under climate change conditions.

6.2.2 Improved irrigation efficiency

Success of climate change adaptation depends on availability of fresh water in drought-prone areas. It should be emphasized that most adaptation methods provide benefits even with the lower end of climate change scenarios, such as improved irrigation efficiency or strengthening the extension services to farmers. Irrigation efficiency and water productivity can be improved by practicing innovative cultivation methods such as the system of rice intensification (SRI), direct-sown rice culture and modern drought resistant varieties. Physical adaptation measures to reduce drought impact on agriculture will mainly focus on improved irrigation efficiency (*boro*), crop diversification (*kharif* II and *boro*), rainwater harvesting (*kharif* II), and use of surface and groundwater for supplemental irrigation (*kharif* I and II).

As water becomes a limiting factor, improved irrigation efficiency will become an important adaptation tool especially in *boro* season, because irrigation practices for boro are water intensive. In that respect, SRI and direct sown rice will be highly beneficial. Climate change is expected to result in decreased fresh water availability (surface and groundwater) and reduced soil moisture during the dry season (*boro*), while the crop water demand is expected to increase because of increased evapotranspiration caused by climate change and the continuous introduction of high-yielding varieties and intensive agriculture in the Barind Tracts.

Although the technical and financial feasibility of such adaptation is promising, it might require adequate training and extension (institutional support). Poor dissemination of these techniques and the weak financial capabilities of the farmers may prove to be the limiting factors in this case. Various forms of water pricing are already in practice in the BMDA irrigation schemes, however it will need to be re-visited in the near future as the water pricing is very low and charged by the hour, not by volume (discharge rate is about 55 litres per second and approximately US$1 per 150 m^3).

Promoting optimal use of both surface and groundwater also may be a possible adaptation although only when applied with great care. In terms of groundwater usage, some areas are already under threat of over-abstraction. Availability of groundwater is therefore a very pertinent question and it is necessary to know the rate of groundwater re-charges and at what level extraction exceeds re-charge**.** Indiscriminate proliferation of deep tubewells has had detrimental effects on afforestation programmes in the Barind Tract. However, such measures could be investment intensive and often are not environmentally friendly, indicating they have medium feasibility.

6.2.3 Rainwater harvesting

There is significantly high rainfall variability in the drought-prone areas, with different types of seasonal droughts (initial, mid and terminal) posing major threats to rice production. Yet, often, high intensity rainfall is wasted due to non-availability of proper storage structures. Rainwater harvesting and recycling are essential to managing seasonal droughts through supplemental irrigation. Thus primary adaptation options need to be concentrated on rainwater harvesting, recycling and conservation. The feasible adaptation options at community level are excavation and re-excavation of traditional ponds and *khari* canals, water control structures and miniponds.

6.2.4 Crop diversification and intensification

Adaptation practices need to target *T. aman* rice, the most important and predominant crop in the Barind Tract under rainfed situations. In non-irrigated, rainfed areas, cropping intensity is 100 percent (one crop in a year). Current activities revolve around the monsoon season and dependency on *T. aman* rice. However, adaptation options need to relate to increasing cropping intensity by adjusting practices and supporting efficient use of limited resources. Careful adjustment of cropping systems involving pulses and oilseeds would be highly useful for using residual moisture from the T.*aman* crop. The most suitable crops for exploitation of residual moisture after T.*aman* rice are mustard, chickpea and mung bean. These crops already are being grown in this region to a small extent. Efforts to intensify it further require careful analysis of rainfall patterns. Introduction of pulses and oil seeds in principally mono-cropped areas could increase the nutritional security of the local people. Introduction of green manure in the system just before T.*Aman* is also another feasible adaptation to improve the soil's water-holding capacity and nutrient content.

Emphasis on more drought-resistant crops in drought-prone areas should help reduce vulnerability to climate change. For example, wheat requires significantly less irrigation water compared to *boro* paddy. However, social acceptability of wheat is still very poor. Diversification towards high value crops is feasible in the medium to long term. Growing mango in the Barind Tract, a kind of autonomous adaptation, shows long-term promise. Growing crops or varieties that are relatively less water-intensive could also be considered in this context. Overall, crop diversity is a high priority adaptation measure in both irrigated and non-irrigated areas. However, because of the traditional high dependence on rice, it will be a slow process.

6.2.5 Alternative enterprises

The Barind Tract offers many opportunities to promote alternative enterprises able to withstand the shocks due to droughts. Promotion of alternative enterprises helps increase overall household income as a drought risk management strategy. It minimizes the impact of drought through stabilization of year-round income from one source even if all other sources fail due to drought. This can include promoting such enterprises as economically viable livestock management, fisheries, sericulture and homestead gardening. Alternative enterprise will also help reduce the internal and temporary migration during the *monga* (seasonal famine) season.

6.2.6 Institutional focus on adaptation options

Measures to reduce drought impact may consider such options as development of drought-tolerant crop varieties and training and extension, and expanding access to credit. More efficient water use also can be stimulated through new cultivation techniques. A promising approach could be found through community-based adaptations rather than regulations, i.e. the community should decide on how to share limited common resources such as water from traditional ponds.

Development of drought-tolerant crop varieties could be stimulated by the National Agricultural Research System (NARS). Once the desired varieties are developed and tested in the fields, there should be a strong follow-up training and extension programme to disseminate the developments. BARI and BRRI have shown keen interest in demonstrating the suitability of BRRI 32 and BRRI 39 varieties. These short-duration varieties would provide the time opportunity for cultivating *rabi* crops such as mustard, chickpea and mung bean. Institutionally, these adaptations are feasible but success will depend on dissemination of information about new and improved varieties, as well as community preference and whether they are appropriate for the growing environment in terms of soil type, climate, pests and diseases.

Various adaptations concerning changes in agricultural practices are required. These adaptations include: direct sown rice, reduction of turnaround time after *T. aman* harvest, dry seedbed method, *ail lifting*, growing vegetables in field bunds, etc.

Although such methods for managing drought are known in the research community, farmers have little awareness of their existence. It will be necessary to disseminate these ideas among the farmers through the existing network of the Department of Agriculture Extension (DAE).

6.2.7 Financial and market risk management

Success of adaptation practices depends on access to credit, especially for the vulnerable population including small farmers and wage labourers. Access to credit requires institutional support and is a high priority for the agriculture and allied sectors. As new practices and crops evolve, additional investment costs and institutional support will be necessary. Guidelines also are needed to incorporate climate change in long-term planning with sufficient credit facilities. Though a stable market system is evolving in response to autonomous adaptations such as mango cultivation, it will require solid institutional support for the adaptation practice to continue. Establishment of cold storage facilities, processing industries and packaging are the types of requirements that must be met if local people are to stabilize their adaptation practices.

6.2.8 Household level income generating livelihood activities

Household-level income-generation activities identified during this study have potential to integrate women into the implementation of adaptation practices. Some of the household-level income-generation activities are: pottery, bamboo work, weaving, woodworking, manual oil-grinding, making hand fans and rearing silk worms.

Sustainability of these household-level, income-generating adaptation practices depends on availability of raw materials. Thus, proposed adaptation options include activities such as afforestation, and introduction of mulberry cultivation and annual crops such as mustard that take advantage of residual moisture from previous crops.

6.2.9 Processing/manufacturing industries

There is potential to strengthen the few processing and manufacturing industries already in operation in the region by providing institutional support. Those that have potential within the scenario of climate change impacts are related to processing of rice husks, rice brand oil, flour mills, mango pulp and oil mills. These industries also could provide adequate employment opportunities to the local population.

6.3. Validation of adaptation options

In evaluating the documented adaptation practices their technical aspects and practical field-level suitability for the Barind Tracts, the project formed technical implementation working groups at national and upazilla levels to assess, analyse and evaluate adaptation options. The National-level Technical Implementation Working Group (NTIWG) and Upazilla-level Technical Implementation Group (UTIWG) members were engaged in the evaluation sessions. Additional evaluation members included experts from Bangladesh Meteorological Department (BMD), Department of Environment (DoE), Space Research and Remote Sensing Organization (SPARSO), North South University of Bangladesh, Department of Relief, Department of Livestock, Department of Fisheries, Comprehensive Disaster Management Programme (CDMP) and UNDP. The outcome of the sessions led to preparation of an adaptation option menu and demonstration strategies. The summary table (Table 16) provides the list of adaptation options and experts' comments on each adaptation practice.

Table 16. Categories of adaptation options and their sources

Sl. No	Categories	Adaptation practice	Experts' comments
1.	Agronomic management	Seedbed method for T.*Aman* rice	The practice would be viable under climate change scenarios of the future as rainfall is expected to show higher variability.
2.		Manures and composting	The compost can be applied in the pit surrounding mango plants. The expert group discussed large-scale availability of water hyacinth for such demonstrations. The other raw material can also be used.
3.		Depth of transplanting for T.*Aman*	The practice is suitable but very difficult to implement under field conditions.
4.		Weed control, reduce water seepage	The practice is useful, but labour intensive.
5.		Manual closing of soil cracks	The practice is useful and may be taken as information and need not be demonstrated.
6.		Strengthening field bunds (Ail lifting)	The practice of *ail* lifting is highly useful in non-irrigated areas and is cost effective.
7.	Water harvesting	Re-excavation of traditional ponds	Careful evaluation needs to be done in consultation with department of fisheries.
8.		Re-excavation of *khari* canals	The *khari* canals are useful to enhance the yield of T.*aman* crop. DAE is interested in developing these structures. Information about number of such canals needs to be documented.
9.		Canals	Possibility of excavating new canals in non-irrigated areas may be assessed.
10.		Water control structures	Evaluation and feasibility need to be conducted.
11.		Miniponds	The optimal size for the small farmers in the region is 5m x 5m x 2m.
12.		Supplemental irrigation	It is a good practice to avoid intermittent drought during T.*aman* cultivation.
13.	Water resources exploitation	Shallow and deep tubewells	Possibility of extending the deep tubewell scheme for non-irrigated areas may be explored.
14.	Water use efficiency	System of rice Intensification	The SRI practice may be demonstrated during *boro* season.
15.		Direct sown rice (drum seeder)	The direct sown rice cultivation is a useful technique for *kharif* II season to reduce the water requirement and to reduce main field duration.
16.		Drought resistant rice varieties	Drought-resistant short-duration rice varieties are highly useful for the Barind region.
17. a)	Crop inten-sification	Green Manure – T.*Aman* system	The practice can improve water storage capacity of the soil and nutrient enrichment.
b)		T. Aus – Chini atap system	Improved cropping intensity and household income; new export opportunities.
c)		*T. aman* – Mustard/ -inseed system	The practice can increase the cropping intensity and improves the nutritional security
d)		*T. aman* – Chickpea	The practice can increase the cropping intensity and improves the nutritional security and soil fertility.

Sl. No	Categories	Adaptation practice	Experts' comments
e)		*T. aman* – Mung Bean	The practice can increase the cropping intensity and improves the nutritional security and soil fertility.
f)		Famine reserve crops (yams and Cassava)	Needs to be included in the homestead area to facilitate effective utilization of available resources.
18.	Alternate enterprise	Mango and jujube cultivation	Mango cultivation is an automatic adaptation practice in the region. Drought-resistant, stable mango varieties may be identified and disseminated to the local people. The private mango seedling growers need to be advised about these latest varieties. Jujube cultivation need to be encouraged.
19.		Homestead gardens	Suggested to develop model demonstration plots including the homestead garden model developed by BARI.
20.		Mulberry intercropping in rice	The practice is not prevalent in the pilot upazillas and hence suitability may be assessed.
21.		Fodder cultivation	The practice is highly suitable for non-irrigated areas.
22.		Fish cultivation in mini-ponds	The practice needs to be demonstrated in both irrigated and non-irrigated areas
23.		Cottage industries	All possible practices and livelihood strategies needs to be documented.
24.		Manufacturing industries	All possible manufacturing industries may be documented and assessed for their suitability.
25.	Alternate energy sources	Community-based biogas plants and tree planting	Suitable tree species may be identified and proposed for policy advocacy.
26.	Post harvest operations	Seed storage bins	Suitable technology and gender integration would be ensured.

Based on expert comments and initial evaluation process, a number of adaptation practices were short-listed for demonstration at field level, giving high priority to adaptation practices under these overall thematic areas:

- rainwater harvesting and recycling,
- alternate livelihood activities,
- improving water-use efficiency, and
- crop diversification and intensification in drought-prone areas.

However, to ensure objectivity of the evaluation process, the adaptation practices are further prioritized based on a criteria-based approach.

6.4 Criteria based prioritization

The adaptation options evaluated by the technical implementation working groups were prioritized based on several criteria. Of the 16 criteria included in the prioritization process (Table 17), most were related to drought mitigation potential, suitability and sustainability under future climate change conditions, relevancy to vulnerable communities, employment opportunities, gender integration and social acceptability.

Table 17. Adaptation option menu and acceptability ratings for each criterion

Sl. No	Adaptation practice	Prioritization criteria (its explanation is given in section 2.4)															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.	Seedbed method for T.*Aman* rice	Green	Green	Green	Green	Blue	Green	Green	Orange	Orange	Orange	Green	Orange	Green	Blue	Orange	Green
2.	Manures and composting	Blue	Green	Green	Green	Blue	Green	Blue	Blue	Orange	Blue	Blue	Orange	Blue	Blue	Orange	Green
3.	Depth of transplanting for T.*Aman*	Orange	Blue	Green	Blue	Orange	Orange	Orange	Orange	Orange	Blue	Orange	Orange	Blue	Orange	Orange	Orange
4.	Weed control-reduce water seepage	Blue	Blue	Green	Blue	Blue	Orange	Blue	Orange	Orange	Blue	Blue	Orange	Blue	Orange	Orange	Orange
5.	Manual closing of soil cracks	Blue	Blue	Green	Blue	Orange	Orange	Orange	Orange	Orange	Blue	Blue	Orange	Green	Orange	Orange	Orange
6.	Strengthening field bunds (Ail lifting)	Blue	Blue	Green	Green	Blue	Blue	Blue	Orange	Orange	Blue	Blue	Orange	Green	Orange	Orange	Green
7.	Re-excavation of traditional ponds	Green	Green	Green	Green	Blue	Green	Blue	Orange	Blue	Blue	Green	Green	Green	Green	Green	Blue
8.	Re-excavation of khari canals	Green	Green	Green	Blue	Blue	Green	Green	Orange	Blue	Blue	Green	Green	Green	Green	Blue	Blue
9.	Canals	Green	Green	Blue	Blue	Blue	Blue	Green	Orange	Orange	Blue	Blue	Blue	Blue	Green	Orange	Orange
10.	Water control structures	Blue	Blue	Blue	Orange	Orange	Blue	Blue	Orange	Orange	Orange	Orange	Blue	Green	Orange	Orange	Blue
11.	Miniponds	Green	Green	Green	Green	Blue	Green	Blue	Blue	Blue	Blue	Blue	Green	Green	Green	Green	Green
12.	Supplemental irrigation	Blue	Blue	Green	Blue	Blue	Blue	Green	Orange	Orange	Orange	Orange	Orange	Green	Blue	Green	Orange
13.	Shallow and deep tubewells	Green	Blue	Blue	Blue	Green	Blue	Green	Orange	Green	Green	Blue	Green	Green	Green	Orange	Orange
14.	System of rice Intensification	Blue	Blue	Green	Blue	Blue	Blue	Orange	Orange	Orange	Blue	Blue	Orange	Orange	Blue	Blue	Blue
15.	Direct-sown rice (Drum Seeder)	Blue	Blue	Green	Blue	Blue	Blue	Orange	Orange	Orange	Blue	Blue	Orange	Blue	Orange	Blue	Blue
16.	Drought-resistant rice varieties	Blue	Blue	Green	Blue	Blue	Orange	Blue	Orange	Orange	Orange	Blue	Orange	Green	Blue	Blue	Green
17. a)	Green manure – T.*Aman* system	Orange	Orange	Green	Blue	Blue	Orange	Blue	Orange	Blue	Blue	Blue	Orange	Blue	Orange	Orange	Blue
b)	T. Aus – Chini Atap system	Orange	Orange	Green	Green	Green	Blue	Blue	Blue	Blue	Blue	Blue	Orange	Green	Blue	Orange	Green
c)	*T. aman* – Mustard/Linseed system	Orange	Orange	Green	Green	Green	Blue	Blue	Orange	Blue	Blue	Blue	Orange	Blue	Orange	Blue	Blue
d)	*T. aman* – Chickpea	Orange	Orange	Green	Green	Green	Blue	Blue	Blue	Blue	Blue	Blue	Orange	Blue	Orange	Blue	Green
e)	*T. aman* – Mung Bean	Orange	Orange	Green	Green	Green	Blue	Green	Blue	Blue	Blue	Blue	Orange	Blue	Blue	Green	Green
f)	Famine reserve crops	Blue	Green	Green	Green	Green	Green	Green	Blue	Blue	Blue	Green	Orange	Green	Green	Orange	Blue
18.	Mango and jujube (ber) cultivation	Green	Blue	Green	Green	Green	Blue	Blue	Blue	Green	Blue	Blue	Orange	Green	Blue	Blue	Blue
19.	Homestead gardens	Blue	Blue	Green	Green	Green	Green	Green	Green	Green	Green	Blue	Blue	Green	Blue	Blue	Green
20.	Mulberry intercropping in rice	Green	Green	Green	Blue	Green	Green	Orange	Green	Green	Green	Blue	Blue	Blue	Orange	Orange	Orange
21.	Fodder cultivation	Blue	Blue	Green	Green	Blue	Blue	Blue	Green	Blue	Blue	Blue	Blue	Blue	Blue	Orange	Orange
22.	Fish cultivation in miniponds	Orange	Orange	Green	Blue	Orange	Orange	Blue	Orange	Orange	Blue	Orange	Blue	Blue	Orange	Orange	Orange
23.	Cottage industries	Blue	Green	Green	Green	Blue	Green	Green	Green	Green	Green	Green	Orange	Green	Green	Orange	Green
24.	Manufacturing industries	Blue	Green	Orange	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
25.	Community-based biogas and tree planting	Blue	Green	Green	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Orange	Blue
26.	Post-harvest seed storage	Blue	Green	Green	Blue	Blue	Blue	Green	Green	Green	Orange	Blue	Blue	Blue	Blue	Orange	Blue

Green – High; Blue – Medium; Orange - Low

Qualitative and objective assessment of adaptation practices through systematic methodologies yielded a viable adaptation menu. The adaptation practices (Table 18) were identified as viable and given high priority for future incremental action at community level to mitigate future drought impacts

Table 18. Assessment of Adaptation options for their effectiveness, current state and future prospects

Sl. No	Categories	Adaptation practice	Water availability situation	Effectiv-eness/ Feasibility	Current state of implementation &/or requirements for improvement	Priority for future incremental action
1.	Agronomic management	Seedbed method for T.*Aman* rice	Rainfed	High	Not existing	High
2.		Manures and composting	Rainfed and irrigated	Medium	Not followed widely due to non-availability of raw materials	Medium
3.		Depth of transplanting for T.*Aman*	Rainfed and irrigated	Low	Not tried yet	Low
4.		Weed control-reduce water seepage	Rainfed and irrigated	Medium	Followed only to control weeds; not to close soil cracks	Low
5.		Manual closing of soil cracks	Rainfed and irrigated	Low	Sometimes followed; but not widely practices as labour intensive	Low
6.		Strengthening field bunds	Rainfed and irrigated	Medium	Sometimes followed; but not widely practiced	Medium
7.	Water harvesting	Re-excavation of traditional ponds	Rainfed	High	Not followed regularly	High
8.		Re-excavation of *khari* canals	Rainfed	High	Needs social persuasion, policy advocacy, institutional support	High
9.		Canals	Rainfed	Medium	Implemented in places close to river	Low
10.		Water control structures	Rainfed	Medium	Some efforts met with limited success; needs community involvement	Low
11.		Miniponds	Rainfed	High	Poor dissemination; Needs institutional support	High
12.		Supplemental irrigation	Rainfed	Medium	Already practiced widely	Low
13.	Water resources exploitation	Shallow and deep tubewells	Rainfed	Medium	Implemented in many villages; but not in all villages	Medium
14.		System of rice Intensification	Rainfed and irrigated	Medium	Not widely practiced; but evaluated intensively; showed high level of yield increase and water saving	Medium
15.		Direct-sown rice (Drum Seeder)	Irrigated	Medium	Not practiced; cost intensive and weeding becomes a problem	Medium
16.		Drought-resistant rice varieties	Rainfed and irrigated	High	Not widely accepted by the farmers as they prefer traditional varieties; needs extra efforts to disseminate short duration drought resistant varieties so as to fit a residual crop after T.*Aman*	High
17. a)	Crop intensification	Green Manure – T.*Aman* system	Rainfed	Medium	Not practiced; dissemination is very poor	Medium

Sl. No	Categories	Adaptation practice	Water availability situation	Effectiv-eness/ Feasibility	Current state of implementation &/or requirements for improvement	Priority for future incremental action
b)		T. Aus – Chini Atap system	Rainfed	Medium	Practiced in one of the villages; needs wider dissemination	Medium
c)		*T. aman* – Mustard/Linseed system	Rainfed	High	Practiced in some places; needs further expansion; promising results expected	High
d)		*T. aman* – Chickpea	Rainfed	Medium	Followed in low Barind areas. Some research is required to identify high temperature tolerant chick pea varieties	Medium
e)		*T. aman* – Mung Bean	Rainfed	High	Not followed widely; DAE is advocating a short duration Mung Bean variety; promising results expected	High
f)		Famine reserve crops	Rainfed	Medium	Not practiced widely	Medium
18.	Alternate enterprises	Mango and Jujube (Ber) cultivation	Rainfed and irrigated	High	Already spreading widely; but needs some scientific intervention such as introducing drought resistant varieties; Jujube cultivation is not followed widely; requires institutional support	High
19.		Homestead gardens	Rainfed and irrigated	High	Followed occasionally; poor combination of crops. No structured model gardens with drought resistant crops	High
20.		Mulberry intercropping in rice	Rainfed	Medium	Not practiced in pilot areas; but is promising for the future in Barind areas; requires institutional support	Medium
21.		Fodder cultivation	Rainfed	High	Not followed due to lack of awareness; identification of drought tolerant fodder crop is required	High
22.		Fish cultivation in miniponds	Rainfed and irrigated	Low	Not practiced; water availability is very poor	Low
23.		Cottage industries	Rainfed and irrigated	High	Not systematically followed due to lack of institutional support	High
24.		Manufacturing industries	Rainfed and irrigated	Medium	Not systematically followed due to lack of institutional support	Medium
25.	Alternate energy source	Community-based biogas and tree planting	Rainfed and irrigated	High	Limited implementation, but needs to be promoted with institutional support	High
26.		Post-harvest practices	Rainfed	High	Limited use at local level	High

The practices listed below are considered priorities for future action although there are also other practices that have potential for future drought risk management.

- Promotion of alternative seedbed method for T.*Aman* rice to manage variability in rainfall pattern
- Re-excavation of traditional ponds to collect excess rainwater and to use as supplemental irrigation during intermittent drought at community level
- Excavation of miniponds to store rainwater and re-use during drought at farm level

- Cultivation of drought-resistant varieties of rice and other crops to improve the productivity and also increase nutritional security
- Crop intensification by adopting *T. aman* – mustard/linseed/mung bean cropping system to use the residual moisture after T.*aman* rice
- Promotion of mango cultivation to increase income and mitigate seasonal drought
- Establishment of model homestead gardens
- Cultivation of fodder
- Promotion of cottage industries as alternate income-generating activities
- Promotion of community-based biogas and tree planting in drought-prone areas
- Advocacy for post-harvest practices to maintain good quality seeds.

6.5. Description of adaptation practices

6.5.1 Seedbed method for T. aman rice

In the northwestern Barind Tracts of Bangladesh, summer monsoons starts in mid-June and end in the last week of September. Inter-annual rainfall variability is relatively higher compared to other parts of the country. Intra-seasonal rainfall variability in monsoon rainfall distribution often creates water scarcity situations at critical cropping stages. Delayed onset of rains shortens the length of growing period. Transplanted *Aman* is the major rice crop in Barind tracts under rainfed conditions. The crop is frequently affected by drought at different growth stages in varied intensities. Farmers start preparing seedbeds with the first rains in early June and transplant the seedlings in early July. Often transplanting is delayed by a month due to delayed monsoon onset, putting the crop under terminal drought in October/November. Under this situation, farmers require an alternative dry seedbed method so they can start producing seedlings in June/July, even if there is delayed onset of monsoon.

However, it is also recognized that the dry seedbed method poses difficulties such as:

- pulling seedlings is difficult under dry conditions and can require twice as much labour as a conventional wet seed bed,
- root systems can be damaged when pulling seeds, if soil moisture is insufficient.

The above deficiencies can be minimized by adopting a new dry seedbed preparation method. By adding more fine red earth, farmyard manure or compost, and sand, it is possible to produce healthy seedlings and reduce the damage.

Seedlings produced from dry seedbeds are known to have greater resistance to drought. Seeds are sown after a thorough ploughing of the soil and also covered with soil. This is different from the wet seedbed method in which the seeds are exposed. In addition, the roots of seedlings from dry seedbed are longer than those from wet seedbeds. Farmers have perceived that the seedlings from dry seedbeds can withstand dry spells of up to 12 rainless days compared to seven days for seedlings produced from wet seedbeds.

Timely transplanting of rice not only helps good crop establishment, it also increases the yield level. Generally farmers face many difficulties, such as inadequate water and irregular monsoons, in preparing prepare land properly and raising the seedlings at the proper time. These problems indirectly affect timely transplanting and reduce the yield. In order to overcome these problems, the techniques of establishing a rice nursery to raise mat-type seedlings in trays, dry seed beds and *dapog* nurseries have been developed.

a) Raising mat-type seedling in trays. With this method, seedlings are raised in 48 x 22 x 1.5 cm trays The quantity of soil required to fill one tray is 1.5 kg. Ten trays cover an area of 1 m^2 square meter of nursery. For one ha, 20 m^2 are required. With a seed rate of about 100 to 125 gm/tray, the seed rate for raising nursery for one ha is 25-30 kg. The procedure for raising nursery is as follows.

- Treat dry clean seeds with fungicides.
- Filled trays of 20 gm/tray with dry powdered soil mixed with organic manure.
- Fill trays with soil up to 10-12 mm depth.
- Spread the treated seeds uniformly in the soil and cover them with 2 to 3 mm of soil layer.
- Keep the trays need in a field that is clean, properly leveled and near a water source.
- Sprinkle the trays regularly with water. Initially one jerry can of water is sufficient to cover 1 m^2 of seedling trays. Water application depends on age of seedlings. Generally, 25-day-old seedlings are used for transplanting. Therefore, watering of trays is to be planned according to the transplanting schedule.
- Stagger sowing according to time of transplanting in the main field by manual transplanter.

The advantages of raising rice seedlings by this method over other methods are:

- seedlings can be prepared with less seed, water, labour and seedbed area,
- seedlings will be healthy and uniform in growth.
- uprooting of seedlings is very easy with less labour and cost involved,
- seedlings can be protected from drought.

The initial cost for the trays needed for adopting this technique comes to US$7.00 for raising enough seedlings for one *bhiga.* However, these trays can be used for more than ten years. Locally available trays can be used to reduce the cost.

Resources required:	plastic trays, soil and manure mixture and paddy seeds.
Potential maladaptation:	none.
Non-climatic benefits:	saving seeds, low water requirement, low labour costs for seedling establishment.

b) Dry bed method: This system of nurseries is prepared in dry soil conditions. Seedbeds of convenient dimensions are prepared by raising the soil to a height of about 5-10 cm. A layer of half-burnt paddy husk or saw dust could be distributed on the nursery bed mainly to facilitate uprooting. In this method, dry seed or seeds that just sprouted are sown in rows about 10 cm apart in the dry nursery bed. Random (broadcast) sowing should be discouraged as weed control is difficult. The site should be free of shade and should have irrigation facilities. Nursery area should be about 1/10 of area to be transplanted. Seed rate should be higher than for wet-bed (about 40 kg/ha) because the germination could be lower. Uprooting of seedlings should be done between 15 and 21 days after germination. The nursery should be without any moisture stress.

Resources required:	seed bed of convenient size, layer of half-burnt husk, paddy seeds.
Potential maladaptation:	high soil temperature before monsoon onset may reduce the germination percentage
Non-climatic benefits:	seedlings are short and strong, have longer root system than wet bed and are ready in 25 days.

c) Dapog method: Dapog nurseries can be located anywhere on a flat surface. However, if lowland paddy field is used, water supply/control should be very reliable. The area needed is about 10 m^2 for 1 ha of the transplantable land which is much smaller than conventional nurseries. Seed rate is about 125 kg/ha. Seed bed should be levelled with the centre slightly higher than the edges to permit water to drain off the surface. The surface should be covered with banana leaves with the mid-rib removed, polyethylene sheets or any flexible material to prevent seedling roots from penetrating to the bottom soil layer. Cemented floors can also be used for this purpose. Cover the seed bed with about 1/4" layer burnt paddy husk or compost. Sow pre-germinated seeds uniformly on the seed bed to a thickness of two to three seeds. Splash the germinating seeds with water and press down by hand or with a wooden flat board in the morning and afternoon for three to four days to prevent uneven growth. Too much watering should be prevented. More frequent irrigation is necessary if seeds are sown without the bedding. The nursery should be transplanted in 12-14 days after germination of seeds. The disadvantage of dapog seedling method is that the seedlings are very short meaning that the field must be very well leveled and free of water.

Resources required:	banana leaf, polythene sheet, paddy husk, manure and paddy seeds.
Potential maladaptation:	none.
Non-climatic benefits:	less area is needed and the cost of uprooting seedlings is minimal. Very young seedlings from dapog nurseries have less transplanting shock than the ones from other nurseries making them more suitable for short duration varieties.

6.5.2 Manures and composting

Farmers recognized that application of organic manures can improve fertility status and water-holding capacity of the soil. Preparation of composts from locally available materials is an age-old practice. However, availability of raw materials for preparation of organic manure is a major limiting factor. Water hyacinth (*Eichhornia crassipes)* is one of the locally available raw materials showing promise for the preparation of compost. Farmers in rainfed areas of the Barind Tract apply 20-30 monds (1 mond ~ 37 kg) of decomposed cow dung before transplanting. Application of organic manure increases water-holding capacity of soil. Soil applied with organic manure/compost can supply water for 11 or 12 days, even without rain, while soil without adequate organic manure holds water for 7 days in high Barind Tracts.

Abundance of water hyacinth in small traditional canals and ponds has been of greet concern to environmentalists, especially in tropical countries as it interferes with water flow. It also interferes with fishing, leading to reduction in fish yield. In Bangladesh, water hyacinth has been used as cattle feed, mulch and compost, energy sources and pollutant removers. Biogass production from water hyacinth is also common in many countries. Converting water hyacinth to organic fertilizer through a composting process provides a reason to remove it from the water supply and make positive use of it. Compost prepared with water hyacinth or locally-available organic matter can be applied to perennial crops such as mango to improve retention of soil water. Water hyacinth and domestic solid waste have been used as raw materials for composting by: collecting it from waste stabilization ponds and canals, chopping it to about 5 cm with a manual chopper, and spreading the pieces on a cement floor to dry in sunlight for three days.

It then can be mixed with domestic solid waste, taking care that it is organic and decomposable. The size of waste should be reduced to about 5 cm to meet the requirement of composting process.

Resources required:	water hyacinth and organic waste.
Potential maladaptation:	none.
Non-climatic benefits:	Improving soil fertility and moisture storage.

6.5.3 Depth of transplanting

Maintaining optimal depth at transplanting is very important for the *T.Aman* rice crop. Transplanting at a depth of 2.5 cm leads to production of more tillers than transplanting at deeper depth of 5 cm or more. It is generally perceived that planting at shallow depth could increase the yield compared to deeper transplanting because deeper planting reduces root development.

Resources required:	paddy seedlings.
Potential maladaptation:	none.
Non-climatic benefits:	improving drought resistance.

6.5.4 Weed control and reducing water loss

Rice must remain effectively weed free during critical stages such as active tillering and panicle initiation stages. Weeds generally are removed between 18 and 25 days after transplanting, depending on the weed population and soil moisture conditions. Sometimes farmers use a *kodal* (hand hoe) to remove the weeds, especially when the soil is dried and soil moisture reaches below saturation under extended dry spell. The practice of weeding and simultaneously closing surface cracks using a hand hoe is helpful to minimize the impact of drought and also consumes less water to break the drought after extended dry spells. Surface cracks consume more water as the water drains into the deeper layers quickly. It is perceived that 60 mm rainfall is required to close surface cracks and also to maintain standing water to a height of about 4-5 cm.

Resources required:	Local and no other specific resources required
Potential maladaptation:	in light textured soils the practices exposes the top soil and causes subsequent water loss.
Non-climatic benefits:	Proper use of household members for weeding.

6.5.5 Manual closing of soil cracks

Barind soils are clayey; cracks are formed even when there are high moisture levels immediately after the disappearance of ponded water. Once surface cracks are formed, they become wider and very quickly expose the subsurface, leading to higher rate of evaporation and percolation of subsequent rainfall. Once cracks are allowed to form, twice the amount of water is required to close the cracks. Traditionally, farmers stirred the surface soil manually to avoid development of early cracks when the soil was nearing saturation. Such practice avoided development of cracks for a few days, even without rain. The practice, known as "*ghata ghati*" in one of the pilot villages, may be introduced to the farmers as a way to minimize the impact of dry spells during *T. Aman* season.

Resources required:	family labour.
Potential maladaptation:	none.

Non-climatic benefits: effective engagement of family labour in on-farm activities and improving water use efficiency.

6.5.6 Strengthening field bunds

Rainwater conservation within a rice field is one of the best rainwater harvesting techniques during monsoon season. Low field bunds do not hold enough water to support crop growth during extended dry spells of more than 10 to 15 days. In the high Barind Tract, standing rainwater is retained for about five to six days, and then the soil reaches saturation and surface cracks starts developing. Once surface cracks are developed, soil dries out quickly and the crop suffers from water scarcity. Strengthening field bunds and increasing the height (*ail* lifting) by 10 cm could delay the development of surface cracks for additional two/three days.

Resources required: limited family labour and low-cost farm implements.
Potential maladaptation: none.
Non-climatic benefits: reduced water use and improved crop yield.

6.5.7 Re-excavation of traditional ponds

In Barind Tract areas, dry spells occur more frequently during the monsoon season and affect the *T. aman* rice crop. Farmers draw water from traditional ponds for supplemental irrigation at critical stages of the crop growth cycle. Mostly, these ponds are under the control of big farmers in the village, often leased out to private users and are poorly maintained.

The traditional ponds are now used for fish culture during monsoon season. As fish culture requires considerable water, water is not allowed for irrigation of the small and marginal farms, Only when the water is above the required level (above 6 feet) is it allowed for irrigation to other farmers. The cost of water for irrigation is US$1.50/hour it it may be based on land area irrigated. About US$0.87 is required to irrigate one *bhiga* of land. Normally 7.5 cm diameter plastic pipes are used for pumping water.

Water level above threshold could be used effectively as supplemental irrigation during drought, but the ponds are silted and are poorly managed. Re-excavating the traditional ponds can increase the capacity to irrigate the rice crop during *T. aman* season.

Resources required: limited family labour.
Potential maladaptation: none.
Non-climatic benefits: benefits short-duration *rabi* crops, brings additional family income.

6.5.8 Re-excavation of Khari canals

Development of khari canals, lengthy pond-like structures up to 2-3 km long and 10-15 m wide, is encouraged in the Barind Tract to provide water storage for domestic or agricultural purposes. It requires making embankments along segments of a drainage or irrigation channel and planting trees and shrubs to reduce further evaporation. Local villagers and community members decide together where to dig the pond and the entire operation – digging and ongoing maintenance – is handled on a cooperative basis. In the past, such ponds were also used for storage of rainwater.

Nowadays, they do not get sufficient water in the dry season as groundwater recedes further. It is important to improve upon this technique to increase rainwater harvesting and storage.

Resources required: digging implements and labour.
Potential maladaptation: none.
Non-climatic benefits: community empowerment and community participation.

6.5.9 Canals

Natural canals which have potential for conserving water and providing water for irrigation and other purposes, may be identified for re-excavation. Afforestation can be set up on the canal embankments and should include multipurpose tree species, such as those with biofuel value that provide climate change mitigation. Such canals can be used to transfer water from nearby

Resources required: high level of initial investment.
Potential maladaptation: soil salinity may develop if water is not available continuously.
Non-climatic benefits: crop diversification and tree planting in embankments and additional biofuel availability for household needs.

6.5.10 Water control structures

Low-cost water control structures of appropriate design need to be built across the re-excavated canals for conserving water that can be used as supplemental irrigation for rainfed paddy (*T. aman*) and for low water-consuming crop cultivation. The water thus stored in the section of the canal may be leased out annually to local groups or individuals to cultivate fish and provide supplemental irrigation. Small to medium check dams are more advantageous and less expensive.

Resources required: locally available materials and limited labour.
Potential maladaptation: none.
Non-climatic benefits: ground water recharge and tree planting in embankment.

6.5.11 Miniponds

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

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

6.5.12 Supplemental irrigation

Department of Agricultural Extension (DAE) has a programme to supply plastic pipes to pump water from the traditional ponds or miniponds. Since plastic pipe is not affordable by the farmers, provision from the DAE is very helpful during drought. Farmers need to transfer water from 100 to 150 meters to irrigate their crops. The cost of the pipe varies from US$0.58 to US$0.72. Normally, low-lift suction pumps are used to pump water from the ponds. The entire assembly consists of a 5-meter suction pump, an engine with a pump and a 1-meter delivery pipe. The cost of the entire assembly works out to US$217. The practice is very useful, but non availability of water in the ponds is a major concern. Further, all farmers are not able to maintain such infrastructure. Re-excavation of ponds and assured continuation of the plastic pipe supply would enhance the adaptive capacity of the farmers during drought.

Resources required:	limited investment on plastic pipes but high initial investment for purchase of engine.
Potential maladaptation:	low energy use efficiency and use of diesel for engines.
Non-climatic benefits:	additional area under cropping and improved yield.

6.5.13 Shallow and deep tubewell

In the early 1970s and 1980s, agricultural development projects were implemented in Barind Tract areas to provide groundwater irrigation through shallow and deep tubewells. Since scarcity of water was the main obstacle against intensive agriculture, pumping up groundwater helped crops grow year round. Through shallow and deep tubewells, high yielding varieties (HYVs) of paddy was introduced to hundreds of acres of marginal and sloped lands, especially during *boro* season.

Resources required:	high level of initial involvement.
Potential maladaptation:	fast decline in groundwater may reduce future coping mechanisms.
Non-climatic benefits:	crop diversification and increased cropping intensity.

6.5.14 System of Rice Intensification

Generally farmers plant 40- to 50-day-old seedlings at the rate of 5 to10 seedlings per hill. Farmers also maintain continuous submergence throughout the crop growth cycles without giving any opportunity for aeration to the root zone. Within the Barind Tract, wherever deep tubewells are present, abundant water is being used. The water productivity in this region during *boro* season is very low.

System of rice intensification (SRI) is a new rice production technology developed in Madagascar two decades ago. The SRI package has increased rice yield by 50-100 percent in different parts of the world compared to traditional practice. The main practices of the SRI technology are as follows:

- transplanting younger seedlings (8-15-day-old seedlings) that preserve full genetic potential to produce more viable tillers,
- transplanting seedlings within 30 minutes after uprooting from the nursery bed,
- transplanting using single seedlings,
- spacing plants widely in square patterns 30 cm x 30 cm to 50 cm x 50 cm,
- aerating the soil with an alternate water regime that allows prolific root growth and maximum uptake of nutrients.

Resources required: none.
Potential maladaptation: care is required during initial stages, high intensity rain may damage the sprouted seeds and young seedlings.
Non-climatic benefits: high water productivity with approximately 40 percent water more savings under SRI system than with conventional systems.

6.5.15 Direct seeded rice

The High Barind Tract of Northwest Bangladesh is drought prone, with the majority of the 1 200–1 400 mm mean annual rainfall occurring from June to October. Limited irrigation potential in non-irrigated areas restricts cropping intensity to 100 percent, considerably less than in districts where irrigation allows two or three rice crops each year. The majority of farmers produce a single crop of transplanted rainfed rice, grown in monsoon season. Some 80 percent of the area then lies fallow in the post-rice *rabi* season. The challenge in the Barind is to simultaneously improve the reliability and yield of rice while increasing total system productivity by increasing the area planted to post-rice *rabi* crops, including chickpea, linseed, and mustard.

Reports from BRRI proposed that the productivity of Barind soils can be increased by switching from transplanted rice (TPR) to direct-seeded rice (DSR) to allow more reliable establishment of *rabi* crops on residual moisture immediately after the rice harvest. Chickpea, a drought-tolerant and high-value crop, can be grown successfully when seeded after rice in late October to mid-November. This can make significant contributions to higher productivity and improved farm income.

A late onset of the monsoon delays transplanting as a minimum of 600 mm of cumulative rainfall is needed to complete ploughing, puddling and transplanting. Direct seeding can be completed after ploughing, however, following only 150 mm of cumulative rainfall. Earlier planted DSR matures one to two weeks before transplanted rice, thus reducing the risk of terminal drought and allowing earlier planting of a following non-rice crop. An earlier rice harvest can also be achieved by planting early-maturing rice varieties. Swarna, the most widely grown cultivar, matures after 140 to 145 days and, when transplanted, may not be harvested until early to mid-November. In many years, soil dries rapidly at this time, reducing the likelihood of successful chickpea establishment. DSR reduces labour and draught-power requirements for rice establishment by 16 percent and 30 percent, respectively, compared with TPR.

However, weeds are a major constraint to the adoption of DSR as the inherent advantage of weed control afforded by transplanted rice in standing water is lost. Labour shortages for many households prevent timely first weeding of transplanted rice. With these current practices, 34 percent of farmers lose more than 0.5 t ha^{-1} of the attainable rice yield because of weed competition. The additional weed problems in DSR may be overcome, however, by applying a pre-emergence herbicide.

Resources required: pre-germinated sprouted seeds.
Potential maladaptation: anticipated problem of high intensity rainfall in future.
Non-climatic benefits: duration shortened by seven to ten days.

6.5.16 Drought tolerant rice varieties

BRRI has evaluated drought-resistant rice varieties for the drought-prone Barind Tract. Among the varieties (lines), the highest yield was obtained from PSBRC80 followed by IR 50. Compared to the local check Parija, PSBRC80 and IR 50 gave significantly higher yields while BR5543-5-1-2-4 and BR6058-6-3-3 were comparable with Parija (Table 19; Fig. 28). The majority of the IR lines obtained from aerobic trials did not perform well under transplanted conditions.

Panicle per hill ranged from 11 to 15.2. Apparently panicle per hill had a little effect on yield. Growth duration of the highest yielding variety PSBRC80 was 115 days which was 10 days longer than local check Parija, while IR 50 was 5 days earlier. The results also revealed that among the lines, PSBRC80 has uniform canopy and better grain shape and size than Parija. At grain-filling stage, natural incidence of bacterial leaf blight (BLB) and sheath blight were reported to be high in Parija and much lower in IR50. PSBRC 80 was almost free from BLB and sheath blight.

Table 19. Yield and other characters of promising advance breeding lines (BRRI, 2005)

Sl.No.	Designation	Yield (t/ha)	Sterility (%)	Panicles /hill	Growth duration (days)
1	IR69715-7-31-3-19-8	2.7	31.5	12.4	116
2	IR71604-4-14-7	2.3	29.6	14.1	114
3	IR71700-247-1-1-2	3.2	34.3	14.7	117
4	IR77298-14-12	2.4	33.2	14.2	110
5	IR77298-5-6	2.4	36.5	15.1	110
6	PSBRC80	4.4	21.3	14.2	115
7	BR6058-6-3-3	3.7	21.4	11.6	100
8	BR5543-5-1-2-4	3.9	19.8	11.6	98
9	BR5563-3-3-4-1	3.0	28.3	12.8	105
10	BRRIdhan28 (Ck)	2.9	32.3	13.5	105
11	Parija (Ck)	3.6	20.3	14.0	105
12	IR50 (Std. Ck)	4.2	22.1	15.2	100

At present, farmers are growing Parija mainly because they do not have the short-duration variety. It has been recommended to provide viable and pure IR 50 seeds to farmers as this variety has performed well in BRRI experiments.

Resources required: good quality seeds of short duration rice varieties.
Potential maladaptation: high temperature, salinity may cause spikelet sterility.
Non-climatic benefits: high yielding and opportunity to plant pulses under residual moisture

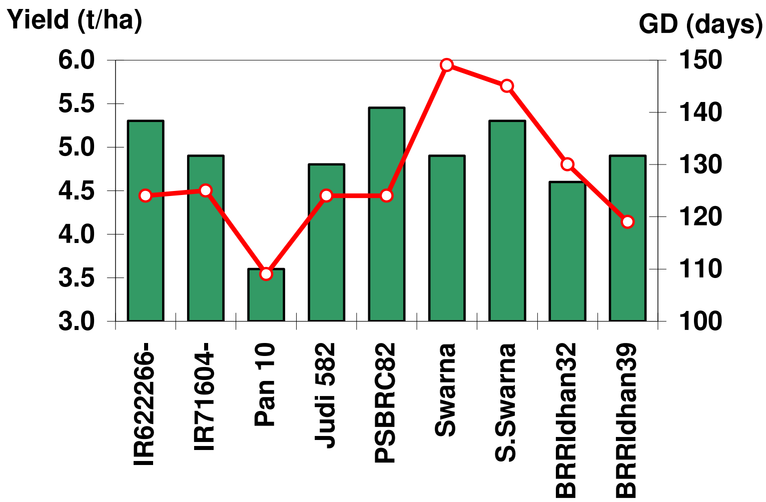

Fig. 28. Yield and growth duration of exotic rice in rainfed *T. aman* (BRRI, 2005)

6.5.17 Alternate cropping pattern

a) Green manure (*kharif* I) – *T. aman* system: Introduction of green manure crops in the existing *T. aman* rice system can improve the fertility status and water-holding capacity of the soil. Rainfall climatology in the Barind tract indicates that there is an opportunity to introduce green manure crops before *T. aman* rice. Summer showers in April and May can be utilized effectively for growing a green manure crop during *kharif* I. Green manure crop, about 50 to 55 days old, could be incorporated into the soil just before transplanting of *T. aman* rice. The most suitable green manure crop under this situation is *Sesbania rostrata*, a stem nodulating green manure that can fix atmospheric nitrogen ranging from 25 to30 kg/ha.

Resources required:	quality green manure seeds, low-cost implements for improving green manure.
Potential maladaptation:	none.
Non-climatic benefits:	soil fertility improvement and higher crop yields.

b) *T. aus* – fine rice (Chini Atap) system: In the drought-prone Barind tract, considerable rainfall is received during May (~150 mm). If lands are prepared well in advance to take advantage of early summer rainfall in March-April, T. *aus* could be planned for *kharif* I season. When T. *aus* is harvested early, there is a possibility to go for short-duration fine rice (*Chini atap*) during August coinciding with late *kharif* II season. In one of the pilot villages, the system has been successfully implemented and cropping intensity has increased substantially under rainfed conditions. The system helps to increase the opportunities for higher income.

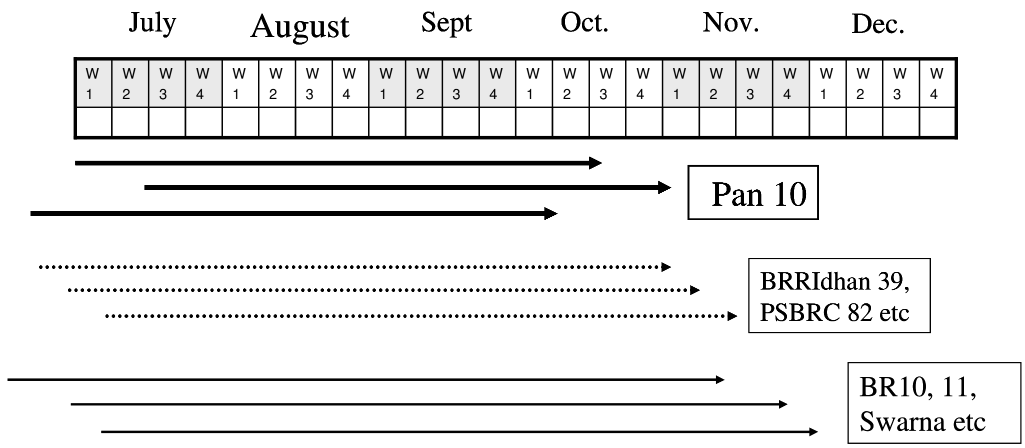

Fig. 29. Cultivation plan of monsoon season rice *(T. aman)*.

Resources required: quality seeds and appropriate seedbed method.
Potential maladaptation: shorter growing period may add additional risk from future droughts.
Non-climatic benefits: high quality fine rice and export opportunities.

c) *T. aman* – mustard system: Crop intensification in rainfed areas is possible by introducing mustard after T.*aman* rice. Whenever T.*aman* is harvested early, mustard could be sown during November by utilizing residual moisture. This system could be successful in low Barind Tracts, where the moisture retention capacity of the soil is relatively higher than high Barind Tracts. Several short-duration rice varieties have been evaluated to accommodate winter crop cultivation under residual moisture (Fig.29).

Resources required: quality seeds of mustard.
Potential maladaptation: shorter growing period may add additional risk from future droughts.
Non-climatic benefits: nutritional security and crop diversification.

d) *T. aman* – chickpea system: Large areas of the Barind Tracts are kept fallow during *rabi* season due to non-availability of adequate rainfall. However, it is possible to grow chickpea with residual soil moisture after the harvest of T.*aman* rice. If short duration rice varieties such as BRRI 39, BRRI 32 and early sharna are grown during *kharif* II season, land can be made available to subsequent pulse crops such as chickpea (Fig.1). Introduction of chickpea helps improve the nutritional security of the local population. BARI has developed short-duration drought-resistant chickpea varieties for Barind tracts.

Resources required: quality seeds of chickpea.
Potential maladaptation: shorter growing period may add additional risk from future drought.
Non-climatic benefits: nutritional security and crop diversification.

e) Famine-reserve crop: The northwestern region of Bangladesh is often hit by *monga*, a seasonal famine condition where food is scarce and prices of whatever food is available are high. The vulnerable groups during *monga* are small and marginal farmers, farm labourers, women, children and elders. After transplanting *aman* crops, the men and women have no work to earn money for investment in food. Seasonal crises that occur with various degrees of severity during approximately the same period lead to food deprivation. Small deviations in normal rainfall can aggravate the situation further. The *monga* period generally lasts from September until the end of November when the new paddy harvest begins. In the *monga* season, the vulnerable groups often take loans from local money lenders with higher rates of interest. The daily labourers sell their labour at reduced rates in advance. Selling domestic animals and essential properties is normal in the area. The workers are bound to migrate temporarily in search of work to other districts. Starvation or near starvation during *monga* has a highly adverse impact on health of the people living in *monga*-hit areas.

Cassava (*Manihot esculenta)* and yams (*Diascorea spp*) can be suitable for cultivation as a famine-reserve crop on highland soils if they do not become waterlogged. The high Barind Tracts with moderately light textured soils are more suitable. These crops are drought resistant and can be cultivated with little water. They can be grown on homestead land and raised cultivation platforms to provide families with an emergency food reserve in case of need. However, methods of cultivation and food preparation would need to be demonstrated to farmers.

Resources required: homestead land or raised cultivation platforms, propagation materials, minimum household labour.
Potential maladaptation: none.
Non-climatic benefits: women's involvement in crop production; minimizing impact of *monga*; reduced migration of labour; employment opportunities.

6.5.18 Mango and Jujube cultivation

Mango and jujube (*Ziziphus jujuba* Mill) are alternative and promising crops to manage drought in Barind areas. The region is known for its quality mango production and higher yield and area under mango is increasing every year. The crop is many times more profitable than T.*aman* rice. The inter-spaces in the young mango plantations are intercropped with *T.aman* and *boro* rice. Many varieties of different maturity groups are widely grown in this region (Table 20).

Table 20. Harvest window of mango varieties of different duration groups under normal climatic conditions

Maturity group	Variety	Starting date of harvest window
Early	Gopalbogh	15 May
Medium	Krishabogh	10 June
Late	Langra	25 June
	Pozli	5 July
	Ashwina	30 July

All varieties flower at the same time, normally in February, showing a synchronized flowering behavior. Maturity of these mango varieties depends on the temperature pattern during summer months from March to May, and their harvest windows vary from 15 May to 15 August. A hotter than normal summer season results in synchronized maturity and low quality. In 2004, synchronized maturity caused farmers to lose their profits due to a fall in market price. The price during the season was 50 percent below normal. During hotter than normal summers, all varieties tend to mature at the same time, leading to more supply. Further, even cloudy weather with slight rain during flowering damages the flowering pattern.

Abnormal flower dropping can cause yield loss of 60-70 percent. According to farmers' experience, varieties such as *langra* are highly suitable for the region as damage due to abnormal weather during flowering is not significant compared to other varieties.

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

Resources required: pits for planting mango or jujube saplings, drought tolerant mango or jujube saplings; low-cost fencing and limited labour.
Potential maladaptation: synchronized maturity under high temperature and associated market problems. Jujube has the potential to withstand high temperature.
Non-climatic benefits: improved standard of living, additional employment opportunities if pulp industries are developed.

6.5.19 Homestead gardening

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

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

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

Resources required:	homestead land, propagation materials and seeds of drought-resistant vegetable seeds.
Potential maladaptation:	none.
Non-climatic benefits:	gender integration in agriculture, nutritional security, year-round income.

6.5.20 Mulberry intercropping in rice

In rainfed areas, rice suffers from drought at different stages of the crop growth cycle. Although farmers are able to produce some rice for their household requirements, they do not have sufficient produce to earn money for their household expenditure. During intensive drought, farmers are not able to meet even household food requirements. After rice cultivation during monsoon season, there is no employment for farm families in rural areas. Mulberry *(Morus* sp.) is one of the promising crops for dry areas which can come up well throughout the year and is resistant to drought. Further, the silkworm cocoon fetches good market price if managed properly. Mulberry is mainly cultivated for sericulture industry – silkworm larvae (*Bombyx mori* L.) are reared to produce silk cocoons by feeding them mulberry leaves. It is a labour-intensive industry and both male and female members of the household can participate. Women participate mainly in larvae feeding, cocoon production and knitting at home. Men work in the field for mulberry cultivation. Involvement of women in income-generation activities can be very well achieved by introducing this practice. Sericulture industry has plenty of scope for utilizing huge numbers of unemployed family labourers in the Barind Tract area. Participation of family labour, particularly women, helps to increase family income, improve livelihoods and, ultimately, ensure gender mainstreaming in the agriculture sector.

The Bangladesh Sericulture Board (BSB), established in 1978, provides sericulture extension and has reached a target of about 8 000 ha including roadside plantation. However, due to low price and quality, the industry has not flourished and many of the mulberry fields have been converted to other crops such as mango, vegetables, rice, wheat, pulses, etc. However, these crops will face serious consequences in the future due to climate change. Thus, a strategy needs to be developed to keep the sericulture industry alive in the Barind Tract because of the employment opportunities it provides.

The Bangladesh Sericulture Research and Training Institute (BSRTI) and BRRI, Rajshahi, have been working to develop sericulture technologies. To address the growing need of the farmers and also to factor in the current climate variability and future climate risks, inter-cropping of rice, wheat, mung bean, garlic, chickpea and mustard in mulberry fields might be a good adaptation practice. Single crop mulberry is not as profitable as the other crops so the cultivation of other crops could increase farm profitability and ensure family food security. The intercropping technology, developed jointly by BSRTI and BRRI, recommends for cultivation of rice, wheat, garlic, mustard, chickpea and mungbean in mulberry fields, following the cropping pattern: rice in the monsoon season, wheat/mustard/garlic/chickpea in winter, and mung bean in pre-*kharif*. The results of the field experiments indicate good performance of the mulberry plus rainfed rice cultivation in monsoon season. In addition, successful crop cultivation could create a unique opportunity for mulberry farmers to increase income and family food security.

Resources required: quality mulberry cuttings.
Potential maladaptation: high temperature may lead to additional diseases.
Non-climatic benefits: additional household income and employment opportunities.

6.5.21 Cultivation of fodder for livestock

Rural people in the Barind Tracts domesticate many kinds of animals as a drought risk management strategy. On average, every farming household has livestock, usually three to four animals (cows, buffalo, goats or sheep). The money made from animal enterprises helps families cover their expenses throughout the year. The paddy straw harvested during *kharif* II season is preserved year round to meet fodder requirements. Occasionally, green fodder is also fed to animals wherever there is access to leguminous trees. During rainy season, restricted grazing is allowed in the field bunds and small fallow lands. During earlier times, when more land was left fallow, there was more opportunity for open grazing, Now, due to population pressure and economic motivation, the cropping intensity has become higher, leaving limited land for open grazing. During droughts, sources of animal fodder become limited and animals are sold for lower prices.

The situation created by monsoon season drought may be managed through alternative fodder cultivation practices. Fast-growing fodder crops, such as napier grass, grow with limited water and could help avoid the need to sell animals during drought. These fodder grasses may be cultivated even in homestead gardens, canal embankments and near miniponds and traditional ponds. Other possible adaptation practices in the livestock sector are:

- construction of cattle sheds to manage high temperature stress,
- conserving water for livestock through traditional water bodies,
- vaccination to avoid outbreak of diseases during drought.

Resources required:	vegetative propagation materials.
Potential maladaptation:	none.
Non-climatic benefits:	enterprise mix, manure availability, alternate sources of protein from animals and income, reduction of migration during drought.

6.5.22 Fish cultivation in miniponds

Installation of miniponds provides an opportunity to cultivate fast-growing fish species. The same practice can be taken up in traditional ponds, *khari* canals and other rainwater conservation structures. The objective is to increase opportunities for higher household income through diversification of enterprises. However, as drought becomes more frequent in the future, additional physical and institutional efforts will be required to sustain the practice in drought-prone areas. Other adaptation practices relevant to the fishery sector in drought-prone areas are:

- re-excavation of ponds;
- cultivation of quick-growing fishes;
- connection of irrigation canals with traditional ponds.

Resources required:	fingerlings and fish pond including miniponds.
Potential maladaptation:	intermittent dry spells during the season may limit the water availability in ponds.
Non-climatic benefits:	alternative livelihood portfolios and income.

6.5.23 Alternate sources of energy

Improved fuel use for women in rural areas and introduction of renewable energy through constitution of biogas plants is considered important. In areas where the Local Government Engineering Department (LGED) has constructed biogas plants, farmers could pay the costs through adaptation-related projects. Community-based biogas plants provide another alternative to meeting household-level energy requirements. Farmers and others in the pilot villages maintain comparatively larger numbers of livestock (on average 3 to 4 animals per household).

Pilot demonstrations of solar-based home lighting are being presented in other areas, under the eco-village concept. This recognizes that the community has to be engaged in order to develop awareness among the poor (preferably women) of the need for checking environmental degradation and climate change. Similar training programmes need to be organized in the pilot villages to make the villagers, particularly the women, more aware of alternative energy sources.

Resources required:	locally available energy source.
Potential maladaptation:	none.
Non-climatic benefits:	potential mitigation options reduces green house gas emissions.

6.5.24 Seed storage bins

Farmers in drought-prone areas of Bangladesh are affected by non-availability of quality seeds in time of drought. They use the available seeds to grow seedlings with the first rainfall. However, erratic and highly variable early season rainfall patterns have led to droughts that damage seedlings. Extended drought conditions during later stage (terminal drought) also lead to production of poor quality seeds. Farmers in the Barind Tracts have need to store their good quality seeds (harvested from previous seasons) for a longer time. There is no well-equipped community-level storage system in the rural villages but some farmers store their seeds in locally made low-cost storage bins made of mud. The sticky Barind Tract soils are highly suitable to use in constructing the storage bins. The bins are small, slightly elevated to protect from water seepage, the tops can be sealed if the seed needs to be stored for long periods, and they can be constructed inside the house for safety.

The traditional storage methods are excellent for helping prevent or control pest infestation. The seed moisture content is maintained at appropriate level. This eliminates some insect pests and inhibits the movement of others. The storage bins can also be used for stocking foodgrains such as cereals and pulses.

Resources required:	soil, seeds, labour, simple tools and skills.
Potential maladaptation:	none.
Non-climatic benefits:	Seeds preserved for longer periods and available for re-sowing in the event of early season drought.

CHAPTER 7

DISSEMINATION AND EXTENSION STRATEGIES

The impact of climate change in drought-prone areas have been translated into a menu of good practices. The viable adaptation options described in the previous chapter need to be tested and disseminated at pilot villages for their acceptance. The approaches followed initially for this purpose are limited to the following.

- *Demonstrations:* Monitoring the benefits of adaptation in cooperation with agricultural extension staff involving the local community, especially the farmers.
- *Farmer-friendly extension tools:* Several farmer-friendly extension tools such as orientation meetings, demonstration rallies and farmers field schools will be adopted to disseminate information on adaptation practices. There are plans to adopt other extension methods in the future.
- *Awareness-raising strategies:* Awareness raising is an integral part of the extension methods followed for demonstration and dissemination. Printed materials will be developed to describe the salient features of each adaptation practice selected for demonstration. Local-level training programmes will discuss the advantages of the adaptation options identified for drought-prone areas.

Extension tools include written and explanatory pamphlets, brochures and pictures of good practices. The printed materials will contain good practice menus with cost benefit analysis. The successfully tested options would be disseminated through radio. The following contains details of some of the extension and dissemination strategies.

7.1 Orientation meetings

Extension support to farmers and local people begins with orientation meetings to form local groups. Orientation meetings are helpful to bring extension staff and farmers groups together to discuss and analyse issues and ideas related to climate change adaptation. This orientation is often the way members of the farmers' group first learn about the concept of adaptation.

7.2 Demonstrations

Next step is the preparation of the demonstration plan for each of the viable adaptation option. This involves all upazilla officers as well as sub-assistant agricultural officers (SAAOs) who play major roles since they have regular contact with the local groups. An upazilla-level technical implementation working group will actively participate in the entire demonstration and subsequent meetings.

Demonstrations of climate change adaptation practices selected for drought-prone areas may be method or results oriented. The method demonstrations are targeted to impart skill, while results demonstrations are organized to show the relative advantage of a particular practice.

7.3 Community-level training

A community-level training day needs to be organized in a suitable place before each season, with a proper training schedule and curriculum, and handouts and other relevant training materials prepared. All training activities should be filed properly, for monitoring by district officers. The selected farmer group leaders and community workers need to be present. Practical issues need to be agreed by the group, and then discussions need to cover the procedures for implementing each adaptation measure, cost requirements, advantages, season and other relevant aspects.

7.4 Field days

A field day is a group extension event conducted at the demonstration site. Successful field days are the most important aspect of the demonstration programme. SAAOs organize field days in respective (*kharif* I, *kharif* II and *rabi*) seasons. At the end of *kharif* II season, a farmer rally needs to be organized. During the field day, the group members should present successful demonstrations. Each member of group can invite at least two neighbor farmers for the field day and the farmers who present the demonstrations should be available to explain the new adaptation practice to the visiting farmers. Local leaders should be present and take part in the discussion.

Upazilla agricultural officers, agricultural extension officers, SAAOs, DMC members and UTIWG members should attend the field day in every season. They should be organized at a time when the technology can be demonstrated and the Upazilla Agricultural Officer (UAO) can explain to the participants about the objectives of demonstrations. Representatives from financial organizations should be present to explain about agricultural credit facilities available to implement adaptation practices. Representatives from research organizations should be present to clear technical doubts arising out of discussions.

7.5 Farmer Field School

The farmer field school approach was initially developed to help farmers and promote integrated pest management (IPM) practices in agriculture. It is a form of adult education, involving practical, field-based learning in weekly sessions during a complete crop cycle. The aim of the field school is to increase farmer expertise on a particular subject so that appropriate decisions may be made. The curriculum encourages community involvement throughout the crop growth period and stresses learning from peers and strengthening communication skills and group cohesion. The farmer field school approach can be utilized for disseminating the advantages of viable adaptation options to climate change in drought-prone areas.

7.6 Extension materials

During field days and demonstrations, maximum use should be made of locally or centrally produced training material, such as leaflets, banners and flipcharts. Role play is another option. The seasonal planner is one of the important tool guides for successful conduct of demonstrations. The local resource groups need to prepare a seasonal calendar/ planner for effective implementation of demonstrations. It is essential to maintain, as far as possible, audio-visual material, including folk songs, video and slide show or other entertainment that can be included under the list of extension materials.

7.7 Demonstration farmer rally

The end of *kharif* II season provides an opportunity to organize a farmer rally. Farmer rallies are large extension events with a combination of group motivation activities covering practices that deal with viable adaptation, crop intensification, water-saving or rainwater harvesting.

Farmer rallies are usually organized outside, like a big field day, gathering 80 to 100 farmers from neighboring villages/blocks. Representatives from local banks, input dealers, local NGOs and other agriculture-related organizations, along with DAE, district and upazilla-level officers and research officials should be present. They also could provide the opportunity for partnership with other extension providers. The following points are to be considered while organizing farmer's rallies.

- A programme of activities should be agreed in advance and should include opening remarks, presentations, audience participation, folk songs, etc., organized in a way to keep people involved and interested. Supporting materials such as leaflets and banners should be created and produced.
- Select adequate venue, ensuring there is enough seating space for a large audience.
- The date and venue, once decided, should be advertised and invitations should be sent to potentially interested parties.
- Partner agencies, when appropriate, should be involved and provided the opportunity to share experiences and resources.

Members of the demonstration group should be active during the rally, and available to explain the adaptation practices to the visiting farmers. Calculations and discussions on benefit-cost ratio (BCR) and economic benefits for the drought adaptation practice need to be compared with control practice or surrounding farmer practice. Discussions should be initiated on adaptation options for the following year's crops, and decisions should be taken on how the group should function in the future. Also, discussions about specific seasonal activities for women should be included in the programme.

The extension staff should meet with the demonstration farmers at some point after the rally to discuss i) the main messages from the rally in order to stimulate their interest in new ideas, and ii) agree on a work plan for the group after demonstration support has stopped.

7.8 Women's involvement

One-day training opportunities for female representatives in the demonstration should be organized in a suitable place near the demonstration site before each season. Training topics can include various drought management practices and household activities. A female SSAO who has received three days of special training on "climate change impacts and disaster risk management", should be engaged to handle this training. After training, all female representatives of selected demonstration farmer groups can participate as a group in implementing some season-wise specific adaptation practices. Each woman of the group can take up specific activities:

- establish a homestead garden with drought-resistant vegetables (BARI model);
- preserve crop seeds in better ways to be used during drought;
- prepare water hyacinth compost or compost from waste materials;
- plant mango saplings and maintain proper husbandry/management of existing plants;
- use environmental friendly energy sources at household level.

CHAPTER 8

COORDINATED ACTIONS FOR CONTINUOUS ADAPTATION

Adaptation to reduce the vulnerability of agriculture and allied sectors to the impacts of climate change requires coordinated actions, proper planning, financial resources and community involvement. Typical planning mechanisms or activities would include the following issues.

8.1 Incorporation of livelihood adaptations in long-term planning

Involvement of BARI and BRRI in a project on livelihood adaptation to climate change would give further direction to the agriculture research community. The efforts to mitigate the impact of climate change in drought-prone areas need to be integrated into the long-term planning of the national and local institutions. In this context, efforts have been made to involve several national and local-level institutions in the entire process including: the Comprehensive Disaster Management Programme (CDMP) of Ministry of Food and Disaster Management (MoFDM), Disaster Management Bureau (DMB), Department of Relief (DoR), Ministry of Environment and Forests (MoEF), Department of Environment (DoE), Ministry of Agriculture (MoA), Department of Agriculture Extension (DAE), Department of Livestock (DoL) and Department of Fisheries (DoF). Several other agencies such as the Barind Multipurpose Development Agency (BMDA) were also involved in the process of finding viable adaptation options for drought-prone areas. Research agencies such as Bangladesh Rice Research Institute (BRRI) and Bangladesh Agriculture Research Institute (BARI) have been involved in the demonstration process.

8.2 Implementation of research and development on new crops

Research and development efforts should include crops better suited to grow under climate change conditions. Crop varieties that are more resistant to extreme weather events will be needed under climate change. However, it takes approximately eight to 15 years to develop new varieties and three to four years to adapt them at field level. Thus research on new crop varieties needs to begin now, based on the requirements that are decided by community preference and local growing environments. Further analysis of potential climate change and crop attributes is needed to offset the effects. To continue adaptation, climate change adaptation units that focus on the Barind Tract areas should be established in local research institutions such as BARI and BRRI.

8.3 Improvement of information dissemination network

Agriculture is a relatively flexible economic sector because farmers can change crops and practices on an annual or more frequent basis. However, in practical terms, change is very slow due to inefficient institutions and markets. For changes to occur quickly and efficiently, farmers need to be aware of changes in crop varieties, crops, practices and technologies that can help in coping with climate change. Often, farmers can make the changes themselves, based on indigenous knowledge. However, in other instances, training and demonstration may be necessary. The capacity of the information dissemination networks involving public and private sectors should be examined and institutional weaknesses should be addressed.

8.4 Market risk management in agriculture

Lifting price supports on crop production and water could induce farmers to switch crops more rapidly in response to climate change. Subsidies or restrictions on crops inhibit farmers from changing practices or crops. This means detailed analysis and interpretation are needed of the location-specific impacts of policy interventions related to livelihood adaptation to climate change. Strong institutional and market support would be required for physical adaptation of some high value crops, such as mango.

8.5 Access to credit

For the agriculture sector to adapt quickly to climate change, farmers need ready access to credit for financing the purchase of new equipment such as low-lift pumps, adopting new technologies such as rainwater harvesting tools, and for investment in alternative crops such as mung bean. An accessible and reliable credit system that would help farmers expand their production capabilities under current climate as well as in response to future climate change is a high priority future action. The state-operated Krishi (agricultural) Bank and private and non-government sector micro-lending institutions (Grameen Bank and other NGOs) could provide timely and safe credit to poor farmers. However, most of the micro-credit activities of NGOs are small and handled by women. Such facilities can help strengthen household-level adaptation strategies, but farm-level adaptations require a different kind of credit facilities.

8.6 Developing enabling institutions and favourable socio-economic conditions

Despite coordinated efforts, institutional and socio-economic conditions may limit adaptation efforts. Lack of access to capital and inputs at proper time is the major impediment to improving agricultural production in drought-prone areas. If the situation does not improve, it will also limit climate change adaptation possibilities in these vulnerable areas. The high number of small land holdings in Barind Tract areas makes the situation more difficult. Average landholding size in pilot villages is about 3 *bhiga*. Further, more than 50 percent of farmers in pilot villages are tenants and highly vulnerable to climate shocks.

8.7 Institutional guidelines

This section recommends measures that can facilitate institutional adaptation to climate change. The recommendations are based on a review of the existing institutional arrangements for livelihood adaptation, actors and stakeholders, policies and processes and their roles and mandates. They also offer interpretations of needs and gaps, and address the needs of the rural population in the Barind Tract, particularly the poorest and must vulnerable and women who are targeted by poverty reduction measures. The recommended adaptation strategy measures included in this section are meant to promote and facilitate a supportive institutional arrangement for adapting and coping with the consequence of climate.

In addition to a range of specific recommendations to changes in institutional arrangements, it is important to emphasize the need to empower local communities and build on their traditional coping mechanisms and the need for greater flexibility in how government institutions respond to climate change. Efforts to deal with climate change at the individual level should receive more support and their focus should be on improving the effectiveness of traditional coping and adaptation mechanisms.

- In view of the growing scarcity of farmland, tree planting should be undertaken around homestead villages, schools and public buildings, along roads and on the banks of common water bodies.
- Traditional water bodies, canals, and ponds need to be dredged and re-excavated to enhance water storage and drainage capacities.
- More effective planning, operation and maintenance is needed of physical infrastructure such as miniponds, water-control structures etc.
- A massive programme to create greater public awareness is required. Government agencies and NGOs should mobilize people by providing education and awareness campaigns.
- Government arrangements should be made so that the poor can get credit, on easy terms, to invest in their adaptation practices.
- High priority should be given to enable women, children, disabled and elderly people to improve their adaptive capacity during drought.
- Proper sanitation systems and medical facilities should be developed in drought-prone areas to respond to increased health threats.

A drought-monitoring centre with responsibility for collecting climatic change and water balance data should be established in Northwest Bangladesh. Such a data source can facilitate regular regional weather/climate forecasts for farmers and predict possible drought conditions in the region.

In order to alleviate the effects of drought, the government should have an understanding of how and why drought occurs and be prepared to undertake appropriate mitigation programmes. The government should work with the NGOs operating in the region for the same purpose. The farmers may be trained to learn techniques of conservation of soil moisture in dry season, bringing about possible change in cropping pattern as well as cultivating drought resistant crops and exploring the possibilities of crop diversification practices.

8.8 Development of livelihood opportunities in vulnerable areas

The long-term sustainability of measures to respond to and cope with the impacts of climate change in drought-prone areas will be contingent upon the sustainable development of the livelihoods of vulnerable communities, as it is through this that their resilience to the impacts of these changes will be increased. A livelihoods approach puts climate-related vulnerabilities within the context of the overall vulnerabilities that poor people face. The development of vulnerability reduction programmes and support to sustainable livelihoods need to be strengthened in drought-prone areas.

There is an urgent need for an integrated and comprehensive development plan and better understanding of the interactions and causal relationship in Barind tracts. Meaningful individual participation and perception should be the focus of development efforts. Local people have the resilience to adapt to gradual change in climate variability. However, more frequent droughts reduce their resilience and increase need for external interference. An adaptive and flexible approach to livelihoods development in the drought-prone areas is essential, given the high level of uncertainty over the character of key determinants of livelihoods activities in the future.

Activities to encourage and support the diversification of livelihoods opportunities amongst the poorest and most vulnerable communities should be introduced and supported by substantial funds from international development partners. Current efforts of CDMP, through other partners, are working to improve sustainable livelihoods. But these also need parallel actions to sustain and enhance the natural resource base in the region upon which most vulnerable communities, especially the poor, depend. Traditional livelihood activities, such as agriculture, cannot be sustained given the current decline of the resource base and the effects of drought.

Disaster management policy should include better preparation for changes and challenges likely to confront the people. Bangladesh has one of the best disaster management voluntary teams indicating that people are resourceful and resilient. The livelihood adaptation to climate change and related aspects has to be integrated into the national policy and needs to be implemented on a sustainable basis.

8.9 Integration of traditional knowledge and practices into adaptation

Traditionally, it was the local community that had the main role in management of drought and scarcity. As a result, irrigation was not much of a problem. However, the technology-dependant perspective of development took no account of existing management processes and the existing tradition of correspondence between profit and responsibility was undermined. As a result, community initiatives for water management eroded to a level where they became marginal and a dependence upon the state to manage water resources developed. One of the best examples in this regard is that this project's interaction with farmers in non-irrigated villages always looks for BMDA's installation of deep tubewells.

The development of institutional capacities that support efforts to combine traditional knowledge and practices with modern technical and management systems needs to be encouraged. The integration of mechanisms that represent and guarantee the participation of local communities in all aspects of water resources planning and drought management, including the enhancement of capacities in local government institutions, needs to play a leading role in these processes.

CHAPTER 9

THE WAY FORWARD

The adverse effects of climate change will disproportionately affect poorer communities. The most vulnerable people in the rural area are the poor, whose dependence on natural resources and low resilience exposes them to potentially devastating impacts from even minor changes in environmental conditions. In Bangladesh, for example, periods of prolonged dry spells or droughts will result in water shortage in all settlements, particularly those located in the drier regions. Water supply is therefore a crucial issue, and the situation is expected to become worse with population growth and continuing development, both of which are expected to increase the demand for water. Extreme climatic events, such as droughts, can have a devastating impact on the economy and on the livelihoods of vulnerable people. With sensitive ecosystems, narrow economic structures, and high population density, they can cause severe economic shocks that deflect the economy from a long-term growth path. There is a danger that Bangladesh's excellent recent record of economic growth and development could be slowed or even reversed by the effects of climate change upon its people and resource base. As the national development depends on grassroot-level developments, livelihood is poised to be given more importance in the future.

9.1 Developing institutional mechanisms

The ability to adapt to climate change is undermined by a lack of financial resources, adequate technology and stable and effective institutions. Institutional weaknesses in particular have a critical effect on initiatives. These constraints add gravity to the need for success in the implementation of action based on a set of sound adaptive strategies. The successful implementation of adaptation measures outlined in this report will depend upon human and resource capability of Bangladesh, cultural and social acceptability, and integration with other programmes and projects. Adaptation measures to address the major impacts of climate change may include new rainwater harvesting methods, improved drought tolerant varieties and improved agronomic management practices. Adaptations have been recommended in relation to institutional, policy and organizational measures. Effective adaptation policies and actions are not separated from the main thrust of development activities or institutional programmes. They must be mainstreamed into all aspects of life if they are to be truly effective in responding to the challenges that Bangladesh will face in the future. In this initiative, significant capacity building and awareness have been added at institutional level within DAE and other key stakeholder institutions. The implementation group at national (NTIWG) and at local (UTIWG) levels may behave as a catalyst for continuous adaptation.

9.2 Developing action plans

Many policy measures or strategic action plans have been undertaken by the Ministry of Food and Disaster management (MoFDM), Ministry of Agriculture and Ministry of Fisheries and Livestock. The representative departments or directorates working under these ministries have started adapting innovative approaches to combat the likely threats to Bangladesh agriculture due to climate change in either the short or the long term. Climate change, in the current trend, may not be so alarming, but needs immediate attention. Planning a vulnerability assessment related to future climatic conditions requires long-term vision. There may be many unknown factors that mask the real situation. Therefore, awareness must be increased about climate change impact on human and natural systems such as agriculture, human habitat, forests or biodiversity. Though awareness has been created to some extent, further effort to strengthen the understanding with the local community is essential.

9.3 Awareness raising

In the event of climate change, the agriculture sector of Bangladesh would be very severely affected. This sector contributes 30 percent to the GDP and employs roughly 63 percent of the labour force: nevertheless there has been no concerted effort to create awareness among the different stakeholders of these threats. The initiatives related to climate change adaptations require field-level application and community involvement. Creating awareness among people about vulnerability to climate change and increasing drought frequencies is one of the areas needing the most immediate attention. In order to do so and mitigate the problem of drought, concerted effort should be made by the Government as well as NGOs and international organizations. Investment should be increased in order to mitigate the impact of climate change in drought-prone areas. Institutional mechanisms and appropriate technologies should be developed, in both the public and private sectors to encourage such investments.

9.4 Targeting vulnerable groups and local communities

Climate change may increase the frequency of extreme droughts in vulnerable areas especially in the Barind Tract. To avoid these, priority should be given to plans for rural development that incorporate climate change adaptation. Women and children are the most vulnerable groups within the communities. Therefore, special contingency plans should be made in order to mitigate their suffering and ensure gender issues are mainstreamed in any development process. There were many adaptation practices suggested to improve the resilience of the vulnerable groups especially the women.

9.5 Early warning systems

A greater sense of urgency and interest is needed from policy-makers and the public to ensure adequate and consistent funding of national weather recording systems, early warning systems for climate-related shocks, research on climate-agriculture relationships, regional climatic monitoring, and interdisciplinary analysis of the results and their implications. Well planned activities under this project focused mainly on capacity building and implementation of long-lead climate forecasts. Continuous efforts to institutionalize these forecasts within Department of Agriculture Extension (DAE) would improve the efficiency of adaptation practices.

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Livelihood adaptation to climate variability and change in drought-prone areas of Bangladesh

The impacts of climate variability and change are global concerns, but in Bangladesh, where large numbers of the population are chronically exposed and vulnerable to a range of natural hazards, they are particularly critical. In fact, between 1991 and 2000, 93 major disasters were recorded, resulting in nearly 200 000 deaths and causing US$5.9 billion in damage with high losses in agriculture. Agriculture is the largest sector of the Bangladesh economy, accounting for some 35 percent of the GDP and 63 percent of the labour force. Agricultural production is already under pressure from increasing demands for food and the parallel problem of depletion of land and water resources caused by overuse and contamination. The impacts of climate variability and change cause additional risks for agriculture.

Within this context, FAO and the Asian Disaster Preparedness Center (ADPC) are guiding a project to assess livelihood adaptation to climate variability and change in the drought-prone areas of Northwest Bangladesh. The project, implemented under the Comprehensive Disaster Risk Management Programme (CDMP) and in close collaboration with the Ministry of Agriculture, Department of Agricultural Extension (DAE), specifically looks at: characterization of livelihood systems; profiling of vulnerable groups; assessment of past and current climate impacts; and understanding of local perceptions of climate impacts, local coping capacities and existing adaptation strategies. It is also developing a good practice adaptation option menu, evaluating and field testing locally selected options, and introducing long-lead climate forecasting, capacity building and training of DAE extension staff and community representatives.

This report summarizes the project methodology developed and successfully tested during 2005/06; it discusses interim findings and recommendations resulting from the ongoing pilot learning process.

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