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).

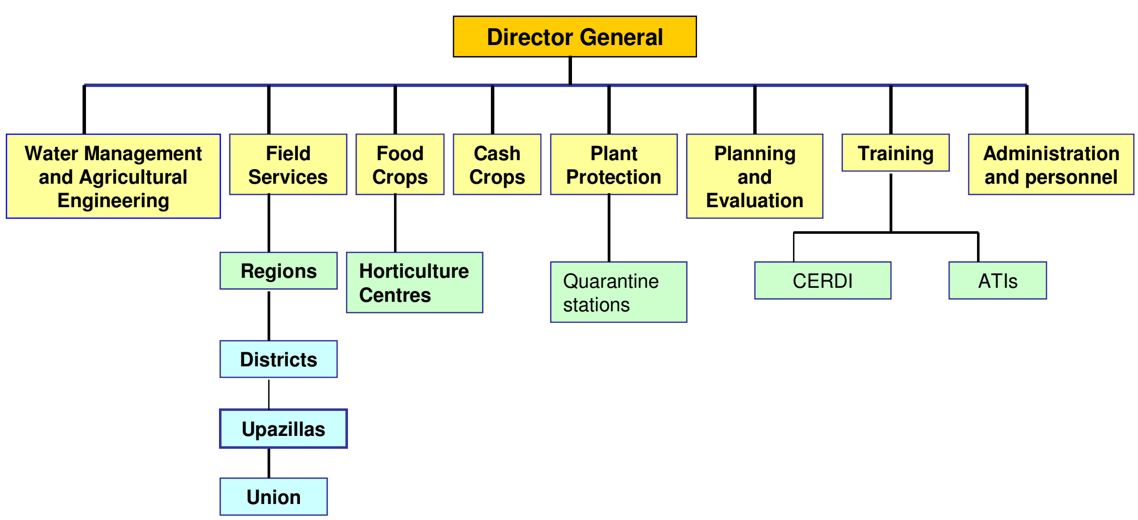

Fig.22 Organizational structure of Department of Agricultural Extension (DAE) in Bangladesh.

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).

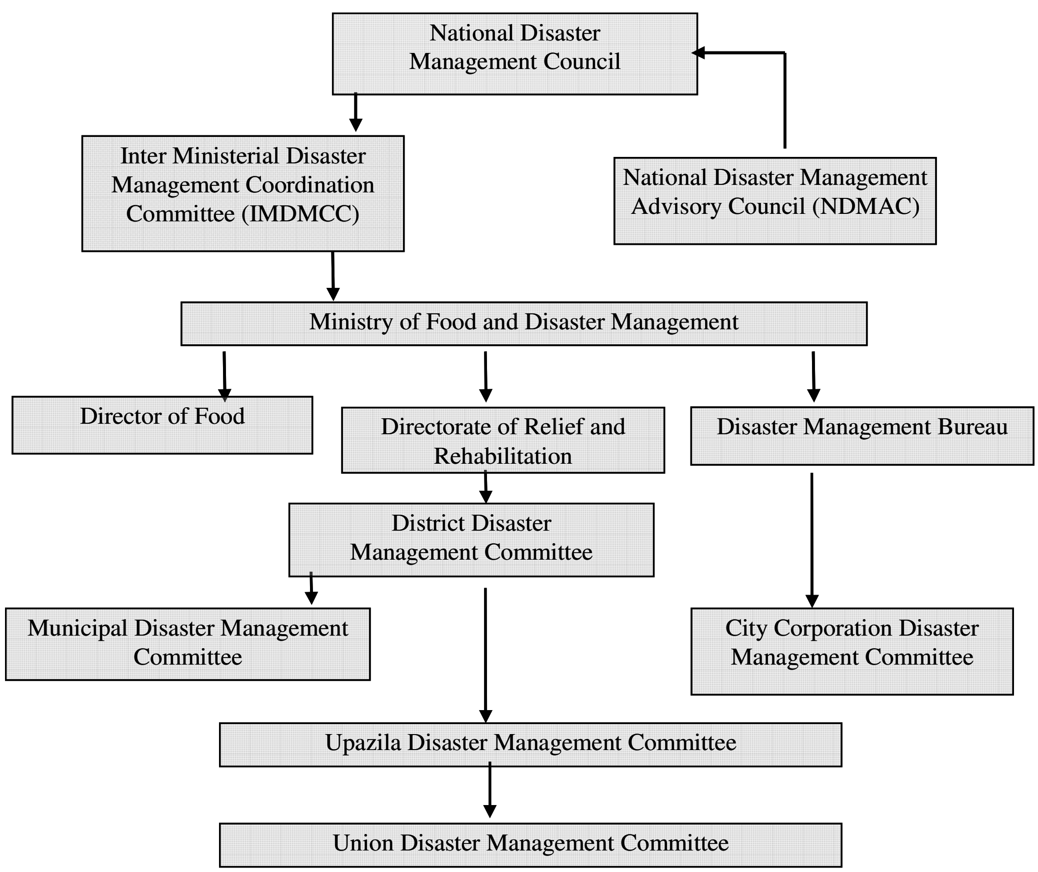

Fig.23. Disaster management systems in Bangladesh

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

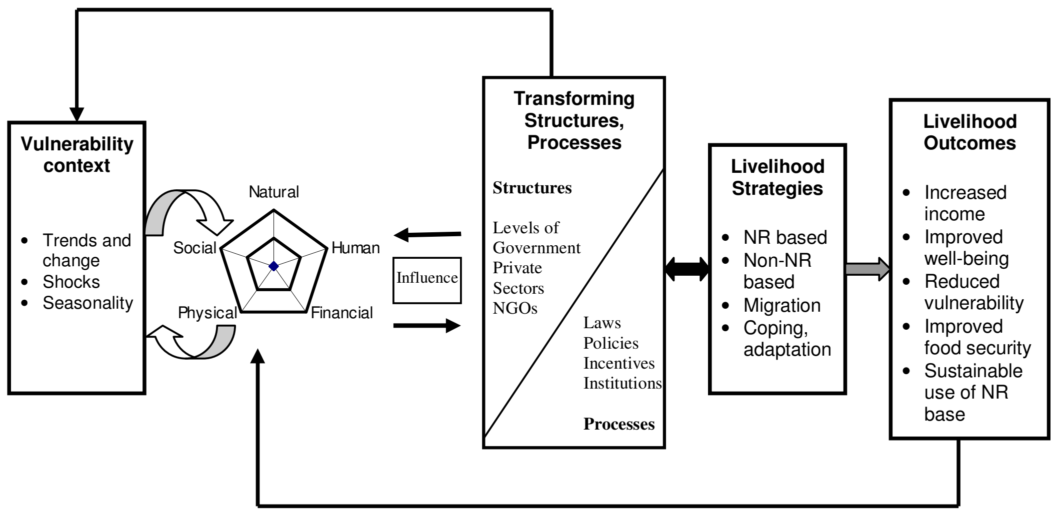

Fig. 24. Overview of the sustainable livelihoods framework (Carney, 1998)

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.

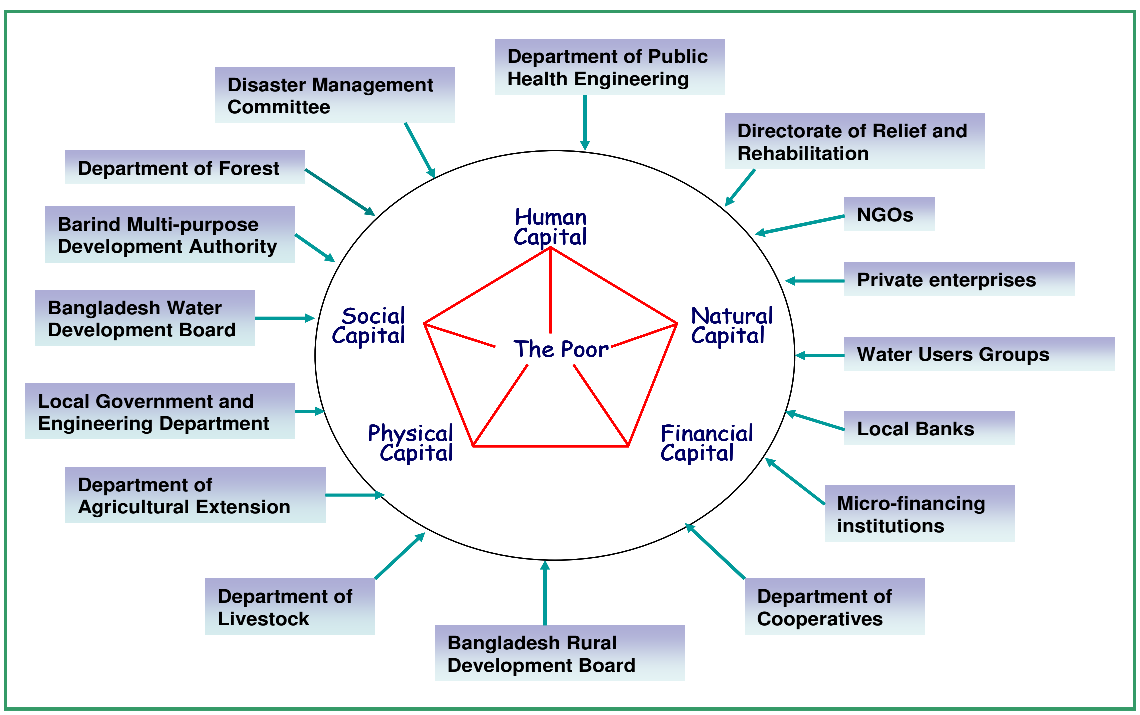

Fig. 25. Institutions targeting livelihood asset development at the local level

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.

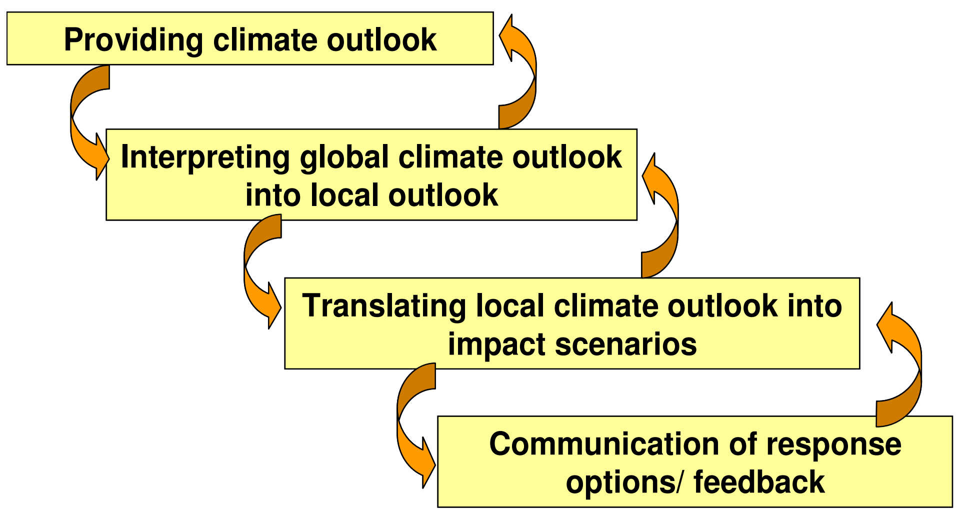

Fig.26. A framework for climate information generation and application system for climate forecast applications as promoted by the project

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.

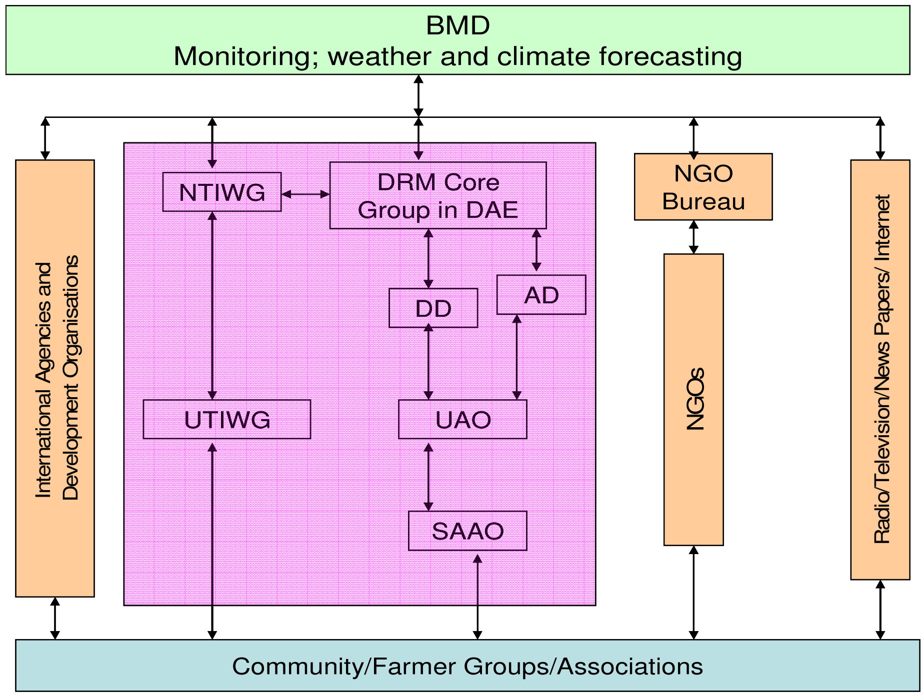

Fig.27. Institutional set-up for generation and application of weather and climate forecast products for drought risk management in Bangladesh

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 intensification	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	G	G	G	G	B	G	G	O	O	O	G	O	G	B	O	G
2.	Manures and composting	B	G	G	G	B	G	B	B	O	B	B	O	B	B	O	G
3.	Depth of transplanting for T.*Aman*	O	B	G	B	O	O	O	O	O	B	O	O	B	O	O	O
4.	Weed control-reduce water seepage	B	B	G	B	B	O	B	O	O	B	B	O	B	O	O	O
5.	Manual closing of soil cracks	B	B	G	B	O	O	O	O	O	B	B	O	G	O	O	O
6.	Strengthening field bunds (Ail lifting)	B	B	G	G	B	B	B	O	O	B	B	O	G	O	O	G
7.	Re-excavation of traditional ponds	G	G	G	G	B	G	B	O	B	B	G	G	G	G	G	B
8.	Re-excavation of khari canals	G	G	G	B	B	G	G	O	B	B	G	G	G	G	B	B
9.	Canals	G	G	B	B	B	B	G	O	O	B	B	B	B	G	O	O
10.	Water control structures	B	B	B	O	O	B	B	O	O	O	O	B	G	O	O	B
11.	Miniponds	G	G	G	G	B	G	B	B	B	B	B	G	G	G	G	G
12.	Supplemental irrigation	B	B	G	B	B	B	G	O	O	O	O	O	G	B	G	O
13.	Shallow and deep tubewells	G	B	B	B	G	B	G	O	G	G	B	G	G	G	O	O
14.	System of rice Intensification	B	B	G	B	B	B	O	O	O	B	B	O	O	B	B	B
15.	Direct-sown rice (Drum Seeder)	B	B	G	B	B	B	O	O	O	B	B	O	B	O	B	B
16.	Drought-resistant rice varieties	B	B	G	B	B	O	B	O	O	O	B	O	G	B	B	G
17. a)	Green manure – T.*Aman* system	O	O	G	B	B	O	B	O	B	B	B	O	B	O	O	B
b)	T. Aus – Chini Atap system	O	O	G	G	G	B	B	B	B	B	B	O	G	B	O	G
c)	*T. aman* – Mustard/Linseed system	O	O	G	G	G	B	B	O	B	B	B	O	B	O	B	B
d)	*T. aman* – Chickpea	O	O	G	G	G	B	B	B	B	B	B	O	B	O	B	G
e)	*T. aman* – Mung Bean	O	O	G	G	G	B	G	B	B	B	B	O	B	B	G	G
f)	Famine reserve crops	B	G	G	G	G	G	G	B	B	B	G	O	G	G	O	B
18.	Mango and jujube (ber) cultivation	G	B	G	G	G	B	B	B	G	B	B	O	G	B	B	B
19.	Homestead gardens	B	B	G	G	G	G	G	G	G	G	B	B	G	B	B	G
20.	Mulberry intercropping in rice	G	G	G	B	G	G	O	G	G	G	B	B	B	O	O	O
21.	Fodder cultivation	B	B	G	G	B	B	B	G	B	B	B	B	B	B	O	O
22.	Fish cultivation in miniponds	O	O	G	B	O	O	B	O	O	B	O	B	B	O	O	O
23.	Cottage industries	B	G	G	G	B	G	G	G	G	G	G	O	G	G	O	G
24.	Manufacturing industries	B	G	O	B	B	B	B	B	B	B	B	B	B	B	B	B
25.	Community-based biogas and tree planting	B	G	G	B	B	B	B	B	B	B	B	B	B	B	O	B
26.	Post-harvest seed storage	B	G	G	B	B	B	G	G	G	O	B	B	B	B	O	B

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.