

CLIMATIC VARIATIONS: FARMING SYSTEMS AND LIVELIHOODS IN THE HIGH BARIND TRACT AND COASTAL AREAS OF BANGLADESH¹

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Geographically Bangladesh is highly vulnerable to climate change. In particular, impacts, of climate variability on the agriculture and consequences on different other sectors are already evident in the drought prone High Barind Tract and coastal regions. The agriculture and fisheries sectors in the High Barind Tract (HBT) and southern coastal region are very likely to face significant yield reduction in future due to climate change. Global circulation model results revealed that because of higher temperature and water stress due to heat would result in decline in vegetation and agricultural production especially in the drought affected High Barind Tract. While the coastal region would suffer from increased degradation of land, salinity intrusion, river bank erosion, siltation, water logging, tidal surge and floods. Drought delays the timely planting of T.Aman- the main crop of HBT, while drought in September, October drastically reduce the yield of the said crop, and the chance of sowing/planting of different rainfed rabi crops markedly decreased. Nation-wide rice production losses due to drought in 1982 were about 50% more than losses due to flood in the same year, particularly in the HBT >80% T.Aman rice production was lost. Moreover, the ground water table of HBT is continuously going down in dry season due to overexploitation by deep-tube well. The 1997 drought caused a reduction of around 1 million tons of food grain, of which about 0.6 million tons was T.Aman, entailing a loss of around \$ 500 million. A cyclone in 1970 resulted in 300,000 deaths, and another in 1991 led to loss of 138,000 lives. These effects are likely to be exacerbated by climate change as peak intensity of cyclones is projected to increase by 5-10% and precipitation rates may increase by 20-30%. The strength of SIDR and economic losses caused by the major Hurricane in 2007 fits into this trend. Even before the new impacts of SIDR about 1.2 million hectares of arable land were already affected by varying degrees of soil salinity, tidal flooding during wet season, direct inundation by saline water and upward and lateral movement of saline ground water during dry season. Inundation of brackish water for shrimp farming is key causes for secondary salinisation of coastal lands. The severity of salinity problem has increased over the years and expected to increase in future due to rise of sea level. Even in non-cyclonic situations, higher mean sea-levels are going to increase problem of coastal flooding and salinisation causing significant pressure on livelihood activities.

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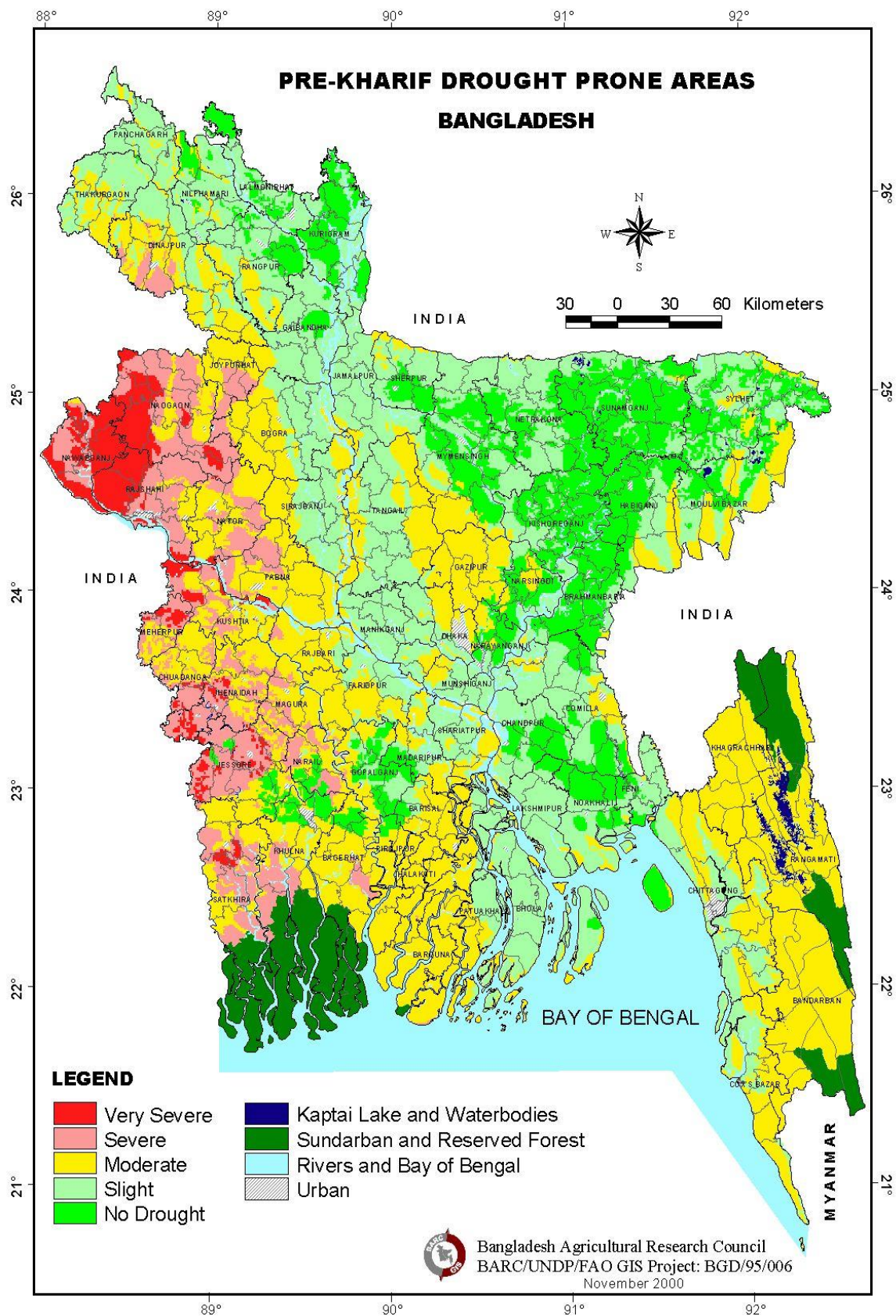
Thus climate change effect has a large negative impact on the farming systems and livelihoods of rural people of HBT and coastal area and on overall economy of Bangladesh.

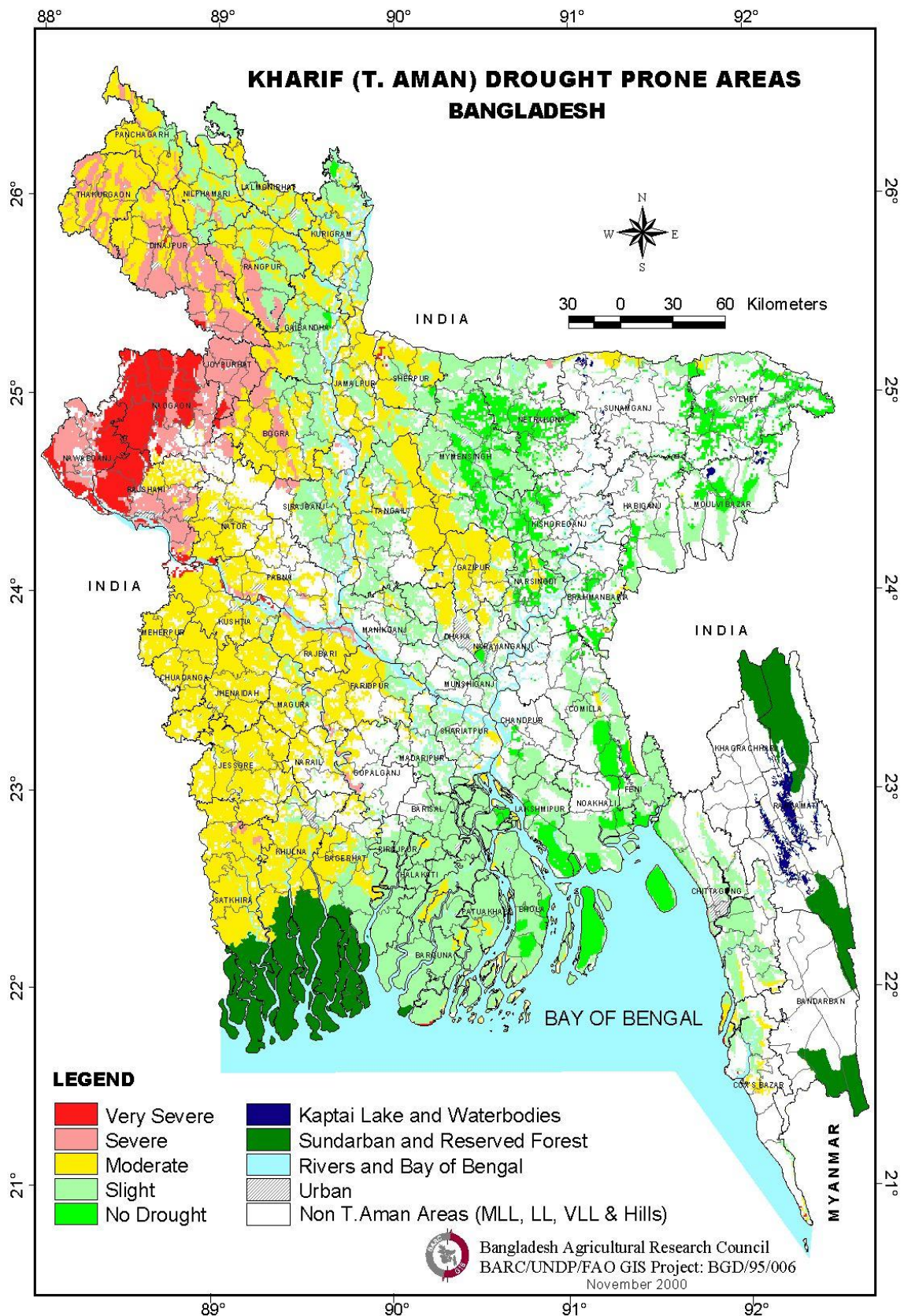
Introduction

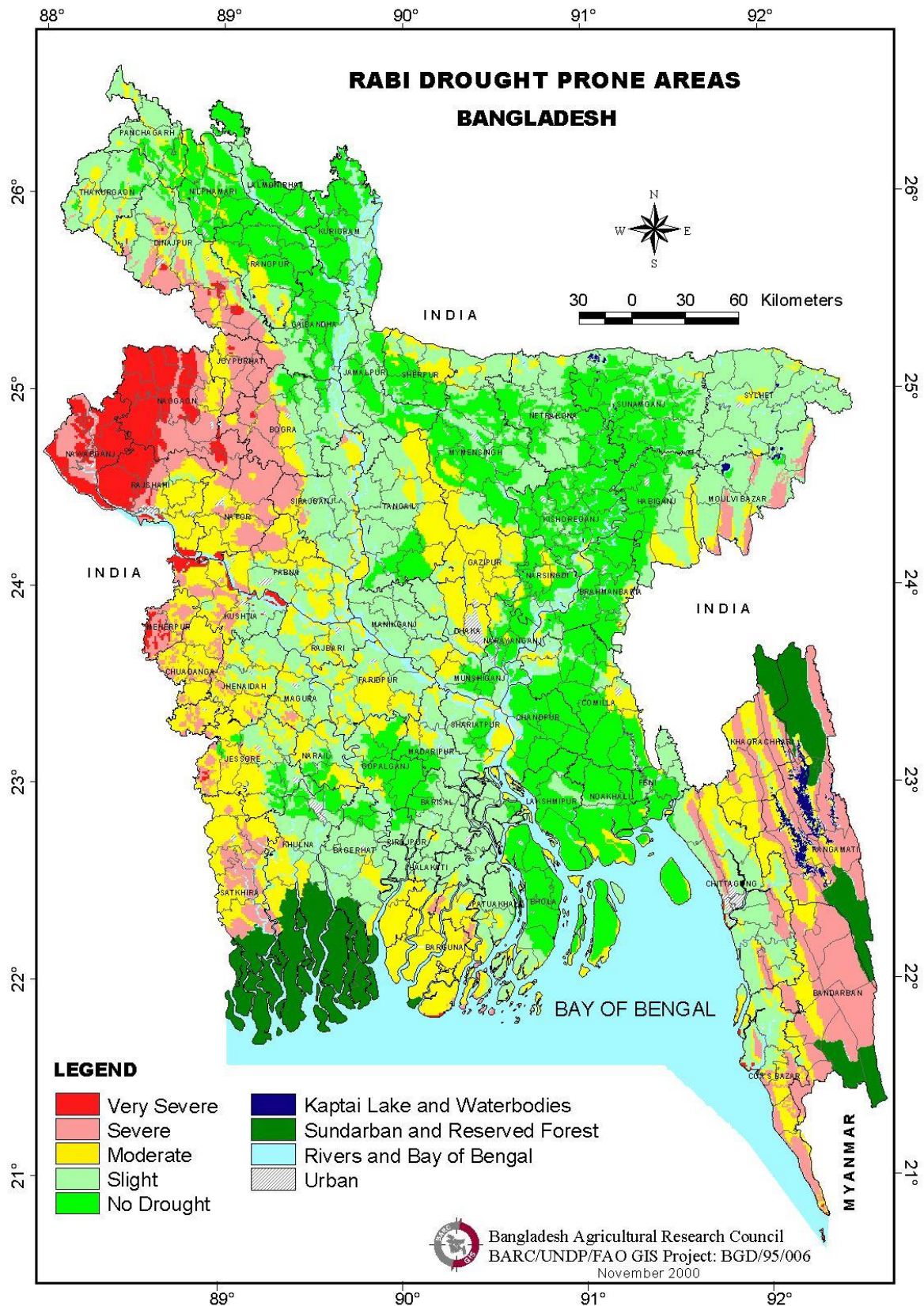
Climatic variations have a profound effect on agriculture and livelihoods of rural communities. The effect of climatic variation is more pronounced in the drought prone High Barind Tract (HBT) and coastal areas of Bangladesh. Among the drought affected areas, HBT is one of largest area (Brammer, 1999). In Bangladesh the HBT of north-west Rajshahi division is different from other parts of the country due to its undulating topography having compact and low fertile soils. The region experienced high temperature with limited soil moisture storage along with low and erratic rainfall(1075 ± 325 mm) (BMDA, 2006). Moreover no river/large water bodies are present within the HBT. Also vegetation is scanty compared to other parts of the country. Moisture holding capacity of HBT soil is poor due to critical organic matter contents and low infiltration of water (Ali, 2000; Ali *et al.* 2007). These situations make the area drought prone along with poor crop productivity. Moreover, recent report indicates that ground water level of Chapai Nawabganj district (within HBT) rapidly falling due to over exploitation through deep tube well (Selvaraju *et al.* 2006). About 55 % area of HBT is rainfed (Ali, 1998) and the deep tube wells have far less command area than expected and also irrigation cost is higher than that of other areas. T. Aman rice is the major crop which suffered regularly due to early or late drought and planting of post-rainy crop. Thus, the areas livelihood is often vulnerable to climate change particularly to drought (Ali *et al.* 2007).

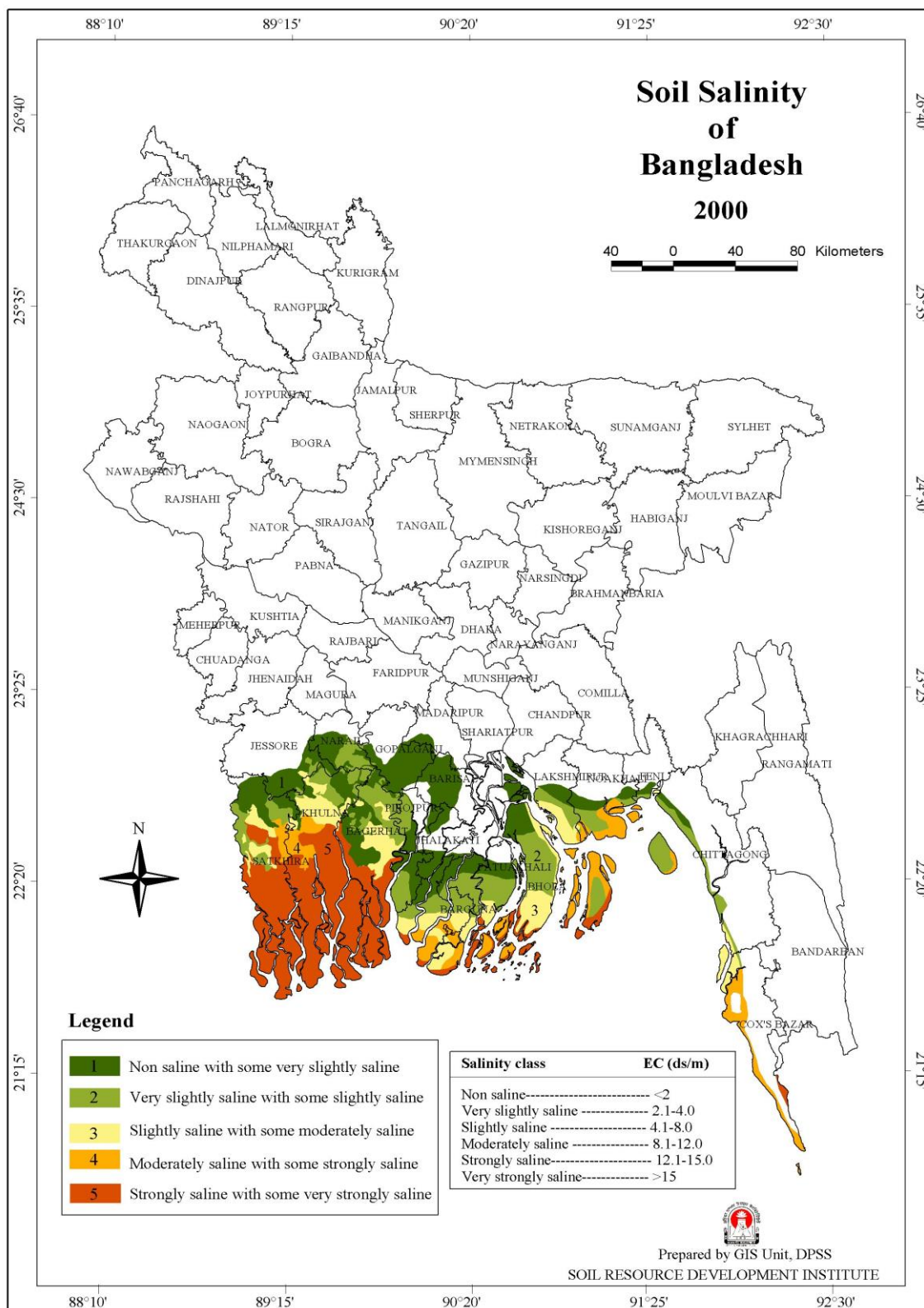
Salinity causes unfavorable environment and hydrological situation restricting the normal crop production throughout the year (Amin *et al.*, 2008) and few crops/cultivars could survive in severe saline soils. In Bangladesh, more than 30% of net cultivable area is in the coastal belt of which about 0.833 million hectares (m ha) of saline soils (Karim and Iqbal, 2001) and already increased up to 1.2 m ha. Salinity gradually increased from eastern coastal belt to western coastal belt mainly due to very low flow of upstream water of the Ganges and its tributaries during November to May because of commissioning of disastrous Farraka Barrage on the Ganges in the West Bengal of India since 1974. The coastal area of Bangladesh has less cropping intensity due to rise of salinity during dry season and other constraints such as, river erosion, flood, poor drainage condition, heavy clay basin, scarcity of irrigation water, low soil fertility status, exposure to cyclone storm surges, risk of early and late rainfall. In Khulna region (secondary salinity), crop lands are converted to shrimp “gher” by the rich man thus rendering the non-saline crop land to saline as a result lands are becoming unsuitable for rice or other crop cultivation. Non-saline lands are becoming saline under four circumstances; (a) when they flooded by saline water during storm-surge or by breaking of a coastal embankment, (b) when drought occurs in pre-monsoon season, (c) when drought occurs in post-monsoon season, (d) if a tube-well (or other irrigation source) starts to deliver saline water during a crop growing period (Brammer, 1999). With the intrusion of strong saline water production of different crops, fruit trees, are seriously affected as a result livelihood and economy of farmers of those area are seriously hampered. Moreover, Global Circulation Model results revealed that due to rise of temperature, drought and salinity/cyclone/storm surge in Bangladesh could increase in an alarming rate in the near future.

In these context, some trials were conducted by OFRD, BARI at coastal and drought areas to overcome the challenges of climate. Some findings of three vulnerable areas are furnished in the report along with some primary data and information on climatic effect on agriculture and livelihoods also given.









Methodology

Crops and cropping pattern with varieties of drought area (HBT) and coastal area (Noakhali, Patuakhali and Khulna) were studied. Beside a survey was conducted at drought prone area of High Barind Tract, Godagari, Rajshahi and for coastal belt of six locations viz. Bagerhat, Dacope of Khulna, Noakhali sadar, Subarnochar, Noakhali, Dumki and Kalapara of Patuakhali to investigate the effect of climatic variations on the farming systems and livelihoods of the people during May-July 2008. Primary information was collected from elderly farmers of above 50 years age who can compare between the present and past agricultural systems, livelihoods and climatic change through pre-designed and pre-tested questionnaire. Collected data were verified through Focal Group Discussion and discussion with key informants. A total of 200 samples were randomly collected from seven Upazilas. Among them for the drought prone High Barind Tract 50 samples were collected from eight villages of Godagari Upazila of Rajshahi district. While for coastal and saline areas 150 samples were collected from six Upazilas viz. Bagerhat, Dacope of Khulna, Noakhali sadar, Subarnochar, Noakhali, Dumki and Kalapara of Patuakhali. For each above mentioned Upazilas 25 samples were collected at random. Besides, meteorological information from Bangladesh Meteorological Department, Dhaka data are presented in graphical forms. Necessary secondary information was also collected from DAE, BARI, SRDI & BMDA reports and through literature review.

Results and Discussion

High Barind Tract (HBT), Rajshahi

In High Barind Tract, the predominant cropping patterns were Fallow-Fallow-T.Aman, B.Aus-T.Aman & Wheat-T.Aman for highland and Fallow-Fallow-T.Aman, Chickpea-T.Aman, Chickpea + Linseed-T.Aman, Mustard/Linseed-T.Aman for medium highland under rainfed condition in 1980s. During that time the local T.Aman rice varieties namely Raghusail, Dadkhani, Magurshail, Batraj, Chengul, Chita etc. and in some extent high yielding varieties of T.Aman rice namely BR10, BR11 and BR4 were cultivated under rainfed condition (Table 1). In 1985, most of the crops produced the lower yield with local varieties. Due to erratic rainfall, poor management practices, unavailable irrigation facilities and use of low yield potential varieties. But in 2007, most of the crops produced higher yield due to use of high yielding varieties, development of irrigation system and use of improved management practices. In 1985, cropping intensity of HBT was 117% and 166% in 1992-93 whereas present cropping intensity of this area is 216% (BMDA, 2006).

Experimental results revealed that in many years drought prevailed during the flowering stage of T.Aman rice. As a result 11-34% yield loss occurred for local T.Aman and 43-50% for modern varieties. Supplementary irrigation by harvesting run off water in a mini pond having an area of 300 cubic meters (10m x 10m x 3m) can save the yield loss for an area of one hectare of land (Annon., 1991). In the recent years the irrigation facilities have further expanded which create the opportunity to cultivate modern varieties of different crops with modern method of cultivation resulted increase yields. Under the changing circumstances different rabi crops like wheat, boro rice, tomato, potato, mustard, hybrid maize etc. have been also cultivated under irrigated condition.

Drought is the major climatic hazard in the HBT. About 82% farmers responded that crop failure (particularly T.Aman) due to low rainfall and acute scarcity of water. However, they have not identified that intensity of drought has increased or decreased. Eighty two percent opined that water hold in perennial ponds round the year in 1980s. Now 66% responded that it has reduced due to drought, low/inadequate rainfall, siltation and increased use of pond water for crop production (Appendix 3, 4 & 5). Seventy two percent farmers opined that more ponds should be excavated and 16% felt the need of pond re-excavation (Appendix 6). Cropping pattern have changed mainly due to development of irrigation facility along with availability of high yielding varieties and modern technologies (Appendix 7 and 8). Livelihood of the farmers has improved through the intervention of modern agricultural technologies along with development of better communication. However, long term effect of increased ground water lifting should be monitored carefully. Maximum and minimum mean temperature have increased slightly (Fig. 1). Rainfall was erratic around 800-2200 mm but at the later it was exceptionally high for HBT (Fig. 2).

Noakhali

In Noakhali, the predominant cropping patterns in 1980s were Fallow-Fallow-T.Aman & relay Khesari - T.Aman for medium lowland and Groundnut-T.Aman, Sweet potato-T.Aman, Cowpea-T.Aman & Chilli - B.Aus/D.Aus - T.Aman for medium highland (Table 2). Cropping intensity as well as yields of different crops increased due to use of improved varieties, quality seeds and use of recommended production practices. In 1980s, the major crops were T.Aman rice, khesari, groundnut and cowpea. These major crops produced lower yield due to higher salinity and unavailable irrigation water. But in 2007, major crops yielded higher due to introduction of modern varieties and use of improved management practices.

Salinity of Noakhali decreased over time by different natural ways such as leaching by rain water and further non-intrusion of saline water (Appendix 10). Crop diversification markedly increased along with adoption of high yielding varieties and technologies for ensuring food security to growing population which resulted in increased food production (Appendix 12). However, fodder production was reduced (Appendix 13) due to bringing of fallow land under cultivation and adoption of modern rice cultivars, which gave reduced amount of straw. Also production of vegetables, fruits, timber tree and poultry birds increased for meeting the demand and higher earning. However, cattle/buffalo/goat population reduced due to fodder/feed crisis and for lack of grazing land. Due to climatic effect and intense cropping, cost of cultivation was increased, higher incidence of insect, pest and diseases, decrease of soil fertility of the area. Open water fish availability was also reduced. Overall livelihoods of the farmers improved ensuring enhanced food security and improvement of other social indicators. Maximum and minimum temperature (Fig. 3) increased slightly and rainfall variation was 2000-4800 mm (Fig. 4).

Bagerhat and Khulna

The cropping patterns which were practiced by the farmers of Dacope, Khulna in 1980s were Fallow – Fallow - T.Aman, Lentil-T.Aman & Sesame-T.Aman in medium highland and Fallow-Fallow - T.Aman in medium lowland (Table 3). The cropping patterns have been changed due to

use of salt tolerant modern rice varieties and to making Gher for shrimp culture. In 1980s, major crops produced lower yield due to high salinity and unavailable irrigation water. But in 2007, major crops yielded higher due to introduction of modern varieties and use of improved management practices. The yields of local T.Aman rice and sesame have been decreased due to increase the salinity level in the recent years (Table 5).

Salinity of Bagerhat and Khulna (Ganges Tidal floodplain) is mainly related to decreased water flow from the upward of the Ganges and its tributaries due to Farraka barrage resulting in increased intrusion of saline water from the Bay. However, secondary salinity (for making shrimp gher) is also another cause of increasing soil and water salinity. Shrimp culture has become a major cause of increased salinity in Bagerhat. Whereas at Dacope, 84 % farmers reported that due to intrusion of saline water within the embankment (by breaking) is the major reason of increasing salinity along with shrimp culture (20% farmers) (Appendix 14). In Bagerhat, crop diversification has reduced due to culture of shrimp. Whereas at Dacope crop diversification has markedly increased through the intervention of modern technology, as shrimp cultivation is still in small area. In Bagerhat, 12% farmers reported that tree population has decreased due to increase of salinity and year round inundation for making shrimp gher (Appendix 15). While at Dacope, change of the agricultural systems is mainly due to intrusion of saline water through embankment breakage (like through SIDR), lack of sweet water for irrigation in dry season (Appendix 15). In both locations yield of T.Aman have reduced due to increased salinity and late planting, though yield of modern variety was more than local variety (Appendix 16). Increased salinity has a profound negative effect on the livestock health due to decrease of fodder production because of salinity, shrimp gher, long inundation, modern rice cultivation and polluted water. Enhanced salinity and climatic hazards like SIDR have ill effect on the health of human along with increased disease incidence and sudden death. Through shrimp gher farmers of Bagerhat increased their income and improved their livelihood. But people of Dacope failed to improve their livelihood through increased crop diversification because of escalation of production cost, and frequent natural hazards as it is closer to the Bay. Mean monthly maximum and minimum temperature increased slightly (Fig. 5) while rainfall ranges from 1100-2600 mm (Fig. 6).

Patuakhali

In eighties, major cropping patterns in Patuakhali were Fallow-Fallow-T.Aman, Chilli-T.Aman under medium highland situation and Sweet potato-T.Aman, Groundnut-T.Aman, Sesame-T.Aman, T. Aus-T.Aman, Relay Khesari-T.Aman & Mungbean/Sesame-T.Aman under medium lowland condition (Table 4). Utilization of fallow land, use of modern crop varieties, appropriate production technologies and intervention of the technologies has helped in changing the cropping systems and simultaneously increased the crop yields in the areas. Traditionally Patuakhali was less saline affected, further salinity was reduced through construction of embankments, wash out by rain water and no further intrusion of saline water (Appendix 10). Cropping intensity was increased through introduction of new crops along with modern varieties and technologies which resulted in increased crop production and food security (Appendix 12). However, fodder production was reduced due to absence of fallow land and cultivation of modern rice varieties

(Appendix 13). Due to climatic effect and intense cropping cost of cultivation was increased, higher incidence of insect, pest and diseases, decrease of soil fertility. Open water fish availability was also reduced. Overall livelihood of the farmers improved through adoption of modern agricultural technologies along with improvement of other social indicators (Appendix 12). Maximum temperature increased slightly while minimum temperature showing a bit reduction (Fig. 7). Year to year rainfall variation (1800-4300 mm) was large (Fig. 8).

Soil salinity status between 1973 and 2000 in Noakhali, Satkhira, Bagerhat, Khulna and Patuakhali are presented in Table 5. It was observed that salinity level of different locations increased in the year of 2000 except Patuakhali.

In Khulna area, 82% farmers responded that they sown their rabi crops timely but in 2007, only 18% responded (Table 6). The incidence of disease and pest was decreased in 1980s by 92% where in 2007 only 8% responded. The crop production affects only 2% in 1980 but it affects 98% in 2007.

In 1980s, 70% farmers opined that they sown their rabi crops timely but in 2007, only 30% responded in Noakhali areas (Table 6). About 98% farmers responded that incidence of disease and pest decrease in 1980s where in 2007 only 2% responded. Only 70% farmers responded that salinity affects crop production in 1980s but in 2007, only 30% responded. In 1980s, the livelihood of the local farmers was increased 15% but 85% farmers reported in 2007.

In Patuakhali, rabi crops sown timely by 75% in 1980s whereas only 25% responded in 2007 (Table 6). The incidence of disease and pest decrease in 1980s whereas in 2007 only 13% responded. The salinity affects crop production by 55% but in 2007, 45% responded. The livelihood pattern of the farmers was increased by 13% whereas in 2007 which showed positive and increased up to 87%.

Bangladesh Agricultural Research Institute has already carried out some study to mitigate drought situation of High Barind Tract and screening of crops/variety for saline areas

Technologies to mitigate drought situation of HBT



- On-farm experimental results revealed that in many years drought prevailed during flowering and grain filling stage of T.Aman rice. As a result 11-34% yield loss occurred for local and 43-50% for modern T.Aman rice varieties. To mitigate the situation supplemental irrigation by harvesting run off water in a mini pond (10m x 10m x 3m) can save the yield loss of one hectare of land (Annual Progress Report, OFRD, BARI, 1991).
- Through on-farm trials seed priming of chickpea increased the seed yield of 20-25% over non-priming under moisture stress situation of HBT

- Chickpea, barley, sesame, linseed, kangkong, stem amaranth, coriander and mungbean were found promising for moisture stress/drought situation
- Besides these, improved crop management practices viz., mulching and minimum tillage were also found to mitigate the challenges of moisture stress/drought/moisture stress of HBT

Screening of crops/variety for saline areas

- Tolerance of rabi field crops to salinity is approximately as follows:
 - Sweet potato > cowpea > groundnut > millets > soybean > triticale > mungbean > sesame > barley > wheat > mustard
- For vegetables, spices and fruits the ranking would look like this:
 - Batishak > chilli > kangkong > garlic > indian spinach > okra > water melon > red amaranth
- Besides these, improved crop management practices viz. raised bed with mulch, mulching, zero tillage, sorjan method etc. were also found to mitigate the challenges of salinity and rise of temperature

In summary the following points may be considered for impact assessment on the basis of climate change scenarios

Climate influence

- Crop production
- Population distribution
- Vegetation
- Soil, water and animal resources
- Temperature, rainfall and natural hazards like cyclone, flooding, drought, salinity changes and erosion
- Human health
- Industry, energy, infrastructure and communication
- Urbanization
- Food demand and supply

Impact on agriculture

- Agricultural crops are highly vulnerable to climate events
- Occurrence of unprecedented floods
- Occurrence of flash floods
- Occurrence of droughts (kharif I and later part of kharif II and rabi)
- Emissions of nitrous oxide, carbon monoxide and nitrogen oxides from agril. residues
- Excessive emission of methane gas has been contributing to the global warming
- The residual effects of climate changes have been destroying the content of organic matter in the soil and also the protein sources.

On the above fact, the following adaptation measures may be taken:

Adaptation measures

- Improved irrigation efficiency
- Crop diversification (introduction of salt and drought tolerant variety for coastal and Barind area)
- Conjunctive use of surface and ground water irrigation
- Change in fertilization techniques (deep placement of fertilizer, hole system etc.)
- Coastal green belt forestry through GO-NGOs collaboration
- Agro-forestry development
- Homestead vegetable and agroforestry development
- Community forest development through GO-NGOs partnership

Institutional adaptation

- Improved of agricultural extension services and proper linkage with farmers for adoption of new technology for those area
- Enhance training program and dissemination activities
- Research and development of salinity and drought tolerant crops and high yielding varieties
- Re-excavation of ponds/cannel in Barind area
- Change practices (cultural and other management practices such as tillage, sorjan, relay, ICM/IPM/IPNS concept)
- Expanded access to incentive for conservation agriculture
- Guidelines to incorporate climate change in future planning
- Development of reserved /protected areas in different agro-ecological zones (coastal areas)
- Co-operative social forestry support services with the involvement of vulnerable women and men.

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Table 1. Crops and cropping patterns with varieties and their yields in High Barind Tract in 1985 and 2007

Land type	Cropping pattern		Crops/variety		Yield (t/ha)		Remarks
	1985	2007	1985	2007	1985	2007	
Highland	Rainfed: F-F-T.Aman	Rainfed: F-F-T.Aman	T.Aman (Local): Raghusail, Dadkhani, Magurshail, Batraj, Chengul, Chita T.Aman (HYV): BR 10, BR 11, BR 4	T.Aman (HYV): Swarna, BRRI Dhan 30	T.Aman (Local): 2.93 T.Aman (HYV): 4.20	T.Aman: Swarna- 5.80, BRRI Dhan 30- 5.10	The rice varieties have been changed due to its high yield potential as well as good grain quality.
	Rainfed: B. Aus-T.Aman	Irrigated: Tomato-T. Aus/T. Aus-T.Aman	B. Aus (Local): Purbisaita, Kalchina, Bhoira T.Aman (Local/HYV)	Tomato (Hybrid): Hitom, Surokkha T. Aus (Local): Parija	B. Aus (Local): 1.74 T.Aman (Local): 2.88 T.Aman (HYV): 4.15	Tomato (Hybrid): 36.37 T. Aus (Local): 2.34 T.Aman (HYV): 5.70	With the development of irrigation systems the cropping patterns have been changed.
	Rainfed/Irrigated: Wheat-T.Aman	Irrigated: Wheat-T.Aman	Wheat: Sonalika T.Aman (Local/HYV)	Wheat (HYV): Kanchan, Shatabdi T.Aman (HYV)	Sonalika- 0.95 (Rainfed), 1.52 (Irrigated) T.Aman (Local): 2.95 T.Aman (HYV): 4.22	Kanchan/Shatabdi- 2.12/2.56 T.Aman (HYV): 5.56	Improved varieties and management practices increased the yields.
Medium Highland	Rainfed: F-F-T.Aman	Rainfed: F-F-T.Aman/ Chickpea-T.Aman	T.Aman (Local/HYV)	T.Aman (Local/HYV) Chickpea (HYV): Barichola-5	T.Aman (Local): 2.95 T.Aman (HYV): 4.26	T.Aman (HYV): 5.87 BARI chola-5: 1020 kg	The crop yields have been increased due to introduce of modern varieties and improved management practices.
	Rainfed: F-F-T.Aman	Irrigated: Boro-T.Aman	T.Aman (Local/HYV)	Boro: BRRI Dhan 29 T.Aman (HYV)	T.Aman (Local): 2.75 T.Aman (HYV): 4.12	BRRI Dhan 29: 6.17 T.Aman HYV: 5.65	Due to development of irrigation facilities the cropping systems have been changed as well as increased the yields.
	Rainfed: Chickpea + Linseed-T.Aman	Rainfed: Chickpea-T.Aman	Chickpea (Local) Linseed (Local) T.Aman (Local/HYV)	Chickpea (HYV): BARI chola-5 T.Aman (HYV)	Chickpea: 532 kg/ha Linseed: 320 kg/ha T.Aman (Local): 2.68 T.Aman (HYV): 3.97	BARI chola-5: 950 kg T.Aman (HYV): 5.85	Yields increased due to modern varieties and improved management practices.
	Rainfed: Mustard/Linseed-T.Aman	Irrigated: Mustard-T.Aman	Mustard: Tori-7 Linseed (Local) T.Aman (Local/HYV)	Mustard (HYV): BARI sarisha-11 T.Aman (HYV)	Mustard: 430 kg/ha Linseed: 332 kg/ha T.Aman (Local): 2.57 T.Aman (HYV): 3.88	BARI sarisha-9: 1.07 T.Aman (HYV): 5.61	Due to development of irrigation systems the cropping patterns have been changed as well as increased the yields.

Table 2. Crops and cropping patterns with varieties and their yields in Noakhali in 1980 and 2007

Land type	Cropping pattern		Crops/variety		Yield (t/ha)		Remarks
	1980	2007	1980	2007	1980	2007	
Medium Lowland	Fallow-Fallow-T.Aman	Fallow-Fallow-T.Aman	T.Aman (Local): Rajashail, Betichikon, Gigoj	T.Aman (Local): Kajalshail T.Aman (HYV): BR 23, BRRI dhan 40, BRRI dhan 41	T.Aman (Local): 2.25	T.Aman (Local): 2.83 T.Aman (HYV): 4.32	With the introduction of modern varieties and improved production technologies increased the yields.
	Relay Khesari-T.Aman	Relay khesari-T.Aman	Khesari (Local) T.Aman (Local)	Khesari (Local) T.Aman (Local/HYV)	Khesari (Local): 620 kg T.Aman (Local): 2.35	Khesari (Local): 810 kg T.Aman (Local): 2.41 T.Aman (HYV): 4.45	Do
	Relay Khesari-T.Aman	T. Aus-T.Aman	-	T. Aus (Local): Hytta T. Aus (HYV): BRRI dhan 27 T.Aman (Local/ HYV)	-	T. Aus (Local): 2.50 T. Aus (HYV): 3.76 T.Aman (Local): 2.45 T.Aman (HYV): 4.61	Due to the development irrigation systems the cropping systems have been changed.
	Relay Khesari-T.Aman	Relay khesari- T. Aus -T.Aman	-	Khesari (Local) T. Aus (Local/ HYV) T.Aman (Local/ HYV)	-	Khesari (Local): 831 kg T. Aus (Local): 2.55 T. Aus (HYV): 3.64 T.Aman (Local): 2.32 T.Aman (HYV): 4.75	Do
Medium Highland	Groundnut - T.Aman	Groundnut-T.Aman	Groundnut (Local) T.Aman (Local)	Groundnut: Dhaka-1 T.Aman (Local/HYV)	Groundnut (Local): 1.02 T.Aman (Local): 2.41	Groundnut (Dhaka-1): 1.31 T.Aman (Local): 2.34 T.Aman (HYV): 4.67	Uses of modern crop varieties have increased the yields.
		Soybean-T.Aman	-	Soybean: Sohag T.Aman (Local/HYV)	-	Soybean: 1.88 T.Aman (Local): 2.37 T.Aman (HYV): 4.59	Soybean has been fitted well into the existing cropping pattern for adaptability in the locality.
		Soybean- B. Aus/ D.Aus-T.Aman	-	Soybean: Sohag B. Aus/D. Aus (Local): Hytta B. Aus/D. Aus (HYV): BRRI dhan 27 T.Aman (Local/HYV)	-	Soybean: 1.84 B. Aus/D. Aus (Local): 2.37 B. Aus/D. Aus (HYV): 3.48 T.Aman (Local): 2.41 T.Aman (HYV): 4.61	Do
	Groundnut - T.Aman	Mugbean-T.Aman	-	Mugbean (Local/ BARI mung-6) T.Aman (Local/HYV)	-	Mugbean (Local): 620 kg Mugbean (BARI mung-6): 850 kg T.Aman (Local): 2.38 T.Aman (HYV): 4.53	Mugbean has been adapted well into the existing cropping pattern in the locality.
	Sweet potato-T.Aman	Sweet potato-T.Aman	Sweet potato (Local) T.Aman (Local)	Sweet potato (Local) T.Aman (Local/HYV)	Sweet potato (Local): 10.5 T.Aman (Local): 2.44	Sweet potato (Local): 11.53 T.Aman (Local): 2.47 T.Aman (HYV): 4.61	Uses of modern varieties and improved management practices increased the yields.
	Sweet potato-T.Aman	Sweet potato- B. Aus/D. Aus-T.Aman	-	Sweet potato (Local) B. Aus/D. Aus (Local/ HYV) T.Aman (Local/ HYV)	-	Sweet potato (Local): 11.61 B. Aus/D. Aus (Local): 2.39 B. Aus/D. Aus (HYV): 3.46 T.Aman (Local): 2.47 T.Aman (HYV): 4.58	Do
	Cowpea-T.Aman	Cowpea-T.Aman	Cowpea (Local) T.Aman (Local)	Cowpea (Local) T.Aman (Local/ HYV)	Cowpea (Local): 625 kg T.Aman (Local): 2.39	Cowpea (Local): 670 kg T.Aman (Local): 2.52 T.Aman (HYV): 4.61	Do
	Cowpea-T.Aman	Cowpea- B. Aus/ D.Aus-T.Aman	-	Cowpea (Local) B. Aus/D. Aus (Local/ HYV) T.Aman (Local/ HYV)	-	Cowpea (Local): 675 kg B. Aus/D. Aus (Local): 2.34 B. Aus/D. Aus (HYV): 3.36 T.Aman (Local): 2.38 T.Aman (HYV): 4.49	Do
	Chilli-B. Aus/D.Aus-T.Aman	Chilli- B. Aus/D.Aus-T.Aman	Chilli (Local) B. Aus/D. Aus (Local): Kerondol, Hytta, Boilam T.Aman (Local)	Chilli (Local) B. Aus/D. Aus (Local/ HYV) T.Aman (Local/ HYV)	Chilli (Local): 730 kg B. Aus/D. Aus (Local): 2.18 T.Aman (Local): 2.22	Chilli (Local): 1.10 B. Aus/D. Aus (Local): 2.37 B. Aus/D. Aus (HYV): 3.42 T.Aman (Local): 2.40 T.Aman (HYV): 4.52	Do

Table 3. Crops and cropping patterns with varieties and their yields in Dacope, Khulna in 1980 and 2007

Land type	Cropping pattern		Crops/variety		Yield (t/ha)		Remarks
	1980	2007	1980	2007	1980	2007	
Medium Highland	F-F-T.Aman	F-F-T.Aman	T.Aman (Local): Kanchra, Chinikani, Nalu dhan, Nonakhacci, Barosha, Birashi, Balam, Tikiram, Patni, Sada	T.Aman (Local): Kanchra, Chinikani, Nonakhacci, Sada mota T.Aman (HYV): BR 10, BR 11, BR 23, BRRI dhan 41, BRRI dhan 40	T.Aman (Local): 3.25	T.Aman (Local): 2.71 T.Aman (HYV): 4.35	Rice yield has decreased due to increase the salinity level and continuous inundation.
	F-F-T.Aman	F-B.Aus-T.Aman	-	B. Aus (HYV): BR 21, BR 22, BRRI dhan 28	-	B. Aus (HYV): 4.42	
	Lentil-T.Aman	Boro-T.Aman	Lentil (Local) T.Aman (Local)	Boro (HYV): BRRI dhan 28, BRRI dhan 29, HIRA	Lentil (Local): 615 kg T.Aman (Local): 3.20	Boro (HYV): 6.10 Lentil (Local): 900 kg T.Aman (HYV): 4.41	The cropping pattern has been changed due to making Gher for shrimp culture.
	Sesame-T.Aman	Sesame-B. Aus-T.Aman	Sesame (Local) T.Aman (Local)	Sesame (Local) B. Aus (HYV) T.Aman (Local/HYV)	Sesame (Local): 900 kg T.Aman (Local): 3.31	Sesame (Local): 700 kg B. Aus (HYV): 4.38 T.Aman (Local): 2.78 T.Aman (HYV): 4.45	Yields of sesame and T.Aman (Local) decrease due to increase in salinity level.
	F-F-T.Aman	F-F-T.Aman	T.Aman (Local)	T.Aman (Local/HYV)	T.Aman (Local): 3.37	T.Aman (Local): 2.81 T.Aman (HYV): 4.37	Do
		Boro-F-F	-	Boro (HYV)	-	Boro (HYV): 5.95	

Table 4. Crops and cropping patterns with varieties and their yields in Patuakhali in 1980 and 2007

Land type	Cropping pattern		Crops/variety		Yield (t/ha)		Remarks
	1980	2007	1980	2007	1980	2007	
Medium High Land	F-F-T.Aman	F-F-T.Aman	T.Aman (Local): Sada mota, Lal mota, Kajalshail, Rajashail, Moulata	T.Aman (Local) T.Aman (HYV): BR 22, BR 23, BRRI dhan 30, BRRI dhan 31, BRRI dhan 40, BRRI dhan 41	T.Aman (Local): 2.55	T.Aman (Local): 3.21 T.Aman (HYV): 4.53	Crop yields have been increased due to use of modern varieties and improved management practices.
	Chilli-T.Aman	Chilli-T.Aman	Chilli (Local) T.Aman (Local)	Chilli (Local) T.Aman (Local/HYV)	Chilli: 950 kg T.Aman (Local): 2.67	Chilli: 1.12 T.Aman (Local): 3.27 T.Aman (HYV): 4.48	Do
	Sweet potato-T.Aman	Sweet potato/Groundnut-T.Aman	Sweet potato (Local) Groundnut (local) T.Aman (Local)	Sweet potato (Local) Groundnut Dhaka-1 T.Aman (Local/HYV)	Sweet potato (Local): 12.25 Groundnut (local): 1.12 T.Aman (Local): 2.58	Sweet potato (Local): 13.78 Groundnut (Dhaka-1): 1.64 T.Aman (Local): 3.32 T.Aman (HYV): 4.50	Use of modern varieties and management practices enhanced the yields of the crops.
Medium Low Land	F-F-T.Aman	F-F-T.Aman	T.Aman (Local)	T.Aman (Local/HYV)	T.Aman (Local): 2.47	T.Aman (Local): 3.23 T.Aman (HYV): 4.47	Do
	T. Aus-T.Aman	T. Aus-T.Aman	T. Aus (Local): Gorishitta, Soloi, Girmi T.Aman (Local)	T. Aus (Local) T. Aus (HYV): BR 2, BR 3, BR 20, BR 21, BR 26, BRRI dhan 27, BAU 63 T.Aman (Local/HYV)	T. Aus (Local): 2.87 T.Aman (Local): 2.63	T. Aus (Local): 3.13 T. Aus (HYV): 3.42 T.Aman (Local): 3.17 T.Aman (HYV): 4.49	Do
	Relay Khesari-T.Aman	Relay Khesari-T.Aman	Khesari (Local) T.Aman (Local)	Khesari (Local) T.Aman (Local/HYV)	Khesari: 712 kg T.Aman (Local): 2.66	Khesari: 825 kg T.Aman (Local): 3.32 T.Aman (HYV): 4.57	Do
		Relay Khesari-T. Aus-T.Aman	Khesari (Local) T. Aus (Local) T.Aman (Local)	Khesari (Local) T. Aus (HYV) T.Aman (Local/HYV)	Khesari: 730 kg T. Aus (Local): 2.76 T.Aman (Local): 2.59	Khesari: 815 kg T. Aus (HYV): 3.38 T.Aman (Local): 3.34 T.Aman (HYV): 4.44	Do
Medium Low Land	Mungbean/Sesame-T.Aman	Mungbean/Sesame-T.Aus-T.Aman	Mungbean (Local) Sesame (Local) T.Aman (Local)	Mungbean (HYV): BARI mung-5, BARI mung-6 Sesame (Local) T.Aman (Local/HYV)	Mungbean (Local): 460 kg Sesame: 716 kg T.Aman (Local): 2.55	Mungbean (HYV): 1.12 Sesame: 820 kg T.Aman (Local): 3.37 T.Aman (HYV): 4.39	Use of modern varieties and management practices enhanced the yields of the crops.

Table 5. Comparison of soil salinity status between 1973 and 2000 in coastal areas of Bangladesh

District	Salt affected area (000'ha)		Salinity class								Salinity increase over 3 decades	
			S ₁ 2.0-40dS/m		S ₂ 4.1-8.0dS/m		S ₃ 8.1-16.0dS/m		S ₄ >16.0dS/ma		Area (000 ha)	%
	1973	2000	1973	2000	1973	2000	1973	2000	1973	2000		
Khulna	120.04	145.25	3.90	28.83	92.54	37.32	13.00	59.49	10.60	19.61	25.21	21.00
Bagerhat	107.98	125.13	8.30	35.66	77.08	41.50	2.60	41.23	20.00	6.74	17.15	15.88
Satkhira	146.35	147.08	16.50	27.03	85.60	38.01	33.50	60.03	10.75	22.01	0.73	0.50
Patuakhali	115.10	139.35	68.50	40.11	46.60	43.62	0	46.10	0	9.52	24.25	21.07
Noakhali	49.6	53.55	6.3	13.04	39.90	16.93	3.40	15.83	0	7.75	3.95	7.96

Source: SRDI, 2003

Table 6. Effect of climate change on the livelihoods in Dacope (Khulna), Noakhali and Patuakhali

Factors/Reasons	% farmers responded					
	Dacope (Khulna)		Noakhali		Patuakhali	
	1980	2007	1980	2007	1980	2007
Sowing rabi crops timely	82	18	70	30	75	25
Incidence of disease and pest increase	17	83	14	86	10	90
Incidence of disease and pest decrease	92	8	98	2	87	13
Cost of crop production increase	0	100	0	100	0	100
Cost of crop production decrease	100	0	100	0	100	0
Soil fertility increase	98	2	100	0	95	5
Soil fertility decrease	3	97	0	100	3	97
No. of trees increase	73	27	8	92	16	84
No. of trees decrease	22	78	90	10	87	13
Water availability increase	86	14	28	72	85	15
Water availability decrease	12	88	70	30	14	86
Farmers' livelihood increase	20	80	15	85	13	87
Farmers' livelihood decrease	85	15	80	20	90	10
Cropping pattern increase	30	70	6	94	8	92
Cropping pattern decrease	68	32	95	5	90	10
Salinity increase	0	100	100	0	74	26
Salinity decrease	98	2	0	100	30	70
Salinity affects crop production	2	98	70	30	55	45

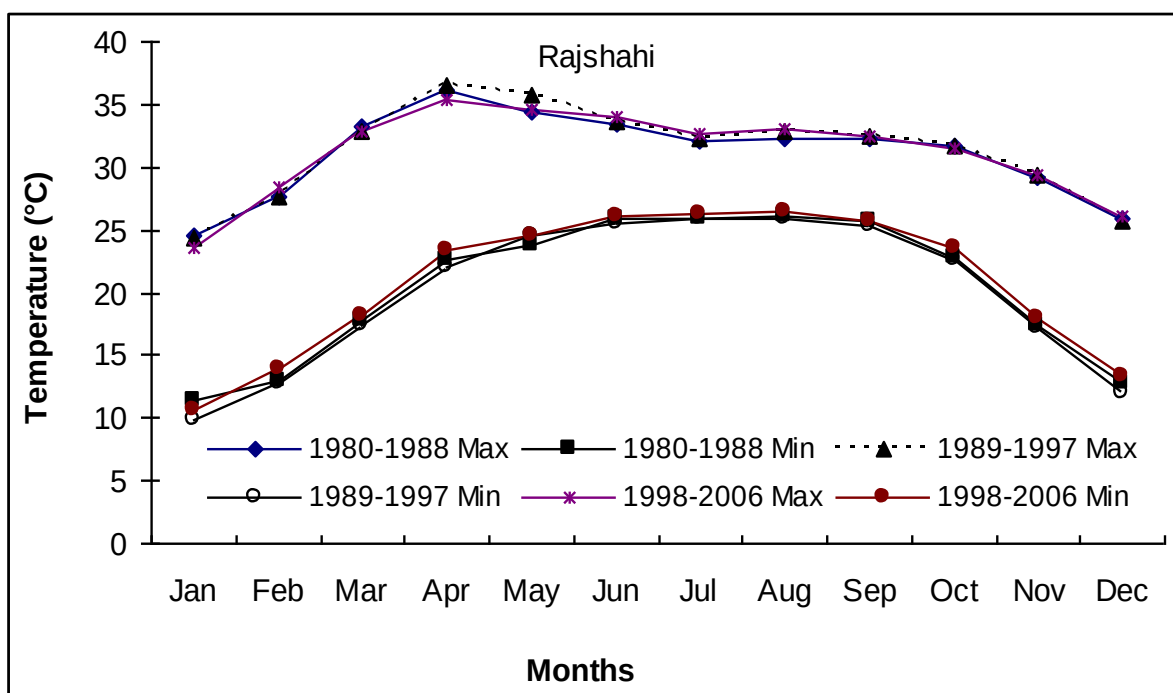


Fig. 1. Mean monthly maximum and minimum temperature in Rajshahi during 1980-2006

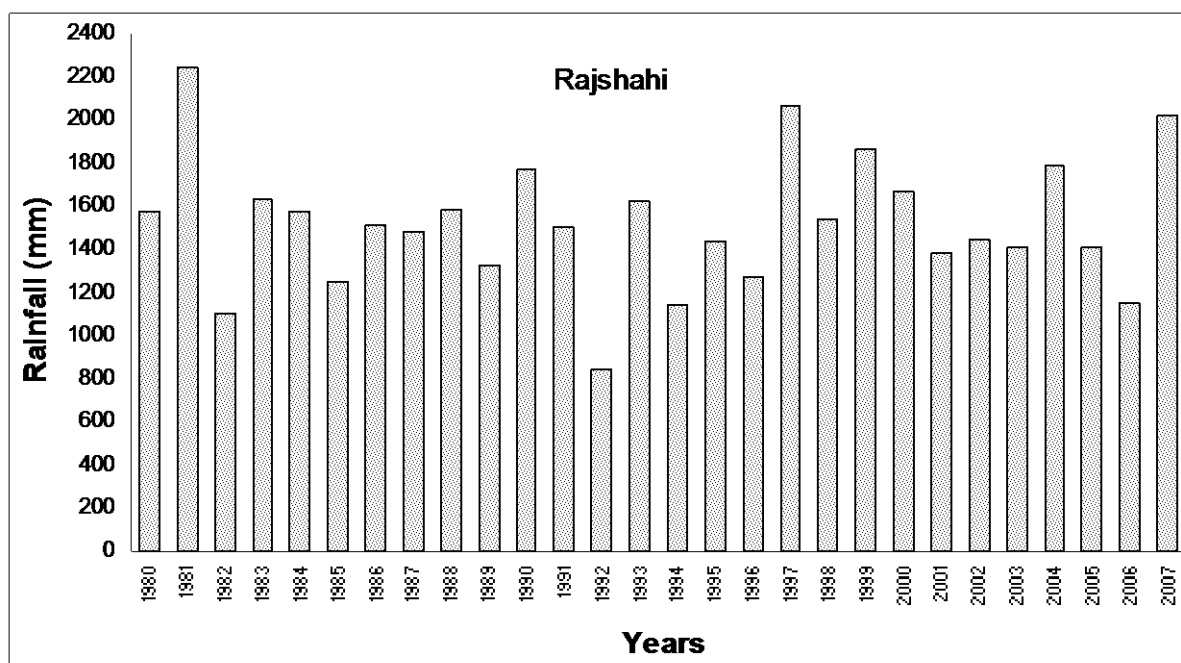


Fig. 2. Yearly total rainfall in Rajshahi during 1980-2007

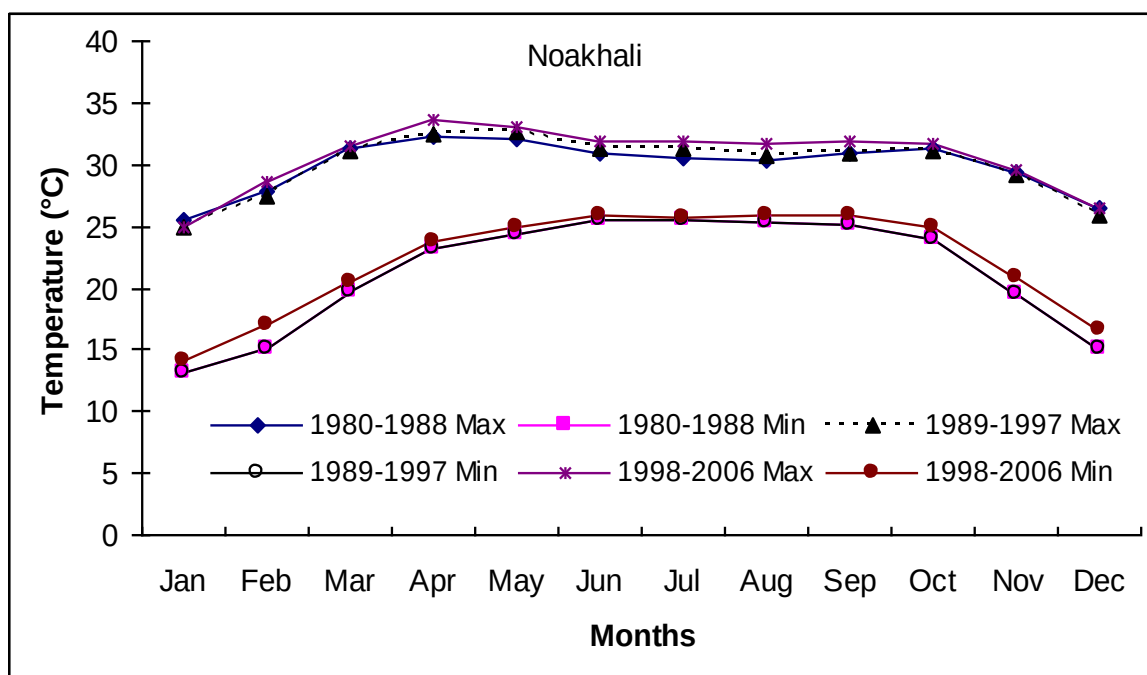


Fig. 3. Mean monthly maximum and minimum temperature in Noakhali during 1980-2006

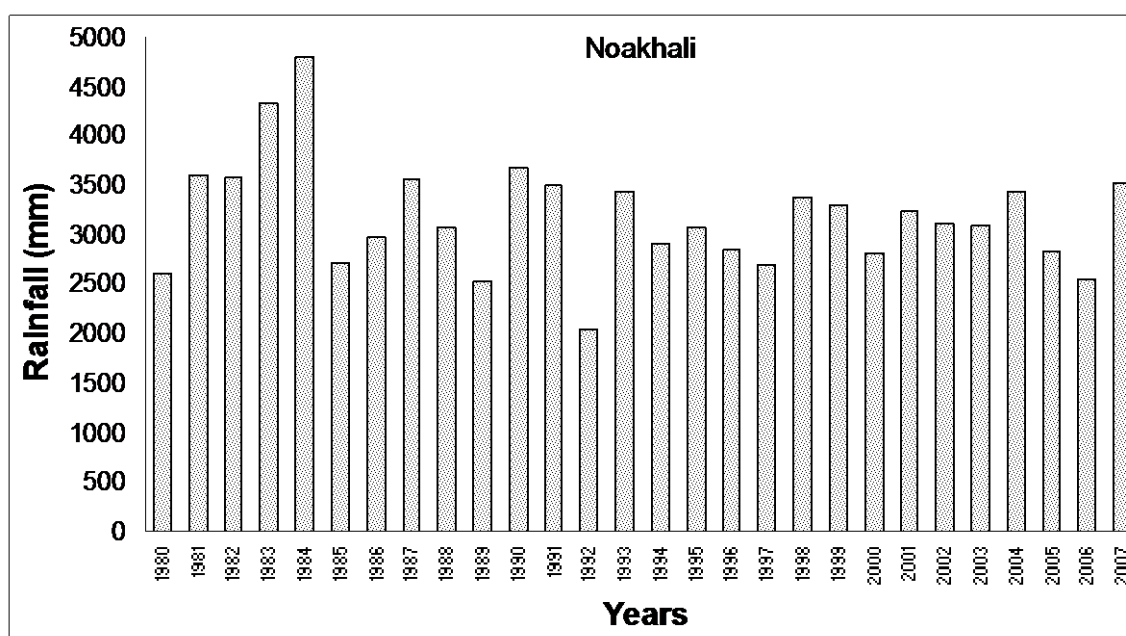


Fig. 4. Yearly total rainfall in Noakhali during 1980-2007

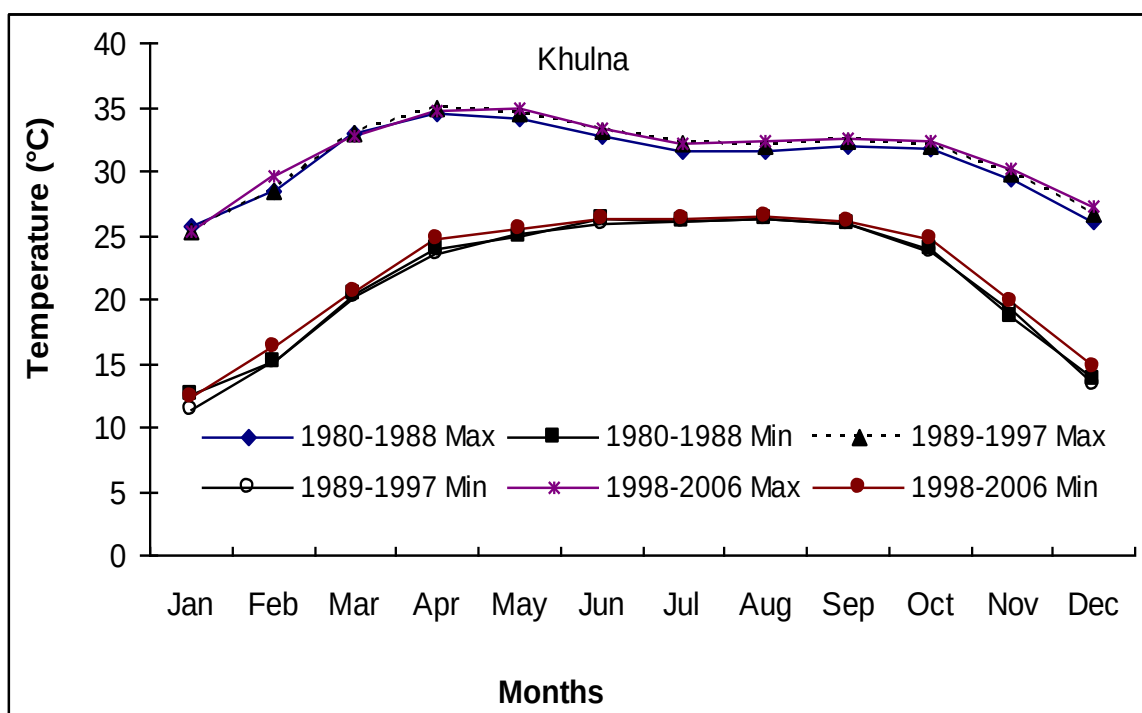


Fig. 5. Mean monthly maximum and minimum temperature in Khulna during 1980-2006

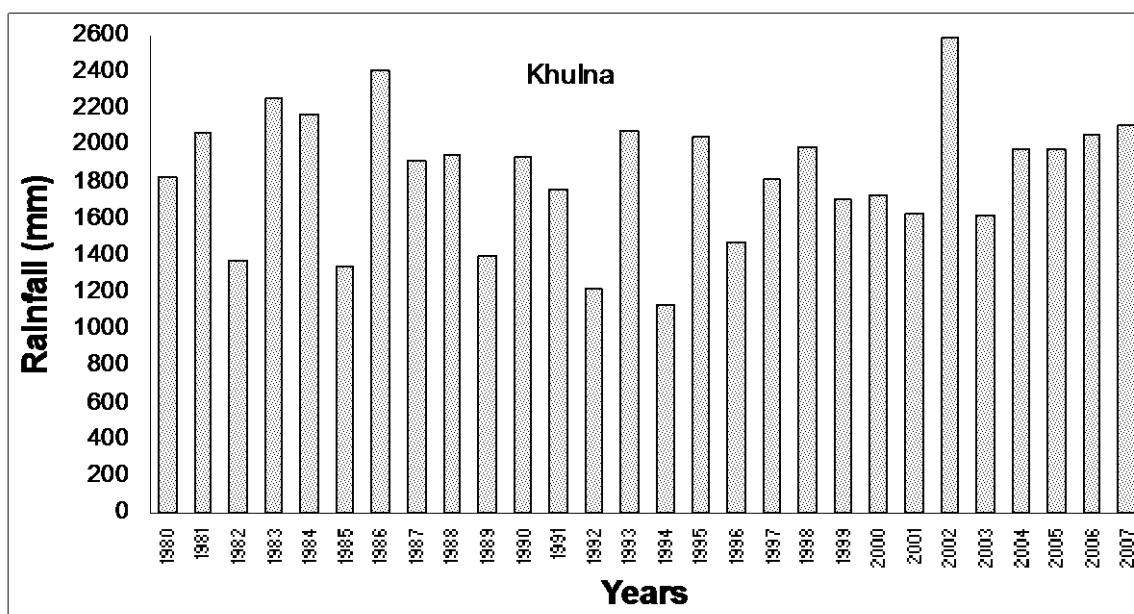


Fig. 6. Yearly total rainfall in Khulna during 1980-2007

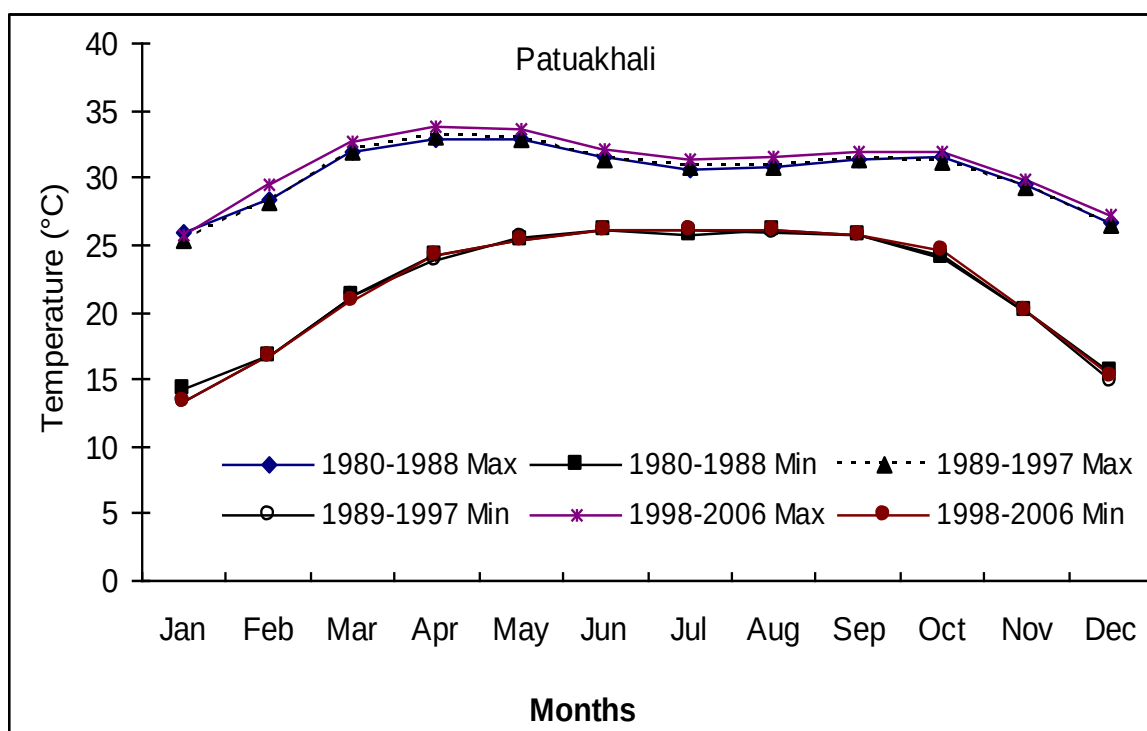


Fig. 7. Mean monthly maximum and minimum temperature in Patuakhali during 1980-2006

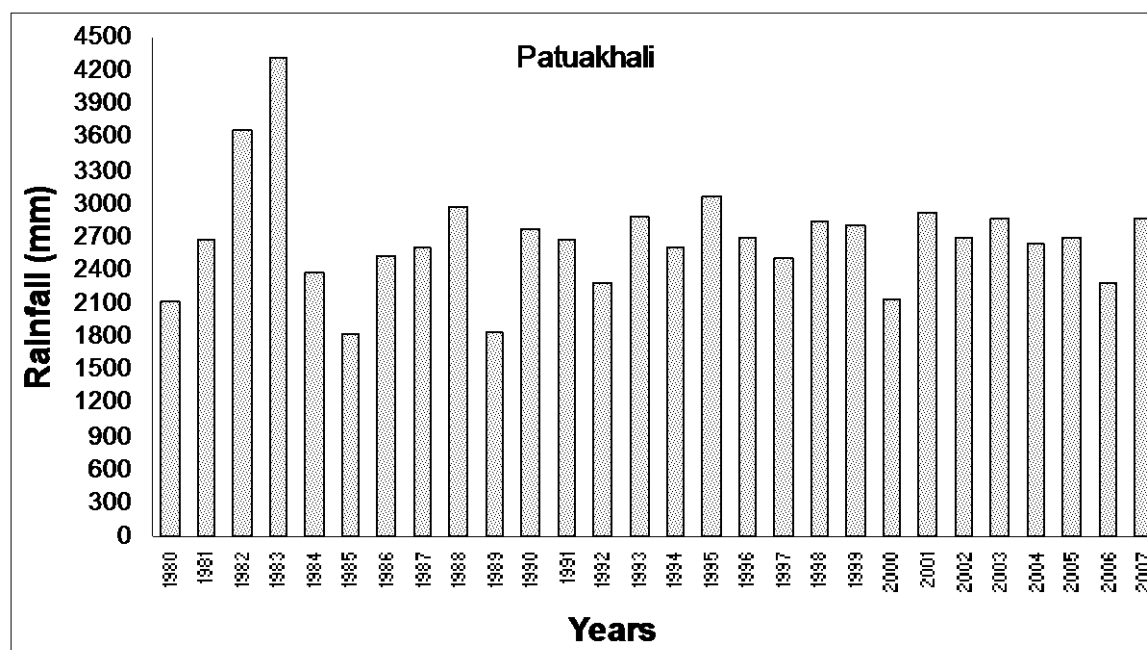


Fig. 8. Yearly total rainfall in Patuakhali during 1980-2007

Appendix

Appendix 1. Perception of farmers about climatic hazards, High Barind Tract (HBT), Godagari, Rajshahi

Climatic hazards	No. of Respondent	%
i) Drought	39	78
ii) Boisaki storm (Kal boisaki)	22	44
iii) Hailstorm (Sila Bristri)	13	26

Appendix 2. Effect of changed weather on agriculture and livelihood, HBT, Godagari, Rajshahi

Climatic hazards	No. of Respondent	%
i) Crop damage	26	52
ii) Tree damage	13	26
iii) Food crisis	15	30
iv) Fodder crisis	10	20
v) Malnutrition	7	14

Appendix 3. Present and past water holding duration of pond in the High Barind Tract, Godagari, Rajshahi

Present duration of water holding	% farmer responded	Past (10 yrs before) duration of water holding	% farmer responded
July-November	8	July-November	14
July-January	10	July-January	20
Round the year	66	Round the year	82

Appendix 4. Causes of decreasing pond water in the HBT, Godagari, Rajshahi

Causes	No. of Respondent	%
i) Drought	41	82
ii) Irrigation	29	58
iii) Decreasing pond depth due to siltation	27	54
iv) Inadequate/low rainfall	9	18
iv) Leaching loss	3	6

Appendix 5. Utilization of pond water in the HBT, Godagari, Rajshahi

Type of utilization	No. of Respondent	%
i) Domestic purpose	41	82
ii) Irrigation in crop field and home garden	39	78
iii) Fish culture	28	56
iv) Use for livestock and poultry rearing	15	30

Appendix 6. Farmers' perception on necessity of more ponds in the HBT, Godagari, Rajshahi

Farmers perception	No. of Respondent	%
More needed	30	72
No need	11	28
Management/ re-excavation of existing pond	9	16

Appendix 7. Cropping patterns of present day (2007) and mid eighties in the HBT, Godagari, Rajshahi

Land type	Present cropping pattern	% farmer practiced	Land type	Past cropping pattern	% farmers practiced
HL	Fallow-Fallow-T.Aman	42	HL	Fallow-Fallow-T.Aman	62
	Boro- T.Aman	31			
	Mustard –T.Aman	18			
	Wheat- T.Aman	16			
	Tomato- T.Aman	24			
MHL	Chickpea-T.Aman	26	MHL	Fallow-Fallow-T.Aman Chickpea/Linseed- T.Aman	80 15
	Boro-T.Aman	40			
	Wheat-T.Aman	16			
	Potato-T.Aman	10			
	Mustard-T.Aman	14			
	Mustard-Boro-T.Aman	6			
	Linseed-T.Aman	6			

MHL= Medium Highland, MLL= Medium Lowland, T.Aman = Transplanted Aman

Appendix 8. Causes of change of changing cropping pattern/Fish culture/Livestock's rearing/plantation, HBT, Godagari, Rajshahi

Causes	No. of Respondent	%
i) Development of modern technologies in agriculture like new crop varieties	46	82
ii) Increase irrigation facilities	23	46
iii) Increase their demands	14	28
iv) Availability of treatment facilities for livestock's	13	26
v) Increase awareness on crops and cropping and tree plantation	9	18

Appendix 9. Livelihood change of changing of cropping pattern/Fish culture/Livestock's rearing/ plantation in HBT

Changing Indicators	No. of Respondent	%
i) Introduce modern crop varieties, i.e. increased yield	41	82
ii) Increase irrigation facilities	23	46
iii) Increase fish culture	14	28
iv) Increase livestock's rearing	13	26
v) Increase food security	10	20
vi) Create employment opportunity	9	18
vii) Increase percent literacy	9	18

Appendix 10. Reasons for decrease of salinity in Noakhali and Patuakhali

Reasons	Farmers' responded (%)	
	Noakhali	Patuakhali
1) Wash out by rain water	92	88
2) Infiltration/run off etc	54	-
3) Crop removal	36	-
4) Further no entrance of saline water	78	76
5) Establish of embankment	-	100

Appendix 11. Effect of climatic change on the human livelihoods in Bagerhat, Dacope (Khulna), Noakhali and Patuakhali

Reasons	% farmers responded			
	Bagerhat	Dacope	Noakhali	Patuakhali
1. Timely sowing of rabi crops hampered due to Cyclone, Tornado, SIDR etc.	40	72	56	80
2. Increase the disease/insect incidence	100	36	72	74
3. Cost of cultivation increased	72	28	100	100
4. Soil fertility decreased	20	-	100	100
5. Number of trees decreased	12	-	-	-
6. Uncertain human death	-	32	-	-
7. Fish availability decreased	-	-	100	100

Appendix 12. Reasons for livelihood change in Bagerhat and Dacope (Khulna), Noakhali and Patuakhali

Reasons	% farmers responded			
	Bagerhat	Dacope	Noakhali	Patuakhali
1. Farmers income increased due to shrimp cum rice culture	100	-	-	-
2. Farmers income increased due to adoption of modern technologies	-	-	100	100
3. Increase of cropping intensity and also gradual reduction of salinity	-	-	66	72
4. Food security increased	-	-	70	70
5. Knowledge and education increased	-	-	78	82
6. Off-Farm income increased	-	-	54	44
7. Semi pacca housing constructed to avoid water logged	72	-	-	-
8. Fuel shortage increased due to decreased the number of trees	72	72	-	-
9. The cost of cultivation increased due to crop, fisheries, livestock system change	-	56	-	-
10. Semi pacca housing constructed due to crop, fisheries, livestock system change	-	40	-	-
11. Improved sanitation system due to crop, fisheries, livestock system change	-	16	-	-

Appendix 13. Reasons for lower fodder production in Bagerhat and Dacope (Khulna), Noakhali and Patuakhali

Reasons	% farmers responded			
	Bagerhat	Dacope	Noakhali	Patuakhali
1. Due to increased of salinity	100	64	-	-
2. Lack of fallowland for fodder production	88	56	100	100
3. Increase of cropping intensity caused no seasonal fallowland	-	-	72	88
4. Less straw production due to cultivation of HYV T.Aman rice	88	68	66	80
5. Due to unavailability of pure drinking water	12	-	-	-
6. Lack of highland	-	100	-	-
7. Due to change of cropping pattern	-	100	-	-
8. Incidence of cyclone/SIDR/sea water damage the rice straw	-	-	48	54

Appendix 14. Reasons for increasing salinity in Bagerhat and Dacope, Khulna

Reasons	% Farmers responded	
	Bagerhat	Dacope, Khulna
1. Entrance of saline water within the gher area	100	84
2. Rice cum fish culture	40	-
3. Due to shrimp culture	-	20

Appendix 15. Reasons for changing crop, fisheries, trees and livestock system in Bagerhat and Dacope, Khulna

Reasons	% farmers responded	
	Bagerhat	Dacope
1. Salinity level increased over time	100	100
2. Due to Shrimp culture	100	-
3. Stagnation of water	96	-
4. Stagnation of water due to constriction of embankment	76	64
5. Lack of irrigation	20	80
6. Number of trees decreased due to increased of salinity	12	-
7. Lack of repair and maintenance of sluice gate	-	24
8. Weather and climatic change	-	24

Appendix 16. Reasons for changing productivity in Bagerhat and Dacope (Khulna), Noakhali and Patuakhali

Reasons	% farmers responded			
	Bagerhat	Dacope	Noakhali	Patuakhali
1. Decreased the yield of T.Aman in gher area	72	-	-	-
2. Rice cum shrimp culture increased the income	72	-	-	-
3. Increased the yield of HYV Boro	60	-	-	-
4. Yield of local T.Aman decreased due to late planting	-	84	-	-
5. Increased the yield of HYV T.Aman modern variety	-	64	100	100
6. Yield of local T.Aman increased due to improve management	-	-	72	68
7. Increased the yield of vegetable	-	4	78	82
8. Decreased the number of trees	-	88	86	-
9. Increased the number of trees/fruit trees	-	-	-	88
10. Decreased the number of poultry	-	12	-	-
11. Increased the number of poultry	-	-	60	78
12. Cattle/buffalos/goat decreased	-	-	100	100