ADAPTATION TO CLIMATE CHANGE IN BANGLADESH:
SOME PERTINENT ISSUES

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1. PREAMBLE

Bangladesh is a disaster prone country due to its hydrological and geo-morphological realities and its location at the bottom of three major river systems- the Ganges, the Brahmaputra and the Meghna and being bound on the south by the Bay of Bengal. About 92% of the run off Bangladesh has to deal with, enters the country from across borders over which it has got no control at all. More than 700 km of coast line of the country in the south has a population of about 50 million who are most vulnerable to cyclones, tidal surges and salinity ingress. Between 22 to 30% of the country gets flooded almost annually while about two-thirds of the country gets inundated during severe floods which are increasing in frequency over the decades. On the other hand the country faces water scarcity during dry season (November through May). The progressive reduction of dry season flows through most of the 54 transboundary rivers entering from India due to cross-border upstream interventions are exacerbating the situation further. The groundwater available in most parts of the country is now contaminated with 'Arsenic' whose continuous use in the drinking and domestic sectors has already given rise to several serious health problems occasionally leading to deaths of people due to prolonged continued ingestion of arsenic contaminated water. Besides, the ingress of salinitty in both the surface and ground water in the southern half of the country is becoming menacingly critical affecting the water quality, soil, bio-diversity in general and the natural balance of the 'Sundarbuns' the largest mangrove forest of the world(and a world heritage site) situated in the south-west corner of the country, in particular. Again, the country is now being increasingly visited by cyclones and hurricanes with disastrous effects. All these phenomena are adversely affecting the general conditions of the life and living of millions of Bangladesh and constraining the national socio-economic progress.

Already gripped with various problems, Bangladesh is now one of the most vulnerable countries of the world to extreme events due to climate change. Bangladesh has no responsibility to this Climate Change, but it is in the fore front of threats from Climate Change effects in terms of increasing sea level rise, salinity ingress, cyclones, floods, droughts, loss of habitats, destabilization of agriculture etc. The country faces climate change not only as a development challenge, but also as a human rights and justice issue. Bangladesh is seeking to combat climate change impacts with its own meager resources to the feasible extent. But given resource limitations, it cannot do much on its own. Bangladesh has adopted Bangladesh Climate Change Strategies and Action Plan (BCCSAP) in July 2009, being the first country in the world to do so, to provide overall policy and action guidance and outline action programs. Bangladesh has also set up the Bangladesh Climate Change Trust Fund (BCCTF) in 2009, which has been receiving annual budgetary allocation for climate action. Bangladesh while pulling its best efforts to face and adopt to climate change, is also facing some formidable challenges, like-

- Agriculture including crop cultivation, livestock and poultry rearing is still the mainstay of Bangladesh economy. It provides employment to about half of the labor force, supplies raw materials to agro-processing industries. This agriculture however is at the cross roads as water scarcity, land degradation, salinity ingress and the climate change impacts are threatening its sustainability.

- Soil related problems are becoming a constraint to agricultural growth. Organic matter depletion is observed in 7.5 million hectares of the total cultivable area of the country amounting to about 9 million ha. It is estimated that Bangladesh soil loses annually some 2 million metric tons of nutrients.
- Other formidable challenges relate to the housing, food security, access to clean water and energy and other services for a population of 160 million people living in a country of 147,570 sq. km. Unplanned land use in setting up development projects, private, industrial and service activities, human settlement, grabbing of wetlands and other common resources by unscrupulous persons and unplanned rapid urbanization is a major problem facing the country. The country is also losing on an average close to 1% of agricultural land per annum to other uses. More agricultural land will be lost in future due to increased salinity ingress and river erosion as a consequence of climate change.
- Increasing withdrawals of dry season flows from the trans-boundary rivers from across the Bangladesh borders are not only drastically curtailing the dry season water flows in rivers of the country but also equally causing problems to the river morphologies. The quantity and quality of groundwater throughout the country are also being adversely impacted. But above all, the natural balance in large areas of the country is now being threatened

Bangladesh however remains highly proactive in facing the adversities of climate change. It is one of the first countries to develop Nationally Appropriate Plan of Action (NAPA) for addressing climate change through a consultative process among GOs, NGOs, Civil societies, Academia, Professional bodies , Private sector, Research organizations, Think tanks and Development partners. The climate change strategy and action plan adopted by Bangladesh is built around six broad thematic areas- (a) food security, social protection and health, (b) comprehensive disaster management, (c) infrastructures, (d) research and knowledge management, (e) mitigation and low carbon development, and (f) capacity building and institutional strengthening.

As a part of its strategies to cope with the climatic change impacts Bangladesh has put priority to issues like (a) changed cropping patterns and crop verities, (b) coping with increased intensities of floods and droughts, (c) fostering cooperation amongst the regional countries on sharing real time data and information on climate events, (d) innovating and improving community based agro-meteorological forecasting and (e) coping with the impacts of climate change on the quality and quantity of ground water in the country. These pertinent issues are being briefly discussed in the following sections.

2. ADAPTATION TO CHANGED CROPPING PATTERNS AND NEW CROP VARITIES FOR FOOD SECURITY.

Agriculture is dominated by crop cultivation, particularly rice, which is the main staple food in Bangladesh. Only recently had there been some move towards other crops, while the previously major non-food crop jute has declined in terms of area under crop cultivation and production. In general there are three cropping seasons in the country namely- Kharif-I (April-July), Kharif II (July-November) and Rabi (December-May). Aus rice is cultivated during Kharif I, while Aman rice is grown during Kharif II season. In Rabi season the Boro rice is widely grown. Aus and Aman were primarily rain fed crops, but with advent of time these are now using water from

some supplementary irrigation projects based on both surface and groundwater. Over the years, there has been a gradual switch towards fertilizer intensive high yielding verities of rice in place of low yielding ones. Now with 'Aus' reduced to a tiny proportion, rice has naturally become a two season crop, one (Aman) dependent on rain requiring supplementary irrigation while the other (Boro) is irrigated (mostly from groundwater) and contributes about 60% to total domestic rice output. Rice production has been intensified through High Yielding Variety (HYV) and other technology infusion. Production of vegetables, fruits and spices has also registered notable expansion. With the introduction of crop diversification program, maize and wheat are also being produced now in wide areas. Horticulture is gradually flourishing. Recently flowers are being produced widely as a cash crop. Most farms in the country are tiny in size by any standard, 88% of them operating on no more than a hectare or so. Most of these small farmers are very open to adopting newer technologies and building resilience to vulnerabilities of climatic events, such as floods, cyclones, droughts etc. On the other hand about two thirds of the land area being less than 5 meters above sea level and the location of the terminal flood plain delta of three large rivers are always vulnerable to extreme climatic events which cause serious damage to infrastructure, crops and overall economy. There are also non-climate related phenomenon such as over extraction of groundwater and serious deterioration of the groundwater quality by salinity and arsenic.

Climate change is expected to make the situation worse. Among the phenomena that would affect agriculture include, the changes of river flows, inundation resulting from inadequate surface drainage, sea level rise and saltwater intrusion and increased occurrences of floods and droughts. A reduction in runoff will be perhaps the most serious impact of climate change which would result in lesser percolation of the river waters in the groundwater aquifers. The intensity and timing of rainfall would change as a consequence of the changing circulation patterns inherent in generalized atmosphere warming. Changing runoff pattern and temperatures may result in water quality that might render it unsuitable for use in agriculture.
In the face of all such eventualities, Agriculture in Bangladesh shall be all about risk management. Every season, farmers will have to make a decision in the face of uncertainty. Plant too soon and seedlings may fail to develop if soil moisture is inadequate or there is a dry spell early in the season. Plant too late and there may not be enough time for crops to reach maturity, or they may become more vulnerable to pests and diseases. All these would however call for the timely and right choices of the verities of crops that would be less susceptible to climate change adversities. Rain fed agriculture will have to adapt to new patterns of rainfall as well as prolonged drought periods. Over dependence on rice (particularly Boro) as a major source of staple food supply will need to be seriously reconsidered. On the other hand deep flood area rice will have to be more intensely produced and provision for supplementary irrigation to cope with untimely droughts or erratic rainfall behavior shall need to be ensured. In this regard it will be logical to invest in the capacity to manage water, essentially paying for greater security and reliability to ensure meeting the crop water requirements. This does not necessarily mean storage in large dams. There are many indigenous farming systems that are based on the construction of small reservoirs to provide secure water supplies during the time of needs. Indeed one advantage of local storage is that it does not require major works o transfer water from the source to the field. With the advent of time the climate change events would become more pronounced and assume some sort of a pattern. It would then be essential to resort to new cropping patterns gradually replacing the older ones to cope with the new changes.

In this regard intensive research and development (R & D) works would play the pivotal role. These R & D works should involve new thinking on how domestic food security goals can be met while sustaining an increasingly fragile environment and a large population dependent on agriculture for their livelihoods. These problems are exacerbated due to the low holding

capacities of the produced crops of the large majority of farmers who, by and large, till by themselves only very small areas of land. Bangladesh has prepared several planning documents to cope with climate change – one of which is related to agriculture. The government has set up a major research fund for innovative research in agriculture. Various research organizations of the government are continuously working to innovate crop verities, crop patterns and other measures to help the country and the farmers to achieve a sustainable food security. Integrated Pest Management (IPM) has already been introduced throughout the country. Through the establishment of "Farmers Field Schools (FFS)" in all Upzila (sub-districts) it is aimed to reduce harvest and post-harvest losses and better managed crop diversification and crop production. GIS based agriculture planning has been introduced based on specific agro-ecological zones. Various research centers have developed and released rice varieties which include those of shorter duration maturity (escaping seasonal droughts thus avoiding the need for supplementary irrigation and saving energy), tolerant up to two weeks of flood water submergence, and tolerant to moderate salinity. The Agriculture Extension Service which diffuses the new technologies to farmers and advises them is the largest public sector provider in the country with its delivery agents in every village of the country. In order to improve the irrigation system to cope with the future, water retention measures in the form of local ponds, mini ponds are being increasingly established to help water security for Agriculture. Rubber dams are being implemented in many small size rivers to augment supplemental as well as dry season irrigation. Farmers are protecting moisture through 'mulching' by straw, water hyacinth rice straws and polythenes. Some are following 'Alternative Wetting and Drying' method in rice cultivation.

In order to cope with the future climatic changes, the research organizations are evolving new rice crop varieties like the following.

- Drought Tolerant: For rice crops Bangladesh Rice Research Institute (BRRI) has developed BRRI dhan 42, BRRI dhan 43 and early maturity BRRI dhan 33, BRRI dhan 39. For acute drought prone areas the variety is BINA dhan-7. The newly innovated hybrid Boro paddy (dhan) BRRI Hybrid Dhan-3 with shorter life time and lower production cost is going to be released soon. Farmers are adopting some innovative practices (viz. zero tillage, priming of seeds during sowing, mulching, relay cropping, dry seeding etc.) in the drought prone areas.
- Saline Tolerant: Bangladesh Institute of Nuclear Agriculture Research (BINA) has released two salt tolerant 'Aman' rice varieties (BINA-8, BINA-9). Besides, BINA Tomato-6 will also be a salt tolerant tomato seed variety. BRRI has already released salt tolerant rice variety (Bridhan 47) for the coastal region. Farmers are adopting some innovative practices like Floating bed agriculture in many flood prone and salinity/ tidal surge areas. Salt tolerant spices like chili, groundnut, methi, water melon, cucumber are being encouraged to be cultivated in saline zones.
- Flood Tolerant: BRRI has released two flood tolerant varieties (BRRI dhan-51, BRRI dhan-46) which can be cultivated just after the flood water recedes till mid-October. Submergence tolerant rice BR-11 sub-1 has been released. the newly innovated hybrid 'Boro' paddy-BRRI Hybrid dhan-3 with shorter lifetime and lower production cost is expected to be released very soon.

Floating vegetable cultivation on water hyacinth mass (heap) are practiced in some low lying areas which for major part of the year remain submerged.

3. COPING WITH INCREASED INTENSITIES OF FLOODS AND DROUGHTS

In Bangladesh water is the primary medium through which climate change will impact people, ecosystems and economics. Changing rainfall and river flow pattern will affect all water users; increased uncertainty and shifting crop water requirements will threaten poor rain fed farmers in particular; intensification of droughts, floods, cyclones and monsoons will make many more people more vulnerable; while risks and uncertainties will proliferate around water borne disease incidence, floods and river embankment breaches and sea level rise.

Bangladesh, since long been recognized globally as a disaster prone country and most of these are primarily water borne disasters. During the period 1990-2008, the Global Climate Risk Index (GCRI), 2010 estimated that on an average 8,241 people die each year in Bangladesh, due to such disasters while the cost of damage was US$ 1.2 billion per year and loss of GDP was 1.8% during the period. Floods, Droughts and cyclones are the calamities which almost regularly visit this country and cause immense damage to the life and living of millions of people.

The Ganges, the Brahmaputra and the Meghna river systems drain a total catchment area of about 1.72 million sq. km through Bangladesh into the Bay of Bengal. Out of this large catchment area, only 7% lies in Bangladesh. Unfortunately, the country faces the problem of either too much or too little water respectively in monsoon (June-September) and dry seasons (November-May). Some 93% of the total amount of runoff that Bangladesh drains to the Bay of Bengal enters the country from upstream India. So that Bangladesh has very little control over the behavior of these water flows. While 22-30% of the Bangladesh normally gets flooded every year, major floods strike with longer return periods. But in recent years, as climate change intensifies, more frequently and devastatingly such floods are occurring. In case of such severe floods, two thirds of the country gets inundated. The hilly regions in the east and north-east have an altogether different hydrological system as these become victims to flash floods. The alarming phenomenon however is that the depth, duration and intensities of the different types of floods are gradually increasing over the last several decades. The reasons behind those are natural and man made as well.

Floods bring with them river erosion and loss of land and homesteads of poor people who live on or by the river banks. Hundreds of hectares of agricultural land get lost due to river erosion every year in this land hungry country. The displaced people migrate to the cities in search of livelihood and are forced by circumstances to live in the slums and create problems for urban congestion and strain on urban services. On the other hand, in the dry seasons, the increasing water scarcity severely constrains agricultural and other economic activities,

In Bangladesh, the water sector development projects have mainly focused on flood control and drainage, irrigation; riverbank erosion control, delta development and land reclamation. The projects involved construction of infrastructure facilities like barrages, cross-dams, regulators, sluices, canals, embankments and sea-dykes along the coast and on rivers. Over the last one and half decade, the government has spent more than US$ 1.5 billion as investment for development of flood control, irrigation and drainage. A comprehensive water sector assessment was done under the Flood Action Plan (FAP) in the late 1980s and early 1990s. The National Water Policy was adopted in 1999, while the National Water Management Plan was approved in 2004.However the challenge remains in implementing both the policy and plan, particularly under adverse conditions of changing climate.

Bangladesh water Development Board (BWDB) has already built more than 5000 km of river embankments as flood control measures and 2100 km of sea-dykes in the coastal polders to protect from damages by cyclonic storm surges.
These embankment and sea dykes are all earthen. During planning and design of most of these older ones, the flood frequency and other design parameters were considered in a constrained manner in view of the budgetary limitations. Again the construction mode was mostly manual and at times very crude devoid of proper earth compaction measures. Again the embankment along the major and medium rivers ultimately proved to be inadequately strong to withstand fury of mighty rivers like the Brahmaputra and the Ganges. The embankments were breached in many locations causing enormous damage and miseries to life, livelihood, crops, cattles, infrastructure and the overall economy. In order to protect these embankments, BWDB implemented some River Training measures in the form of spurs and groynes but in an isolated manner. While some of these could be sustained, some could not withstand the fury of the rivers and collapsed. Again due to extreme budgetary constraints BWDB was not able to properly look after the operation and maintenance (O & M) aspects of these embankments. Some knowledgeable experts opine that the river embankments were built as stop gap measures. Their sustainability issue was not properly addressed. As for the coastal embankments (sea dykes) around the polders, they served their purpose in an excellent manner initially. But with the continuous neglect of the O & M issue, many of the regulators, flushing sluices in the coastal polders became totally
choked, dilapidated and became major headaches causing drainage congestion.

As for the River Training works, these were planned and implemented in an isolated manner which essentially should have been done on a holistic basis covering the entire reach of the rivers from source to outfall. Decades of experience have amply shown that river embankments along the major and medium rivers must be planned, designed and implemented in conjunction with the river training works like spurs, groynes and etc. As for small rivers indigenous river training and bank protection works should be considered. The return period of severe floods as well as the danger levels of the river flows in the country should be freshly fixed under the new scenario. The embankments must be equipped with adequate numbers of regulative structures like Regulators, flushing sluices and etc. Consideration may be given to equip the regulatory structures with reversible pumps to facilitate drainage from the country side during the monsoon and supply of river waters into countryside during the dry season. Above all, these infrastructures must be properly operated and regularly maintained. Otherwise huge investments will only go into the water.

The coastal embankments along the polders and some sea- fronts would need to be addressed with more care and caution. To cope with the future events these would need to be further heightened, strengthened, repaired, rehabilitated, renovated and reconstructed as well. More regulating structures must be put in place to facilitate proper drainage from inside the polders. There are bright prospects of expediting land accretion along the sea fronts by intelligent engineering interventions such as cross dams. Past efforts in this regard have already yielded good results that reclaimed several hundred sq. km of newly accreted land. Such expedited accretion would no doubt help to offset the negative impacts of sea level rise to a certain extent and provide some succour to this land- hungry country. In the inlands, the country should strictly implement the flood proofing methods to save large infrastructures, roads, bridges, homesteads, business centres etc.
As for coping with the droughts and dry season water scarcities Bangladesh really faces a precarious future. During the dry season, there is hardly any rainfall. The groundwater reserves which many in the past claimed to be huge are increasingly becoming unusable due to contamination by salinity and life threatening Arsenic. Most of the concerned experts point their

fingers to the over exploitation and mismanagement of groundwater for severe deterioration of its quality. As such, the government has taken up the principle of reducing dependence on groundwater and increase the use of more and more surface water. The topography and the land scarcity in Bangladesh severely constrain the prospect of any large scale surface water storage. But this should not deter the people from pursuing more and more small scale surface water impounding by retention structures. Large, medium, small ponds as well as other indigenous type of water conservation structures must be seriously considered for retention of rainwater as well as flood waters. But above all, the country should more vigorously try to secure its legitimate share of waters from the 54 transboundary common rivers from India. Whether one likes it or not it remains a fact that during the dry season, the rivers Ganges and Brahmaputra supplies 85% of that total surface water in the country while the other cross border rivers and their distributaries supply the rest amount.

More stringent measures should be implemented to reduce wastage of the precious water resources. In the urban areas recycling and reuse of water would become a must irrespective of the fact that it would require huge investments. Engineered approaches to flood protection within the boundaries of Bangladesh may protect communities from normal floods but would leave them highly vulnerable to catastrophic infrastructure failures as seen during 1988, 1998 and early 2000s. Since 93% of the flood water in the major rivers comes from upstream areas across the borders, the appropriate solution to this flood problem also lies there. Basin wide management of the waters of the Ganges, Brahmaputra and Meghna and appropriate scientific catchment treatment can largely alleviate this problem in the basin areas. To that end meaningful regional cooperation among the co-basin countries of the Ganges, Brahmaputra and Meghna rivers shall be the essential pre-requisite. The best option investment for any individual country in these basin areas may lie outside its borders, for example in basin- wide monitoring system or investments in joint infrastructure and/or operating systems in a neighboring country. To the extent that specialized adaptation funds are made available, they could go beyond single-country solutions to promote cooperative transboundary river basin solutions in the best interest of all riparians.

4. COOPERATION ON REAL TIME SHARING OF DATA AND INFORMATION RELATING TO CLIMATE CHANGE EVENTS

It has already been stated that Bangladesh is the lowest riparian of the three great rivers of the world viz.- the Ganges, the Brahmaputra and the Meghna. Besides Bangladesh is the lower riparian of more than 50 other transboundary rivers entering from India. Only 7% of the three great rivers mentioned above lie in Bangladesh. More than 90% of the water that inundate most of the country during the high monsoon floods, generate from outside its borders. On the other hand, the cross- border upstream diversions from the transboundary rivers are increasing the water scarcity more and more during droughts and dry seasons. It is projected that river runoff and water availability during the wet monsoon periods will increase and decrease during the dry seasons when the drought will become more prolonged and intense due to climate change. Such events would make Bangladesh more vulnerable. As already indicated by Experts, one effect of temperature increase would increase evaporation rates and the balance between evaporation and rainfall determines whether a climate is ‘humid’ or ‘arid’. In Bangladesh aridity will tend to increase with rising temperature not matched by adequate timely rainfalls particularly beyond the monsoon periods. A change in the timing and intensity of rainfall could also drive the transition from humidity to aridity. Changes in aridity will have a major impact on both surface water run off and groundwater recharge.

Bangladesh, recognizing the fact that climate change would induce more severe floods, droughts, cyclones with greater frequency and intensity are making all efforts to improve its flood forecasting and warning systems. The Flood Forecasting and Warning Centre (FFWC) of Bangladesh Water Development Board (BWDB) is the agency responsible for providing flood forecasts and warnings. There are limited scale coorporation between Bangladesh and India on sharing of some river flow and rainfall data on a very limited scale. Besides the country being occasionally deluged by major rivers floods, the eastern and north eastern areas of the country are vulnerable to flash floods almost annually. Since all these waters which flood Bangladesh are coming from across the borders, it is essential that Bangladesh receives advance and timely data and information related to floods. Under the existing bilateral arrangements of sharing flood related data and information, India sends the river water level of the hydrometering station at Farakka on the Ganges and Pandu/ Dhubri stations on the Brahmaputra. As for the Meghna, the water level data from Amalshid station of India is transmitted. But all these data transmission are some what conditional. For example when the water levels of the ganges or Brahmaputra or Meghna monitored at the Indian station are nearly touching the danger level or has crossed the danger level then only the data is transferred to Bangladesh. On the rainfall, data from the few indicated Indian stations are transmitted only when its quantity has surpassed certain limits. These data from the Indian stations just adjacent to the Bangladesh borders do not allow the FFWC of BWDB to provide Flood Warnings with sufficient Lead time. For example the water of the Ganges during floods with extreme high velocity would take only a couple or more hours to reach Bangladesh localities. In these cases, Bangladesh warnings at times do not have even 4 hours of Lead time. In the face of such realities Bangladesh has been, over the decades, urging the Govt. of India to provide flood related data and information of the transboundary rivers on a real time basis from further upstream reaches in India in the catchments of the Ganges, Brahmaputra etc. to help Bangladesh to provide flood forecast with sufficient Lead time. In this regard, it needs to be appreciated that there is no other route for the huge flood run off generated in the upstream catchments of the rivers to be transferred to the Bay of Bengal or any part of the Indian Ocean excepting through Bangladesh because of the geographical location. So, if there are heavy cloud outbursts generated in Kathmundu of Nepal or Patna of India, the run off generated in the Ganges would definitely flow down to Bangladesh within a few days. Same thing will happen with the Brahmaputra and Meghna catchment flood flows. Bangladesh also receives flood related data from a few Nepalese small tributaries of the Ganges and Chinese data of the Yarlung Zhang Bo (upstream reach of the Brahmaputra river from China) The Nepalese data that Bangladesh receives are too meager. While the major floods generated in the Brahmaputra that cause severe floods in Bangladesh are generated in the Indian territory. As for the hilly rivers in the north and north eastern borders of Bangladesh, whenever there are intense rainfall/ cloud outbursts in the hills of India adjacent to Bangladesh, flash floods are caused in the Bangladesh border areas, at times even within six hours. Although there is a system of point to point communication of water related data between India and Bangladesh for a few such hilly border rivers, some flash floods do occur during the periods when there is no communication, For example the Indian station transmits data during morning and evening, but at times the intense rainfall and the resulting flash floods do occur in the period between the morning and evening transmissions of the data and information from India. It needs to be noticed that India does not provide any sort of dry season data on river flows and rainfall to Bangladesh. FFWC of BWDB, with the application of more modern techniques is frantically trying to reduce the existing Lead time of flood warnings from 24 hours to 72 hours for the major river flood and at least 6 hours for the flash flood prone areas. The endeavor would come to fruition if only the Upper riparian India in particular, extend meaningful assistance by providing real time flood related data and information from the upstream hydrometric stations of all the transboundary rivers. Bangladesh all alone can do little any further in this matter without such external support.

Although China and Nepal are eager to extend more support in this regard, it would be really meaningful for Bangladesh, if India provides all the related necessary data. These data and information, if provided in time, would help to save crops, infrastructure, lives and properties from the wrath of floods in Bangladesh, These are required to provide relief to the suffering humanity. Inside Bangladesh, efforts are underway to improve the dissemination techniques to make the flood warnings reach more people more early and in languages which can be easily comprehended by all. Bangladesh has not been able to make substantial headway in its Drought forecasting. Relevant research organizations and the Bangladesh Meteorological department (BMD) in particular, are trying to evolve appropriate drought forecasting systems in the country. But in this case too, the active assistance of the upper riparian, India, in particular will be an essential pre-requisite.

In Bangladesh, weather forecasting on cyclones, storms, tornados etc are mainly provided by the Strom Warning Centre (SWC) and on weather parameters like temperature, flood drought, rain fall, and sunshine hour etc. by the agro-met division of BMD. The Storm Warning Centre of BMD issues daily forecasts and warning on meteorological events such as cyclones, storms, tornados, heavy rainfall etc. based on (a) Synoptic Chart Analysis, (b) Pilot Chart Analysis, (c) Radio Sonde Analysis and satellite data. The weather data are mainly disseminated through print and electronic media, fax, telephone and internet. The Centre maintains close linkage with the Disaster Management Bureau and FFWC of BWDB.

The people and the government of Bangladesh are all keen to improve and modernize its floods, drought and weather forecasting techniques and dissemination procedures for the welfare of the millions of its people. These efforts can largely be augmented by meaningful Cooperation from the upper riparian countries of the three great rivers. It would only be proper if all the relevant countries agree at government level to establish sustainable Institutional mechanisms under the aegis of basin wide organizations for free flow of all flood, drought, weather data and storms and cyclone forecasts and warnings between Bangladesh and other countries. This would not only cement the friendship among relevant countries but shall also open new avenues for more and more regional cooperation in other sectors.

It is now widely recognized that engineering solutions, while vitally important and an integral part of the future approach, will not by themselves be enough to solve the regions water problems. There is a range of social, economic and political challenge that have to be addressed. There is need, on a regional basis, for investments in better and more accessible information, stronger and more adaptable institutions and natural and man made infrastructures to store, transport and treat water. These needs will manifest at all levels to projects, communities, nations and river basins. Balancing and sequencing a mix of ‘soft’ (institutional) and ‘hard’ (infrastructure) investment response will be complex. Information, consultation, cooperation and adaptive basin wide management will be needed. To that end a climate of trust and confidence shall be the prime need. Sincere Political will on the part of all the governments and people pf the co basin countries can only help achieve this.

5. AGRO METEROLOGICAL FORECASTING FOR OPTIMIZING AGRICULTURAL PRODUCTIVITY

Water resource managers in Bangladesh would need the ability to track changes and to devise and support the implementation of appropriate responses. This requires extensive data and ability to analyze and interpret it in order to guide planning and inform the broader community of its implications. Bangladesh would require increased adaptation research, capacity building,

development and changes in policies. Weather based agro-met advisory is one such adaptation strategy where Bangladesh needs to really develop for betterment of the farming communities of the countries. There are enormous opportunities to warn people about the hazardous impacts of climatic parameters and increase productivities in the country through agro-met advisory services. The primary objectives of the Agro-meteorological services are (a) to provide location specific weather forecast and Agro-met Advisory Services (AAS) as per varying climatic conditions and cropping pattern, (b) to implement a efficient outreach system so that the farmers receive weather based agro- advisories specific to their areas and crops on real time basis; and (c) to set up operational arrangements for AAS involving extension and information disseminating agencies. There is a need in Bangladesh to extensively develop its own Advisory system network who can translate the weather forecast information to farmers, and communicate agricultural management advice to cope with the climate change weather situations. Such situations could affect agriculture in its productivity (quality and quantity), agricultural practices (water use, agricultural inputs such as herbicides, insecticides and fertilizers); environment (soil drainage, soil erosion, reduction of crop diversities); as well as adaptation techniques.

In Bangladesh, an agro- meteorological unit was established as a division of the Bangladesh Meteorological Department (BMD). The Agro- met Division now operates its activity through a network of 12 Agro-met stations. The stations record weather forecast information synoptically on rainfall, average maximum/minimum humidity, average maximum/ minimum temperature, flood and drought around the area. The stations are responsible to collect weather data as inputs for the preparation of agro-met bulletin for different end users. The data are collected twice a day at 0000 GMT and 1200 GMT from all agro-met stations and submitted to the Agro-met division of BMD at Dhaka for consolidations. The agro-met bulletin is issued for every seven days of each month using data collected from the 12 agro-met stations and disseminated by different modes.

The Agro-met bulletin is published with the following weather information:

- 7 days actual rainfall in mm
- 7 days climatic normal rainfall in mm
- departure % of actual rainfall from normal
- No. of rainy days
- Max. temperature
- Min. temperature
  Normal Min. temperature
- Average evaporation
- Average maximum humidity
- Average minimum humidity
- Average sunshine hours
- Weather forecast for next 7 days (rainfall, temperature, sunshine hours, evaporation, fog, hail, storm)

Also advisories for the farmers (selection of technologies. time of application of fertilizers and irrigation based on weather forecast, time of application of pesticides based on the incidence of pests and diseases etc.) are published.

The bulletin also includes 7 days location specific forecast (rain fall, temperature) . To improve the quality of agro-met bulletin and advisory services model outputs of different meteorological Centres of the world are used for making deterministic forecast. The agro-met division of BMD needs aerospace Remote Sensing (RS) and Geographic Information System (GIS) facilities to obtain accurate Weather data. The existing stations are not also adequately staffed and equipped. Again there is also a need for few agricultural scientists at BMD with expertise in Integrated

Crop management (ICM), RS and GIS to correctly analyze weather forecast data on location specific technologies.

Droughts in Bangladesh are associated with late arrival of early withdrawal of monsoon rain and sometimes complete failure of monsoon. Droughts of different intensities affect about 2.32 million ha. land in Kharif seasons (April-October) and 1.2 million ha. In rabi (November-March) season almost every year. Kharif drought affects transplanted (T) aman rice whereas Rabi drought impacts wheat, potato, mustard and pulses mainly. Yield reduction of T- aman rice ranges from 20 to 60 % due to Kharif drought whereas Rabi drought also significantly (20 to 70%) reduces the yield of crops like wheat, potato, mustard. Advisories given to farmers mainly by Directorate of Agricultural Extension (DAE) and NARS (National Agricultural Research Agency) to avert the risks are shown below:

Crop	Kind of risk	Advisories to avert the risk
T Aman rice	Dry spell in march/ April	Timely/ delayed sowing
Boro (winter) rice	Inadequate soil moisture at transplanting	Delayed transplanting, application of supplementary irrigation.
Wheat	Inadequate soil moisture at sowing	Sowing under maximum tillage to exploit residual soil moisture.
Rabi Crops	Inadequate soil moisture at sowing	Timely sowing under minimum tillage to exploit residual soil moisture

Floods in Bangladesh mainly affect Aus/ T. aman/ Boro rice, jute and summer vegetables. Advisories given to farmers to avert the risks are given below

Crop	Kind of risk	Advisories to avert the risk
Aus rice	Flood during harvest	Advanced harvest at physiological maturity.
T. aman rice	Chance of late Flood	Early transplantation HYV/ late transplanting of Low Yielding verities.
Boro	Flash Flood at harvest	Transplanting short duration verities for early harvest
Jute	Early Flood	Early harvest through early sowing
Summer Vegetables	Early Flood	Sowing short duration vegetables/ cultivation of vegetables on high grounds.

In order to reduce the losses of potato yields by late blight disease due to foggy weather, the farmers are advised to go for delayed planting of potato or arrange timely application of appropriate pesticides to control the disease.
Scientists opine that crop agriculture urgently needs medium/ long range weather forecasting for planning and for this a dynamic regional model should be developed. In addition, it is necessary to establish an Agro-met crop yield model which should be calibrated under the local weather condition of the country.

The task of Agro-met advisories is to provide infrastructure to help farmers make the best possible use of weather and climatic information and take appropriate management decisions. But all these are subject to successful dissemination with good outreach. Proactive initiative may be started to disseminate the agro-met advisories amongst the communities and farmer groups through different modes like Internet, mobile and mass media etc. Again there is a need to develop a system of feedback to assess the accuracy of the forecast and advisories from the different stake- holders and end users.

At local level or farm level agro-met advisories can provide long range forecasts indicating monsoon rainfall variability. To deal with such variabilities, farmers in response could undertake measures like,

- change variety for one with shorter or longer duration;
- change crop species or mix of species, especially combinations of cash and food crops;
- implement soil and water conservation techniques;
- increase or decrease area planted, either total, by crop or by upland or low land location;
- adjust timing and land preparation;
- increase or decrease borrowing of inputs;
- sell or purchase livestock depending on anticipated cost and availability of feed; or
- remain in village or migrate to seek off-farm employment or better grazing for livestock.

The relevant scientists strongly recommend that Agro-met services should further be improved and developed; regional forecasting in SAARC region may generate the forecast and share the products amongst the member as well as non-member countries. Medium range weather forecast for 5 to 7 days with sufficient dependability need to be developed for use in Agro-met advisory services.

6. IMPACT OF CLIMATE CHANGE ON GROUNDWATER AVAILABILITY OF BANGLADESH

One of the most difficult water resources management challenges is monitoring and managing underground water on which Bangladesh heavily depends on for domestic and municipal water supplies and for irrigating crop fields. Because it is essentially ‘invisible’ its unsustainable use is often only recognized when the pumps run dry or the groundwater is heavily polluted by salinity, arsenic and etc. If the run off from rainfall that flows into rivers or the natural flows of the rivers and streams are affected by changes in temperature, land use and different types of human interventions, so would be affected the infiltration of water into underground formations. In Bangladesh, water often lies on the surface for days and weeks in the rainy periods during the monsoon season. Before the advent of the monsoon, when the soils are often dry, the first rain that falls is absorbed by the top layers of soil; if a dry period follows, much of this moisture is used by vegetation or evaporate back into the atmosphere. It is only when there is a relatively

large or sufficient amount of rainfall, concentrated over a period of a few days, that sufficient water can accumulate on the surface and upper layers of the soil, allowing the surplus to percolate into the underlying aquifer. The intensity and duration of rainfall is thus critical in determining what proportions of rainfall will eventually contribute to the recharge of aquifers; the soil moisture condition and the nature of vegetation cover are also related. All of these dimensions are expected to change under the climate change impacts. Intrusion of sea water into the coastal freshwater systems which is already posing a serious problem will be further exacerbated. This will not just occur in areas affected by sea level rise but also when the river flows are not sufficient to prevent seawater from flowing upstream. As estuaries and groundwater become increasingly saline, less freshwater will be available for human and ecosystem use in the southern half of Bangladesh in coastal areas.

Bangladesh has a mostly unconsolidated aquifer system. The system can generally be split into two parts- upper aquifer and lower/ deeper aquifer. Aquifer test data indicate that the whole of upper aquifer sequence behaves as single multiple aquifer system in which all the units are hydraulically connected. Main aquifer transmission properties are good over most of the country, but poor in the south and east. Groundwater in the country is drawn mostly from the upper aquifer. The upper aquifer is annually recharged through rainfall and flooding and replenishes every year but with decreasing quantities. Heavy extractions of ground water by the metropolitan and urban areas for municipal water supply and extensive pumping of Groundwater for irrigation of crop fields during dry season are now approaching to exceed annual recharge. In the city of Dhaka experts opine that groundwater is almost mined now. Over most of the country, vertical components of the annual groundwater balance predominate over horizontal component. Recharge from river flooding or through horizontal flow during monsoons is not significant. Potential groundwater resources are, therefore, primarily derived from rainfall and flooding. Excessive thick layer of clay in the North Central, North West and some parts of the South east regions of the country preclude extraction of majority of the resources using affordable cost technology. In some other parts groundwater development is not considered to be feasible.

In its frantic bid to achieve self sufficiency in food production, Bangladesh has been excessively exploiting groundwater resources for irrigating its food crops. Over the last several decades, progressive reduction of water flows from the transboundary rivers, the major arteries of supply of water during dry season, have allowed salinity from the Bay of Bengal to creep into further inland and pollute the groundwater quality with salinity. This ingress of salinity has rendered both the surface as well as groundwater highly saline in the coastal and adjacent areas. The intensity of salinity of the water at places are so high that people are now unable to use for drinking and cooking and for irrigating crop fields.

Another major phenomenon has occurred over the last few decades which has rendered groundwater in many places contaminated with' Arsenic'. More than 60% of groundwater sampled countrywide, indicated presence of 0.01 mg/l arsenic while 35% of groundwater sampled, showed arsenic above 0.05 mg/l. The problem of Arsenic contamination of groundwater in Bangladesh is increasingly becoming critical. More than 50 districts of the total 64 of the country indicate presence of arsenic in the groundwater. After extensive investigations, it has been known that the highest concentration of arsenic occurs at depths between 20 and 70 meters below ground. Many of the aquifers deeper than 200 meters have also been found to contain arsenic in varying degrees. With the passage of time, the problem is getting aggravated both in terms of extent and intensity. For example, tube wells lifting Groundwater that were 'safe' a year back are no longer safe now. This in itself is alarming as no one can possibly know when a tube well water would become unsafe as arsenic in water has neither taste nor smell.

Millions of people are either directly or indirectly affected by arsenic contamination of groundwater which is the principle source of supply of water for drinking and cooking to about 95% of the total population. People have reportedly died and are dying due to continuous ingestion of arsenic contaminated water in many areas, while thousands are suffering from various consequential diseases. Investigations have already found presence of arsenic in leafy vegetables and green coconuts in some areas. The government and the people are desperately trying now to overcome this crisis. There is a general consensus that over exploitation and utter mismanagement of the groundwater resources have led to such a situation. Experts believe that arsenic contamination of groundwater has been triggered by the process of 'Oxidation' that releases arsenic in to the groundwater when sulfide compounds containing arsenic get in contact with oxygen (facilitated by the millions of bored tube wells). Experts have suggested three major options to combat the situation. These are – (a) Wise use and management of groundwater which are still free from arsenic; (b) treatment of arsenic contaminated groundwater in quantities for supplying to meet drinking and cooking requirements; and (c) increased use of surface water for irrigation reducing the use of groundwater for this purpose.

With the above background, the climate change impact on the groundwater quantity and quality would put Bangladesh in a further critical condition. Erratic behavior of rain fall and frequent and prolonged droughts will severely constrain the recharge of the groundwater aquifers, reduction of surface water flows through the river and streams will allow further and further inroads of salinity into the country. Desperate needs would force people to exploit more groundwater during drought periods and dry season that would further aggravate the arsenic contamination of groundwater situation. It needs to be borne in mind that if he invisible groundwater gets contaminated with arsenic it might take even more than a century to restore its quality. Again overexploitation and even mining of groundwater would trigger large scale subsidence of the ground in this country that would undoubtedly aggravate the flood situation and more engulfment of habitats by the Sea level rise.

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