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Integrating traditional and modern adaptation practices towards climate-smart agriculture in Bangladesh

Awal MA

Laboratory of Plant Ecology, Department of Crop Botany, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh
E-mail: awalma7@bau.edu.bd
Telephone: +8801720343625
Fax: +8809161510

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ABSTRACT

Agricultural enterprises in Bangladesh are highly vulnerable to extreme and aberrant weather conditions. To face such threats of climate change farmers utilize their own knowledge or practices that varies for different geographies. To boost production several scientific innovations are evolved and disseminated by the service providers in recent times. However, literatures suggest that traditional local technologies offer solutions to numerous climate change impacts. The importance of such local technologies has not been assessed holistically from the perspective of climate-smart agriculture (CSA). Therefore, the aim of the study is to explore the prospects for promoting indigenous technologies along with the dissemination of recent innovations by extension agencies for sustainable food production as well as CSA. The study was based on the qualitative data collected from primary and secondary sources from climate hotspots of Bangladesh. Literature review, field visits, focus group discussions, stakeholder consultation etc are the major tools employed for collection of information. With emerging innovations or technologies by research institutions and universities and those were disseminated by extension workers, farmers are gradually benefitting with those technologies for their local production. Historically used age-old indigenous technologies for various climate-stressed hotspots of Bangladesh are also valuable for designing future direction of researches. However, over use of so called hybrid crop varieties marginalized the traditional varieties those have potential to combat weather adversities. Research institutions may take the proper research items from the farmers' traditional practices those observed at local level. However, negligible research, policy and extension supports are available for farmers to scale-up those local technologies. The study reports valuable findings of such traditional adaptations those practiced at local level in extremely climate-stressed areas of the country. The study, which has implications for researchers, practitioners and extension agencies promoting CSA, argues that although recent scientific innovations are available more areas should also be brought under local technologies if we want to combat the present and future climate change threats efficiently. The paper emphasizes best practices along with suitable genetic resources as well as modern innovations to enhance the application of indigenous and traditional ecological knowledge and technologies for achieving CSA.

Key words: Climate shocks and stresses, Climate-smart agriculture, Extension activities, Indigenous technology, Innovation, Local adaptation, Traditional practices

1. INTRODUCTION

Due to spatial geo-morphological setting, climate change intercepts all of the development sectors of Bangladesh. Among those agriculture sector is under greatest risk as majority of workforce of Bangladesh is associated with it. About 47 percent of the total labour force employs in agriculture and the sector contributes 16 percent of GDP of the country (World Factbook, 2016). Agriculture in Bangladesh faces a variety of risks associated with climate change, such as erratic rains, flood, drought, tropical cyclones, sea-level rising, water logging, salinity, increased evaporation rates, higher temperatures (heat shocks), increased pests and diseases and changes in diseases and pest distribution ranges, and spatial shift in optimum growing regions, resulting in substantial yield losses (Hossain and Majumder, 2018). Additionally, the projected changes in climate will more adversely affect the agricultural production in Bangladesh. The extreme weather events, including cyclone, floods etc are expected to induce food vulnerability to the already food insecure 60 million people (which includes 38% of total population) of Bangladesh (WFP, 2016) and this increases the cost of coping dramatically.

Weather aberration poses enormous threats throughout Bangladesh. Entire southern belt of the country is severely affected by tropical cyclone and salinity. In the south-western part salinity intrusion and water logging, monsoon flood in the central part, early or flash flood in the north-east and drought in the north-west are gradually increasing. These are causing increased vulnerability for agricultural production. The emergence of such risks calls for urgent, ambitious actions are to be implemented to ensure the resilience of Bangladesh agricultural sector for ensuring optimum production through climate-smart agriculture (CSA). There are numerous traditional technologies available in local level throughout Bangladesh and these have the potential to cope with adversities of climatic threats. Considering the climate change impacts, these technologies are valuable for present and future sustainability of agricultural production. Therefore, such indigenous measures need proper assessment to further escalate the scale of these practices for achieving CSA.

Climate change adaptation (CCA) is a context-specific action and the associated practices should be based on science, and incorporate knowledge of indigenous peoples and traditional innovations (FAO, 2017). CCA does not occur in isolation and it is an incremental process that can build upon a long history of previous adaptation (Burton, 2000). Evidence suggests that activity to combat climate change threat can be improved if CCA programmes integrate indigenous knowledge (Agrwal, 2010; Ajibade and Eche, 2017). With integrating mitigation avenue to CCA, the CSA is an approach that can transform and reorient agricultural systems for better management of climate change to ensure food security (Lipper et al., 2014). Nevertheless, the great challenge to expand agriculture production on shrinking land, as in Bangladesh, the CSA could address the food, fiber and fuel issues which are prime needs for the growing population. Thus, the CSA can contribute to poverty reduction and economic development of the country. It also focuses to enhance the productivity and resilience of ecosystem functions for conserving natural resources through minimizing the trade-offs therein. CSA offers befitted and context or location-specific solutions for managing climate change through implementing state-of-the-art policies and financing measures. The concept of CSA is still evolving and there is no 'one-size-fits-all blueprint' for how it might be pursued.

To feed huge and over increasing population, agricultural sector of Bangladesh has adapted to modern technologies and high yielding cultivars as paradigm with green revolution. Consequently, the country has reached to a mark for agricultural production since decades against the gradually reducing agricultural land @ 0.45 per cent per annum (FPMU, 2013), but at cost of huge climate change, environmental pollution, degradation of soil health and microbial biodiversity. Additionally, such chase mostly ignored the immemorially tuned locally used traditional technologies (Zaman, 2016). Though discover of many modern technologies during recent times, many climate change hotspots of the country did not get proper attention. Farmers of Bangladesh are struggling with climate change since year after year; therefore they have some own inventions or traditional technologies although the production per unit of area is not so satisfactory. Uses of such technologies are also declining rapidly since the pressure or introduction of modern technologies including so called hybrid crop varieties. The modern varieties are more susceptible to weather extremes such as flood, drought, high temperature, cold, fog, and pests. Thus, the modern crop varieties may not be properly adapted to the changing climatic conditions in many instances as substantiated by the production failure of some crops in recent times.

Mean temperature of the world is predicted to elevate from 0.5 °F to 8.6 °F by the end of the twenty-first century (IPCC, 2013). That means climate systems are continually changing and a suitable cultivar which disseminated once may not be suitable over the wide range of time for future climate. Thus many modern crop varieties could not keep pace to continually changing climate especially increasing temperature. It requires fast release and dissemination of new cultivars by rapid breeding cycles along with seed systems that deliver new varieties to farmers quickly, and then just as quickly replace obsolete ones, keeping pace with the changing climate (Atlin et al., 2017). Farmers in many temperate regions have this access, due to competitive seed sectors that encourage varietal turnover; however it is hardly possible for most smallholder farmers in climate-vulnerable areas of the developing world like Bangladesh where cultivars selected thirty or more years ago, in a different climate (Atlin et al., 2017). Against this backdrop, utilization of traditional crop cultivars with indigenous technology may be a good alternative, where possible. Because traditional varieties proven as candidates to less sensitive to changing climate.

Traditional agriculture with indigenous knowledge's has potential in CCA and mitigation process, low CO_2 gas emission, pest management, low energy inputs, biodiversity conservation and sustainable production (FAO, 2010; Srivastava et al., 2016; Patel et al., 2020; Upadhaya et al., 2020). Thus, traditional agricultural practices have regained the increased attention worldwide as climate-smart approach (Singh and Singh, 2017). Indigenous farmers and local people perceive climate change in their own ways and prepare for it through various adaptation practices (Tripathi and Singh, 2013). Thus uses of traditional or indigenous knowledge and local genetic resources may play key role to adapt to climate change as the approach support CSA for sustainable food production (Singh and Singh, 2017). For designing befitted technologies to achieve CSA, the traditional or indigenous ones used by the local people should be scaled-up where climate shocks are more severe. However, practice of traditional agriculture in full spectrum could not provide sufficient agricultural products from continually decreasing cultivable land to over increasing population in Bangladesh.

Therefore, the study was carried out to explore the traditional or indigenous adaptations practiced at local level by the farmers as well as recent advancement of agricultural innovations towards the CSA in Bangladesh. The output of the study will help researchers, policy planners and extension workers to redesign proper technologies befitted for agricultural practices in worst hit climate shock's areas of the country.

2. MATERIALS AND METHODS

The study was conducted in the Department of Crop Botany, Bangladesh Agricultural University, Mymensingh during the period from 2012 to 2016. Qualitative method has been employed to collect the data from grass root level or local level. Focus group Discussion (FGD) meetings with victimized farmers or villagers from climate change hotspots throughout the country have been conducted (Awal, 2015a) to assess the indigenous and traditional knowledge of local people as well as use of modern technologies to combat or minimize the worst effect of climatic threats. The traditional knowledge can be defined as the knowledge and belief of dynamic practice, know-how or skill of local or indigenous people which socially and spiritually developed from their empirical observations and on interaction with ecological systems to use or manage the natural resources, and sustained and gained as a cumulative form of perception through cultural transmission over generations (Berkes, 2012; Nakashima et al., 2012). Indigenous people act as custodians or guardians or owners of traditional knowledge or traditional ecological knowledge. Indigenous knowledge is essential for climate change adaptation process as it focuses on elements of significance for local livelihoods, security and well-being (Nakashima et al., 2012). Whereas the technology in agricultural point of view means the application of techniques to control the growth and harvesting of plant and animal products. It is also regarded to be a contributing factor to changes in the "structure" and organization of agriculture in developed countries like Bangladesh. Direct field visit to observe the promising or best agricultural practices against the climate shocks and stresses was conducted. The term 'best practices' may be referred to a practice that, upon evaluation, has demonstrated success in contributing to the goal that it was set out to achieve, and that can be replicated providing that a certain set of predetermined conditions are fulfilled (FCCC, 2013).

Stakeholder consultation meetings were conducted with the experts working at Ministry of Agriculture, Ministry of Disaster Management and Relief, Ministry of Water resources, and Ministry of Environment and Forestry (Awal, 2014; Awal and Islam, 2020).

Review of literatures and document analysis from hard copies and online sources, and personal communication to resource persons whenever necessary were carried out. In order to filling-up the gaps or scaling-up the indigenous knowledge towards the CSA, examples of available modern scientific innovations including stressed-tolerant modern crop varieties which have promising characteristics to fit and link with the local adaptation practices were explored. It can be mentioned that, CSA has three pillars or objectives: (1) sustainably increase productivity (production), (2) enhance resilience (adaptation), and (3) reduce/remove greenhouse gases (mitigation). The practices are considered CSA if they enhance food security (production) as well as satisfy one of the other pillars, either adaptation or mitigation, of CSA (CIAT World Bank, 2017).

Invention can be defined as a discovery of new thought, method, idea or imagination that has never been discovered before. In contrast, innovation is the utilization of an invention in to a solution or new goods or service meeting the market demands. There are some other meanings of innovation like 'introducing something new' or 'as change that creates a new dimension of performance' etc. More likely, innovation may by defined as a mechanism by which society adapts to changing resource endowments, and which is in turn driven by social and cultural values (Chhetri et al., 2011). This study considered two major types of climate-induced technological innovation: (i) innovation of location-specific crop varieties in diverse growing seasons and regions of Bangladesh, and (ii) development of climatically appropriate location-based production techniques or practices.

3. RESULTS AND DISCUSSION

3.1 Adaptation of agricultural practices to climate change stresses

Due to the worst experience from recurrent and multiple climatic stresses the farmers of Bangladesh are resilient enough who practice some local adaptations in agricultural production which vary from location to locations. Most of those adaptive strategies are addressed to reduce the negative impacts of slow onset disaster like water logging, salinity, drought etc. Some of those adaptation practices are mentioned.

3.1.1 Adaptation to water logging

Historically, some places like Barisal, Gopalganj, Jalokathi, Pirojpur etc in southern region of Bangladesh are waterlogged or swampy. However, from beginning of the twenty first century, many low elevated pockets (locally called *Beel*) of south-western districts like Khulna, Jessore and Satkhira became waterlogged due to a variety of reasons like natural changes in river flow, increased sediment in riverbeds due to reduced sediment deposition on floodplains protected by embankments, etc (Awal, 2014; Awal and Islam, 2020). Local people are being utilized such water congested land for production purposes using following techniques:

(a) Floating agriculture/garden/farm or natural hydroponics: A floating bed is constructed with the help of water hyacinth and bamboo where different types of leafy vegetables, lady's finger, tomato etc they produce (Haq et al., 2004; CDMP, 2009; Awal, 2014). It is revealed that floating bed farming for vegetable production has huge potentials to mitigate problems against flood or water congestion where land remain submerged for most of the time in a year. Such types of *soil-less* agriculture (locally known as *Baira*) are also common in similar types of landscape exist in many regions like Lake Inle in south-eastern Myanmar, the Tonle Sap in Cambodia, but in different, traditional ways (Huu et al., 2013; Ferguson, 2014; Htwe et al., 2015). Although decomposed plant debris's supply nutrients to the growing crop plants, few specific nutrients as required for some crops can be applied. Therefore, it warrants experimental work whether the nutrients supplied from floating bed is enough for the crops grown.

(b) Kandi or sorjan method of crop production: Crops like potato, cabbage, sugarcane, arum, banana etc can be grown on alternatively raised beds and deep sinks (CDMP, 2009; Awal, 2014). HYV's of crops can be incorporated into the system along with trapping fishes with maximum economic profitability. Better nutrient management should also be considered, if any.

(c) Cultivation of tall statured crops: Farmers utilize some local rice cultivars like Sadamota, Motabalam, Muthamota, Lalmota etc characterized with tall cum especially at seedling stage. They transplant the field with high density of old-age seedlings (45 to 60 days). Recently, Bangladesh Rice Research Institute (BRRI) has recommended two submergence tolerant rice varieties like BRRI dhan76 and BRRI dhan77 having taller seedling and plant height for southern tidal flooding ecosystem of Bangladesh (Barua et al., 2017). Some other crops or crop cultivars having submergence tolerance features like sesame (cv. BARI til3), kenaf (cvs. HC2, HC3 and HC95), jute (cvs. BJRI deshipat5 and BJRI deshipat8), sugarcane (cvs. Isd39 and Isd40), dhaincha (*Sesbania*) etc can be cultivated in waterlogged areas provided that the sowing or planting time as well as initial establishment period of those crop remains water free.

(d) Dewatering for crop establishment: Water is drained out for rice cultivation in dry or *Boro* season (Photograph 1). It is an expensive strategy for rice production and may fail on heavy downpour. Therefore, windmills can be used to pump water from congested areas (Wikipedia, 2019a). Another strategy for downing water table is groundwater recharge (Singh, 2011). Both strategies require government intervention.

Photograph 1: Draining out of congested water from a sluice gate of a polder in order to cultivate *Boro* rice in Tala upazila of Satkhira district. Photo Credit: Author.

Photograph 2: Some year-round waterlogged lands of Keshabpur upazila of Jessore district are converted to fish culture by elevating and widening the periphery with soil brought from same land. The periphery is commercially used for bean cultivation. Photo Credit: Author.

(e) Dyke farming/gher farming: Farmers elevate and widen the border of waterlogged land or low-lying areas making the shape as a *gher* (like a pond or lake) for fish culture and boundary is utilized for horticultural crop production like banana, country bean etc (Photograph 2). The venture intends to utilize the waterlogged lands with maximum economic profitability and to reduce vulnerability by using *sifting agriculture*. Duck rearing can be incorporated into the dyke farming.

(f) Alternative sources of food: Many people or households altered livelihood from existing rice cultivation to catching fishes together with many other floras like water lily and faunas grown or propagated in the waterlogged areas (CDMP, 2009).

The acceptance of above mentioned practices within the local people in the coastal areas of Bangladesh has proved their success. The practices are continually scaling-up to a great extent with emerging of recent innovations and extension activities from GO and NGO bodies. However, maximum economic profits can be achieved by incorporating the crops with HYV's along with better nutrient management into the systems.

3.1.2 Adaptation to salinity

Southern coastal areas of Bangladesh constitute about 2.5 million hectares equivalent to 25 percent of the total cropland of the country. More than a million hectare of land from that coastal area is affected by salinity with various magnitudes, resulted very poor utilization of land (Karim et al., 1990). 'Local transplanting *Aman* rice–Fallow–Fallow' is the major cropping pattern used by the farmers in coastal area. The people of those areas have been cultivating saline tolerant (low to moderate levels) local rice varieties like Jotabalam, Ashfall, Ghunshi, Benapol, Sadamota, Lalmota, Muthamota, Tekshoil, Kutepatnai, Tikepatnai, Birpala, Nuneshwer, Nonakhochhi, Raenda, Burimonteshwer, Dudkalam etc for more than hundred years. Beside rice cultivation, local people have adopted some coping strategies like sheep and duck rearing, shrimp cultivation, shrimp-rice-cultivation, reed cultivation, cultivation of prawn *renu*, golpata and salt production etc since ages. However, recent scientific innovations and extension works have suggested following practices in the areas:

(a) Varietal intervention or cultivation of salinity tolerant crop varieties: Main crop in the coastal salinity intrusion areas of Bangladesh is *Aman* rice which entirely depends on monsoon rain when salinity concentration gets minimum level. Some moderately salinity tolerant HYV rice like BR23, BRRI dhan40, BRRI dhan41, BRRI dhan53, BRRI dhan54, BRRI dhan78 etc are recommended for *Aman* season (Table 1). In contrast, when salinity level or concentration getting higher in *Boro* season onward from December/January where recommended rice varieties are BRRI dhan47, BRRI dhan53, BRRI dhan55, BRRI dhan61, BRRI dhan67, BINA dhan8, BINA dhan10 etc. Salinity tolerant wheat cultivars like BINA wheat1, BARI gom25 etc are also recommended for those areas. Among the fruit trees guava, hog plum (*Spondias mombin*; cvs. BARI amra1 and BARI amra2), Indian jujube (*Ziziphus mauritiana* Lam.) etc can survive in saline and waterlogged areas.

Table 1: Some salinity- and drought-tolerant crop varieties suitable for special geographies of Bangladesh (BINA, 2013; Gurung and Azad, 2013; Hassan and Shaw, 2015; BRKB, 2020; Digital Herbarium: http://dhcrop.bsmrau.net/)

SL No.	Crops/ Crop groups	Crop varieties	
		Salinity-tolerant	Drought-tolerant
1.	[a]Rice		
	Local varieties	Jotabalam, Ashfall, Ghunshi, Benapol, Sadamota, Lalmota, Muthamota, Tekshoil, Kutepatnai, Tikepatnai, Birpala, Nuneshwer, Nonakhochhi, Raenda, Burimonteshwer, Dudkalam	Sonashail, Batraj, Jhingashail, Malshara, Subondari, Hansraj, Biyanophul, Magurshahil, Randhunipagol, Chiniatab
	Aman season	BR23, [b]BRRI dhan40, 41, 53, 54, 73 & 78	BRRI dhan55, 56, 57, 66 & 71
	Boro season	BRRI dhan47, 53, 55, 61, 67, BINA dhan8, 10	BRRI dhan55
	Aus season	BRRI dhan55	BRRI dhan42, 43, 55 & 65
2.	Other cereals		
	Wheat	BINA wheat1, BARI gom25	BARI gom26, 28, 30, 32 & 33
	Maize	Khoi buhtta and BARI hybrid maize5 & 9	BARI hybrid bhutta11, 12 & 13
	Barley	BARI barley4, BSH32 & 142	BARI barley5, 6
	Sorghum	Genotypes IS3158 & IS9745	Pahat (Indonesia)
	Foxtail millet	Genotypes BD881 & 897	
3.	Pulse		
	Mung bean	BINA mug6 & 8	BARI mug6
	Lentil	BARI masur5	BINA masur10
	Chick pea	BARI chola9	BARI chola5

	Grass pea	BARI khesari1 & 2	BARI khesari1 & 2
	Cow pea	BARI falon1	BARI falon1
	Groundnut	BINA chinabadam1, 2 & 6, Dhaka 1, BARI chinabadam8	ICGV93269 & 3232, BINA chinabadam4
4.	Oil crops		
	Mustard	M-27-E2-1-5, BARI sarisha9, 11, 12, 16 & 17, BINA sarisha5 & 6	BARI sharisa16, 17
	Soybean	n-b0-1, BARI soyabean6	BARI soybean5 and Sohag
	Sesame	BARI til3	BARI til4
	Sunflower	Hysun33 & 36	
	Safflower		BARI saf1
	Linseed		Nila
5.	Other crops		
	Jute	BJRI deshipat5 & 8, BJRI tossapat5	
	Sugarcane	Isd38, 39 & 40	Isd20
	Potato	Saikat, CIP102 & 139, BARI potato72 & 73	
	Sweet potato	BARI mistialo6, 7, 8 & 9	BARI mistialo8 & 9

[a]*Aman, Boro* and *Aus* seasons designate the time where rice varieties which are planted in mid July, November-December and March-April, and harvested in mid November-December, March-April and mid June-July, respectively.
[b]BRRI dhan40, 41, 53, 54, 73 & 78 refer to BRRI dhan40, BRRI dhan41, BRRI dhan53, BRRI dhan73 & BRRI dhan78. The same concept is applicable for other varieties.

Cultivation of sunflower, sesame, mungbean, grass pea, watermelon (hybrid), groundnut etc is also common and getting popularity as cash crops during dry season in the areas (Photograph 3) as these crops withstand salinity effects to some extent. However, local people don't care to select the cultivars of those crops. By cultivating salt-tolerant verities with high yielding characters (Table 1), CSA can be achieved.

Photograph 3: Cultivation of sunflower in salinity affected Soronkhola upazila of Bagerhat district during dry season from December to April. Photo Credit: Author.

(b) Agronomic practices: Mulching controls salinity by preserving soil moisture in soil profile by restricting capillary rise. Discontinuing soil capillary pores by ploughing top soil is also an acceptable exercise to control soil salinity (Gurung and Azad, 2013). Similarly, growing of cover crops (using dhaincha or *Sesbania*, for example) is also beneficial which is practiced in India. Transplantation of aged seeding is also an agronomic practice to minimize salinity effect as older seedling can tolerate salinity as compared to the younger ones especially for rice. More seedlings should be planted per hill to keep the plant density as normal under saline conditions allowing some plants to death. Continuous maintenance of 2-3 cm water level in paddy fields until milking is necessary when salt accumulated paddy fields are used for cultivation (Gurung and Azad, 2013).

Photograph 4: Growing *Boro* rice in Shyamnagar upazila of Satkhira district using harvested rain water (in adjacent pond) during last monsoon. Nearby a vast land remains fallow due to lack of water and higher degree of soil salinity. The rice varieties are also saline tolerant: BRRI dhan47 (nearest), BINA dhan8 (middle), and then BRRI dhan28. Photo Credit: Author.

(c) Rain water harvest for crop production: In few instances some farmers those have ponds in the locality harvest rain water during monsoon rain which is utilized to cultivate crops in dry season when the degree of salinity goes higher (Photograph 4). It requires special attention for replicating the practice to the wider number of famers in the areas as most of the land remained fallow in the dry season.

(d) Early sowing/planting of crops: Early established crops can utilize the residual soil water (non-saline) of previous monsoon. While the late sown crops miss this opportunity expose to higher salinity. Thus the profile water can be utilized for winter crop production if the crop seed are sown early of the winter season. Short duration or early maturing varieties are also beneficial to this system (Kabir and Sarker, 2019).

Photograph 5: Crab culture with a crab farmer in extremely saline prone place of southern Shyamnagar upazila of Satkhira district. Photo Credit: Author.

(e) Cultivation of economic halophytes: Some selected halophytes those who survive in strong saline habitat can be grown. A facultative medicinal halophyte like *Salvadora persica L.* (Meswak), is identified for growing in highly saline habitats (up to 50 dSm^{-1}) in coastal and inland black soils of India (Rao et al., 2004). An alkaloid named 'Salvadoricine' and some resins are found in the bark of this halophyte. The seeds are good source of non-edible oil rich in C-12 and C-14 fatty acids having immense applications in soap and detergent industries. The growing plants also provide a niche for eco-restoration through environmental greening. Cultivation of salt tolerant forage grasses like *Dichanthium annulatum* and *Leptochloa fusca* are also practiced in some saline affected areas of India (Gurung and Azad, 2013 and references therein). Accordingly, Bangladesh can seek these opportunities, and the intervention needs special attention.

(f) Crab aquaculture: Crab culture is a common adaptation in the areas where salinity concentration is so higher that's why crops could not cultivate (Photograph 5). Crab marketing channel should be improved so that the associated people can ensure maximum profit. Advanced researches are also essential to promote/scale up the crab culture.

3.1.3 Adaptation to drought

The north-west Bangladesh especially the high Barind Tract that comprised Chapainwabganj, Naogaon, and Rajshahi districts has been experiencing extreme hot weather and frequent droughts due to erratic rain. Historically, the farmers of that area have being cultivated rice in three consecutive seasons with some drought-tolerant rice varieties like Sonashail, Batraj, Jhingashail, Malshara, Subondari, Hansraj, Biyanophul, Magurshahil, Randhunipagol, Chiniatab etc. Local people plant trees and shrubs to reduce accelerated evaporation (Zuberi, 1998). Digging ponds also facilitates to storage water for domestic and agricultural purposes (CDMP, 2009). Some drought-tolerant HYV rice like BRRI dhan42, BRRI dhan43, BRRI dhan55 and BRRI dhan65 for *Aus* season, and BRRI dhan55, BRRI dhan56, BRRI dhan57, BRRI dhan66 and BRRI dhan71 for *Aman* season are also available for cultivation. However, scientific innovations along with recent extension activities have modified the agriculture of those areas with the following practices:

Photograph 6: A mini-pond in drought prone Nachole upazila of Chapai Nawabganj district. The stored water in this pond is utilized for crop production purposes in nearby land. Photo Credit: Author.

(a) Digging mini-pond for rain water harvest: The community people have adapted to harvest or trap rainwater in mini-pond that digging at the agricultural site to be used in time of necessity for watering to the crops (Photograph 6) (Awal et al., 2013). Farmers use the water from mini-pond for rice cultivation too. It also facilitates to cultivate fishes as well. In dry season when mini-pond becomes dry some farmers pour that with water from deep tube well. If the deep tube is far away from mini-pond they use a long flexible pipe for bringing water to their ponds over the uneven topography.

(b) Adjustment in cropping pattern: Due to scarcity of water farmers are recommended to cultivate wheat, pulses, oil crops, millet, pearl millet etc instead of *Boro* rice in dry season. Some drought-tolerant crop varieties suitable in that dry area are available (Table 1). It is mentioned that wheat's crop growth especially at reproductive stage of this crop is badly affected by high temperature leading to poor grain yield (Hossain et al., 2011, 2013; Hakim et al., 2012). Due to short winter in Bangladesh, wheat's grain filling mostly occurs at warmer weather in early spring thus grain production becomes lower. To overcome such climatic constraint some drought plus temperature or heat tolerant wheat cultivars like BARI gom26 and BARI gom28 can be cultivated in the dry areas which also produce higher grain yield even with late planting (Table 1).

(c) Alternate wetting and drying (AWD) technology: It is a method of controlled and intermittent irrigation, practiced to cultivate lowland rice with much less water than the usual system of maintaining continuous standing water. Rice field experiences periodic drying period for a few days followed by a flooding by irrigation in such a way that could not imposes any stress to growing crops. It reduces water demand for irrigation and greenhouse gas emissions without reducing crop yields. In conventional system, *Boro* cultivation is completely irrigation dependent while *Aman* needs it partly. To produce one kilogram of rice, a huge amount of water like 3000 to 5000 litre is essential, of which about 15-30 percent can be saved using AWD technology without hampering in grain yield as proved by IRRI (Bouman, 2009). Starting from about 15 days after transplanting, the land is irrigated until the water table goes 15 cm below the ground level when first small soil cracks are visible. A perforated plastic pipe with 7-10 cm diameter is inserted to a depth of 20 cm of soil to monitor the water level (Fig. 1). The practice is continued to heading and thereafter the rice field is kept submerged with 2-4 cm water until dough stage. It follows the principle of mitigation, a pillar of CSA, as it uses comparatively less amount of ground water thus needs less energy to lift that. Ground water is the main source of arsenic contamination in rice, therefore, absorption of less amount of ground water by this crop is a basic reason to decrease arsenic content in grain as well as in straw.

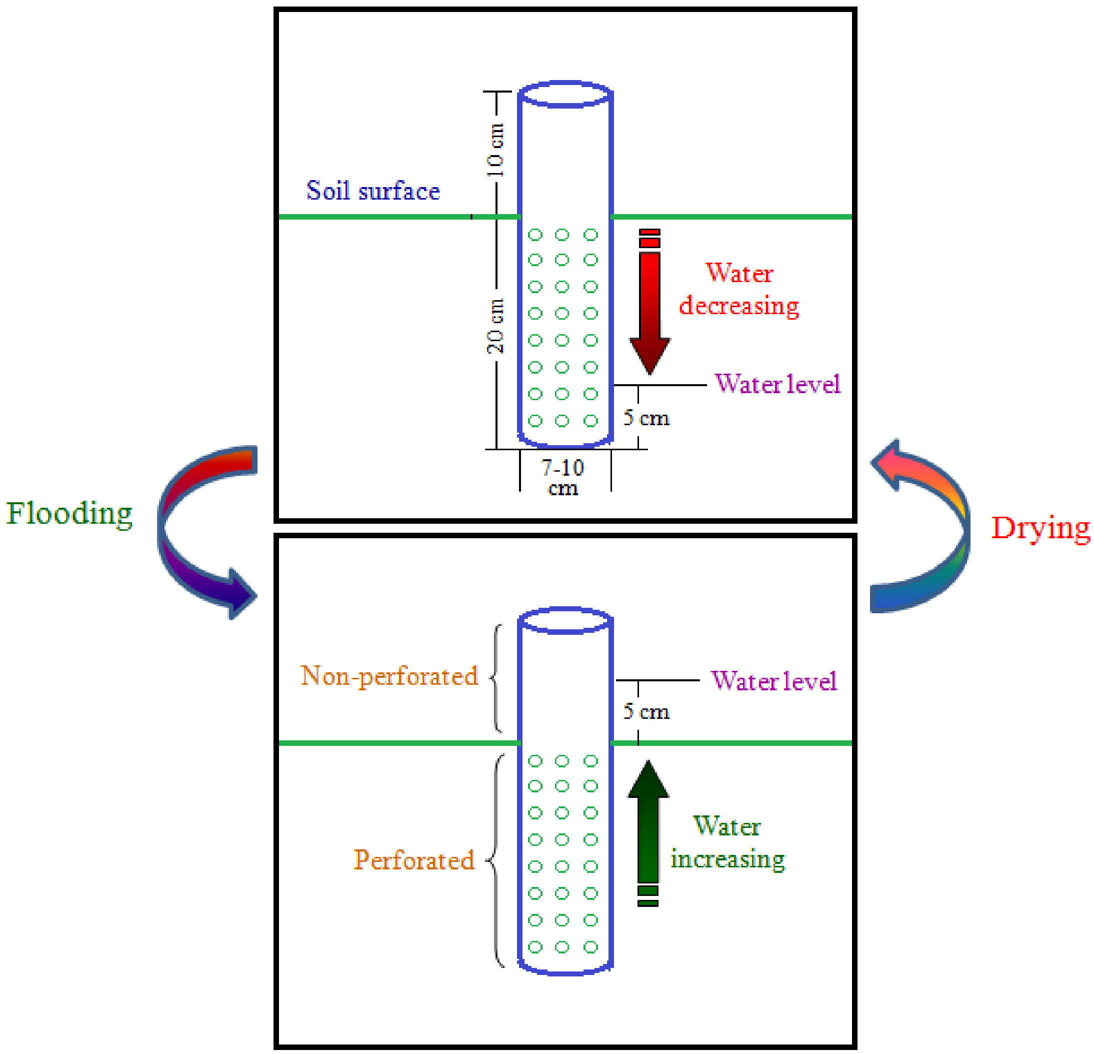

Fig. 1. Operation technique of alternate wetting and drying method in rice field.
Sketch Credit: Author.

With growing water stress, the practice helps rice farmers become more resilient and reduces emissions (i.e. mitigation effort). The rice varieties suitable for AWD practice in Bangladesh are BRRI dhan28, BRRI dhan67, BRRI dhan69 etc in *Boro* season, and BRRI dhan71, BRRI dhan75 etc in *Aman* season. Heavy rainfall can impede the application of AWD. It can be used in any season throughout Bangladesh except in the southern coastal areas where the soil is affected by salinity.

3.2 Adaptation of agricultural practices to climate shocks or extreme weathers

Bangladesh agriculture experiences two major extreme weathers like flood and cyclone. The adaptation measures to those climate shocks are hardly found.

3.2.1 Adaptation to flood

Bangladesh faces various types of floods like early/flash flood, river/monsoon flood, tidal flood etc. Flood sometimes heavily devastate the growing crops in the field. Duck rearing is the most common alternative economic activities of local people living in the flood prone areas of Bangladesh.

Photograph 7: Growing short duration *Boro* rice at Dingapota *Haor* of Mohonganj upazila of Netrokona district. Photo Credit: Author.

a) Early flood or flash flood or hilly flood: This flood destroys agriculture field and crops like *Boro* rice most severely within a short period of time. Farmers are recommended to cultivate short duration *Boro* rice like BRRI dhan28 especially for north-eastern *Haor* region (saucer or bowl shaped depressed lands remained marshy or submerged from May/June to November/December) of Bangladesh to avoid early flood that often strikes during the month of April when growing paddies are at matured or semi-matured stages (Photograph 7). In order to get higher yield however, some famers utilized the variety BRRI dhan29 that often falls to early flood due to its longer life span of about 20 days as compared to BRRI dhan28. With scientific cooperation from the International Rice Research Institute (IRRI), the Bangladesh Rice Research Institute (BRRI) and the Bangladesh Institute of Nuclear Agriculture (BINA), have developed and promoted some submergence-tolerant (Sub1) rice varieties like BRRI dhan51, BRRI dhan52, BRRI dhan78, BRRI dhan79, BINA dhan11 and BINA dhan12 for cultivation in *Aman* season in northwest Bangladesh where flash flood hits frequently. Depending on the varieties, they can tolerate minimum period of 7-14 days to a maximum up to 20-25 days of submergence and revive on recede water (Mackill et al., 2012; Rahman and Zhang, 2016).

b) Monsoon flood: It persists long time in the field from July to September/October. Many places of Bangladesh are experienced to this type of flood with deep water. Farmers usually cultivate local deep water broadcast *Aman* rice where culm elongation is occurred with flood level. It is very long duration rice sown in March/April and harvested in November/December. Rice varieties like Hijoldigha, Molladigha, Kaika, Vasa dhan, Dhepodhan, Chamara, Digha, Dhepa, Gabura, Lakkhi and many other local cultivars are still in practice for *Aman* season in low-lying flood prone areas of Bangladesh. The rice requires a special habitat of prolonged flooding. Some local varieties of rice like Chamara, Dhepa, Boron etc grow with rising water and the plants grow 3-15 feet (Zaman, 2016). These varieties have a matching affinity with water levels, while the life cycle of these varieties is so fine tuned with water regimes. These varieties can grow both in floods and with less water. Most local varieties are strongly sensitive to photoperiod and low filtering, producing a very high amount of biomass for culm elongation but with the least harvest index. However, the most important constraints of this rice are lack of varieties with high yield potential. Some late varieties of *Aman* rice like BR22, BR23, BRRI dhan46, Binasail etc can be transplanted after recede flood water. The varieties are important if early planted rice destroyed by flood. Flood tolerant sugarcane variety like Isd 34 can also be cultivated in flood prone areas (Hassan and Shaw, 2015).

3.2.2 Adaptation to cyclone

Tropical cyclone mostly hits Bangladesh coast during pre-monsoon (throughout May) and post monsoon periods (from mid October to mid November) (Awal, 2015b) largely corresponding to the harvesting time of *Boro* rice and *Aman* rice crops, respectively. Tidal surges accompanied by cyclonic storm make the areas saline as well as waterlogged. Farmers adjust the planting time to avert the cyclonic time (Khan and Awal, 2009) with short duration rice varieties like BINA dhan8 and BINA dhan10 in the *Boro* season and BINA dhan7, BINA dhan11, BRRI dhan62 etc in the *Aman* season which are also salt tolerant characteristics to some extent. Previously, farmers used some low yielding local rice especially in *Aman* season as described in the sub-section 3.1.2.

4. CONCLUSION

The traditional system or practices are implemented using basic and locally available inputs. The practices often integrate careful management of natural resources with intimate local or indigenous knowledge of environment and spiritual beliefs. It is usually passed on from generation to generation with improvements and adaptations taking place according to changes in local conditions. Thus the traditional practices may act as powerful devices to manage natural and cultivated ecosystems for meeting the societal needs. Although the productivity of the system is generally low, considerable potential exists to improve the productivity and efficiency using appropriate recent technology and innovation. Integrating indigenous or traditional knowledge with scientific innovations to planning, designing and implementation may strengthen the approaches of CSA.

Appropriate technologies can help farmers and other producers to overcome the physical and environmental constraints in fragile or exposed areas, improve productivity and incomes, and help them to adapt to changes in the climate. These are those which can be managed and maintained by the growers over the long term, and which integrate environmental, economic and social sustainability principles. The innovations have enabled farmers to cope with various climatic challenges and have been fundamental to the promotion of CSA throughout the country.

Drawing on examples from diverse climate-stressed hotspots of Bangladesh, this paper highlights the promising or best practices and available tools and modern innovations for, identifies gaps and link in, as well as recommends possible actions to enhance, the application of indigenous and traditional knowledge and practices for achieving CSA. The research workers may be benefitted by observing the interface between the traditional technologies and recent scientific innovations in Bangladesh agriculture which appeared in this study.

Immemorially tuned indigenous technologies and genetic resources used by the farmers at local level have outstanding features to withstand the negative impact of climate change threats. Such indigenous ones should be prioritized for promoting/adopting recent innovations for combating over increasing threats of climate changes in agricultural production. That means, befitted scientific innovations should be devised by the local communities through their indigenous knowledge. Proper management and maintenance of indigenous technologies, coordination among practitioners, policy planners and service providers, and good governance are essential to achieve the CSA in Bangladesh. Donors and funders may be benefitted by learning from best-practices and local knowledge as well as recent innovations when investing in adaptation works. Key messages may reach to policy makers, researchers, practitioners and extension service providers to promote CSA in Bangladesh.

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