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Profiling Climate Smart Agriculture for Southern Coastal Region of Bangladesh and its Impact on Productivity, Adaptation and Mitigation

M Yusuf Ali[1] and Md Emdad Hossain[2]*

[1]Independent Consultant in Agricultural development, Climate-Smart Agriculture, Dhaka, Bangladesh

[2]Project Leader, Climate Change, Agriculture and Food Security (CCAFS) project, WorldFish Center, Bangladesh and South Asia Office, Banani, Dhaka, Bangladesh

***Corresponding Author:** Md Emdad Hossain, Project Leader, Climate Change, Agriculture and Food Security (CCAFS) project, WorldFish Center, Bangladesh and South Asia Office, Banani, Dhaka, Bangladesh.

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Abstract

Now a days ensuring sustainable food security is a great concern because of devastating effects of climate change on the most vulnerable country like Bangladesh. Its coastal southern region agriculture and peoples livelihood is mostly affected by recurrent cyclone, tidal surge, flood, salinity and dearth of appropriate technology options to manage those. Applying climate smart agricultural practices at community level could minimize the climate change related effects. Thus, climate smart agriculture (CSA) practices those are used and developed by local community, innovator, extension workers and agricultural researchers are being collected through desktop work, survey, field visit, personal communication and focus group discussion. Lastly through expert level workshop 41 CSA practices were selected under 13 major production systems. Through written questionnaire expert evaluated the production practices and gave climate smartness score for each practice along with their impact on three pillars of CSA viz. productivity, adaptation and mitigation. The major production systems were selected as per their contribution to food production and livelihoods. Those production systems are T.aman rice, boro rice, aus rice, jute, spices, oilseeds, vegetable, wheat, pulses, maize, fruit, pond and floodplain aquaculture, and livestock. Climate smartness score largely varied (0.60 to 3.93) because of positive, negative and neutral effect on different criteria. However, most of the production practices have positive effect on production, adaptation and carbon sequestration. Some have impact on reducing greenhouse gas (GHG). Therefore, adoption/adaptation of these production practices would be instrumental to mitigate/minimize the detrimental effect of climate change towards achieving food security and to conduct further research and development work.

Keywords: *Climate Smart Agriculture; Bangladesh; Inventory; Production*

Introduction

Bangladesh still largely an agrarian country, 75% of its 161 million population lives in the village areas depending mainly on cultivation of field crops, vegetables, fruits, livestock, fisheries, labor selling, and small business. The total cultivable land of the country is only 7.9 million hectares [1]. The south-central Barisal and south- western Khulna regions comprises of 21.6 % of Bangladesh mostly under the agro-ecological zone 14 called Ganges tidal floodplain [2]. The population of these areas is more dependents on agriculture as industry is mostly absent, except a few numbers but the area is being recurrently battered by cyclone, tidal bore/surge and salinity due to its proximity to sea. Thus, poverty and food insecurity is a major concern in this region. The coastal zone covers 19 out of 64 districts facing or in proximity to, the Bay of Bengal, encompassing 153 upazilas [3]. A total of 48 upazilas/thanas of these districts are considered as "exposed" directly to vulnerabilities from natural disasters [4]. Bangladesh occupies a unique geographic location spanning a relatively short stretch of land between the mighty Himalayan mountain chain and the open ocean. It is virtually the only drainage outlet for a vast river basin complex made up of the Ganges, Brahmaputra and Meghna rivers and their network of tributaries. These rivers, which cause almost regular and serious floods over much of the country during the summer monsoons, are reduced seriously during the dry winter months [5]. In Bangladesh, salinization is one of the major natural hazards hampering crop production. About 53% of coastal area is affected by different degrees of salinity [6]. According to BARC [2], light 0.29, moderate 0.43 and high 0.12 million hectares land salinization was observed in Bangladesh which cost 586.75 million USD per year [5]. According to the Global Climate Risk Index, Bangladesh is the most climate change vulnerable country in the world [7]. Salinity affected soil increase 21% in last three decades in this region [8]. Future changes of temperature and rainfall are estimated for Bangladesh and it was found from the observed data that the temperature is generally increasing in the monsoon season (June-August) [9].

Bangladesh made significant progress in ensuring the nutrition and health of its population and in meeting the Millennium Development Goals (MDG) targets of halving hunger by 2015 but still 17% population remains under poverty level [10]. Over the past decades, Bangladesh's high population growth led to a stark decline in per capita agricultural land availability (0.05 ha/capita) [11]. The trend is exacerbated by the increasing nonagricultural use of cultivable areas resulting from unplanned urbanization (e.g. for housing), road construction, and other infrastructure projects.

Since yields of summer monsoon rice depend on consistent, predictable rainfall, disruptions in normal monsoon behavior can produce significant losses in rice yields all over South Asia, including Bangladesh. Rain-fed monsoon rice, for example, which constitutes over 38% of total rice production in Bangladesh, is highly vulnerable to water supply volatility, caused by changes in seasonal monsoon occurrence [12]. On one hand, early monsoon arrival can cause flood damage when rice seedlings are submerged in early growth stages, especially when farmers are not using submergence tolerant varieties. On the other hand, late monsoon arrival can lead to water stress. Results from the CERES-Rice model indicate that high water stress during flowering and maturing stages can lead to rice yield losses as high as 70% [13].

Extreme weather conditions (floods and cyclones) are expected to increase in frequency and intensity in Bangladesh [14]. Most rainfall in Bangladesh occurs in the summer months between June and October, while the winter months (November to February) receive only 4% of the annual rainfall. Early monsoon rain in March-April 2017, for example, caused heavy flooding in northeastern haor (vast low depression areas) that damaged pre-mature boro paddy incurring a loss of 0.8 million tons of rice [15]. On the whole, rainfall is expected to increase in Bangladesh by 9-12% by 2050 which suggest more flooding in future [14].

Climate-smart agriculture (CSA) is an approach or strategy that helps to guide actions needed to transform and reorient agricultural systems to effectively support development and ensure food security to cope with changing climate. CSA aims to tackles three main objectives viz. sustainably increasing agricultural productivity and incomes; adapting and building resilience to climate change; and reducing and /or removing greenhouse gas emissions, where possible [16].

CSA technologies and practices present opportunities for addressing climate change challenges, as well as for economic growth and development of the agriculture sector. For this Bangladesh profile, practices are considered CSA if they enhance food security as well as at least one of the other objectives of CSA (adaptation and/or mitigation). Hundreds of technologies and approaches around the world fall under the heading of CSA. Many of the CSA practices identified here have been used by farmers in the southern coastal plains of Bangladesh for centuries, in response to increasing floods and cyclones.

With the above context it would be worthwhile to make an inventory of CSA practices applicable for southern coastal areas of Bangladesh for future up-scaling, further research and development for better adapting with the changing climate and socio-economic conditions.

Methodology

Primarily detailed desktop browsing was done to collect related literatures including relevant book, brochures, websites, journal articles, research results and reports of different national agricultural research institutes were collected to analyze the situation, collate the adaptation measures against climatic variation/climate change applicable for southern coastal region of Bangladesh. Besides this we met a large number of stakeholders of the regions including agricultural scientists, extension workers/officials, officers of Fisheries department, NGO workers, local administration officials, businessmen, policymakers and investors. Extensive peered group field visit was organized to visit the area affected by tidal surge, salinization and other human activities. Moreover, through personal communication with scientists and innovators potential adaptation options were recorded. We conducted six focus group discussions (FGD) across different coastal areas of southern Bangladesh. In each FGD more than 20 key informant farmers participated. At final stage a workshop of 30 scientists, extension workers, concerned NGOs, Consultative Group Centers representatives and policy makers was organized in February 2017 at Dhaka to select the promising CSA practices for their mandated commodities and to give a score of climate smartness for each practice along with theirs impact on productivity, adaptation and mitigation, and mentioning applicable farm category. For each CSA practices three to six experts gave their opinion. The average climate smartness score is calculated based on the practice's individual scores on eight climate smartness dimensions that relate to the CSA pillars: yield (productivity); income, water, soil, risks (adaptation); energy, carbon and nitrogen (mitigation). A practice can have a negative/positive/zero impact on a selected CSA indicator, with 10 (+/-) indicating a 100% change (positive/negative) and 0 indicating no change. Practices in the Tables have been selected for each production system key for food security identified in the study. As per the Bangladesh Bureau of Statistics (BBS) five years average data (2011 - 2015) highest area/production given by the production systems (crop/fisheries/livestock) were selected. For selecting CSA practices and measuring climate smartness CIAT guide was followed (https://ccafs.cgiar.org/climate-smart-agriculture-prioritization-framework#.Wf9bcdCnHDc) Bangladesh cultivable land is only 7.9 million ha but total cropped area is more than that, as in the same year in the same piece of land more than one crop is grown, sometimes up to three or four crops. Thus, total percent of land area shown in tables are much more than 100 percent. In these way 11 production systems in crop sector was selected and one for fisheries and one for livestock. Under each production systems one to several promising CSA practice/practices were selected for evaluation and 41 CSA practices/technologies are furnished in tabular form. The region is only above 1.5 to 4 meter above mean sea level and lies within geographical area 22-23° N and 89-91° E. Long term (1981-2015) rainfall varies from 1753 to 2633 mm/year, however major portion rain occurs during monsoon (June to September). Winter (November to February) is mostly dry having scanty or no rainfall. Long term maximum temperature varies from 25 - 35.6°C while minimum temperature ranges from 13.5 to 26.8°C. The area is tidally flooded. In general, tidal water enters crop field during April to October. Major soil type is non-calcareous grey floodplain heavy silty clay and general soil fertility level is high [2].

Results and Discussion

Production system: T. aman

T.aman is the major monsoon season rice and grown in 70 % of cultivable land during July-December. It is comparatively low cost rice as grown mostly with rain water. It is particularly important for southern Bangladesh where salinity is a problem in dry months but with the onset of monsoon rain the river/canal water and soil become non-saline and the environment become suitable for rice cultivation. Table 1 indicates that the CSA practice short duration high yielding T.aman rice is suitable for small and medium category famers, its climate smartness score is 1.94. Its impact on productivity is clear as the practice help to get early season rice when farmers are in crisis of cereal food security as traditional local T.aman rice is harvested about one moth latter (December) than short duration one. The said CSA practice also help the farmers to establish post-rainy season (called rabi season) high value winter crops at proper time to achieve good yield. In case of adaptation the CSA technology is helpful to avoid biotic stress and late season climatic shock such as cyclone, tidal surge. As its field duration is about one month short it helps to avoid late season drought when happened, so more water efficient. It also helps to moderately reduce the GHG emission through ensured canopy and root growth.

Southern Bangladesh often faces water congestion during late monsoon when huge rainfall, upward retreating water and extra tidal water (full moon and new moon time) combines at a time, the cultivable land, mostly growing T.aman rice goes under water for several days to weeks causing huge loss to rice crop. But by adoption of newly developed CSA practice submergence tolerant high yielding varieties the above water submergence shock could be avoided.

The practices possess 2.03 climate smartness score (Table 1) having increased yield and profitable return. Through cultivation of this submergence tolerant rice cultivars grain yield, root and canopy growth of crop is ensured thus C- sink increased.

Production system: Boro rice

Boro rice or winter season rice is now the major rice in Bangladesh though its area (61 %) is less than T.aman rice. As its duration is more and gets enough sun shine to convert the photosynthates to grain. But the southern Bangladesh is often affected by water and soil salinity during winter or dry season. So, adoption of CSA practice- saline tolerant varieties is important for ensuring high and economic yield. Climate smartness score of the practice is moderate-2.60 (Table 1) having significant yield elevation. As grain yield, canopy growth and root development is more C-sink is also higher.

USG (Urea-Super Granule) application in boro rice is a CSA practice which reduces nitrogenous fertilizer need of plant by reducing spoilage of urea fertilizer after application in soil. Its climate smartness score is moderate-1.71, applicable for small and medium farmers. Though application of USG boro rice yield is ensured having slight increase but the main benefit is the significant reduction of emission of nitrous oxide gas which is normally emitted by using prilled urea fertilizer (Table 1).

By using CSA practice-Axial flow pump (AFP) for irrigation in boro rice in non-saline south-central Bangladesh irrigation cost could be reduced by 30 - 40% (Table 1). As the irrigation cost is reduced by using AFP and irrigation is used from surface source, so good quality water is used, which ensures sustained and economic yield. Normally centrifugal diesel pump is used for irrigation which burn30-40 % more diesel for irrigation compared to AFP, so GHG emission is high. Thus, by using AFP, GHG emission could markedly be reduced. The climate smartness score of the practice is 1.80 and applicable for small and medium holders.

Production systems: Aus rice

Aus rice or spring rice is grown in 14 percent area during March to July (Table 1). It often faces drought, storm and weather extremes. It helps to ensure cereal food security of early summer months. The CSA practice-direct dry seeding helps to establish the crop in right time thus ensures yield. As in direct seeding soil is less disturbed, so it reduces soil degradation and soil erosion. It also reduces GHG emission as less power is required for tillage. Its climate smartness score is good-2.23.

The CSA practice drought tolerant short duration high yielding aus rice varieties could help to avoid drought and ensure grain production. As growth of crop is ensured, it also increases C-sink. Its climate smartness score is 1.35 (Table 1).

Lodging tolerant taller aus rice varieties is a CSA practice suitable for tidally flooded southern Bangladesh. As sometimes excessive tidal water or tidal surge damages standing aus rice crop. Thus, the submergence tolerant taller varieties can avoid this sudden hazard. As growth and yield is ensured it sinks more carbon in crop canopy and in underground root system. Its climate smartness score is high-2.29 (Table 1).

Production system/Crop name (% area)	CSA practice	Applicable farm category	Climate smart ness score	Impact on		
				Productivity	Adaptation	Mitigation
1. T.man rice (70)	1. Short duration high yielding (HY) varieties for facilitating timely planting of rabi/winter crops	Small and medium	1.94	Increased and early season rice yield. Ensured winter crops planting	Resilience to biotic stress and climate shocks. Enhance water use efficiency	Moderate reduction in GHG emission
	2. Submergence tolerant HY varieties	Small and medium	2.03	Increased and economic yield	Can endure tidal surge/ flood	Carbon sink increased

2. Boro rice (61)	1. Saline tolerant HY varieties	Small and medium	2.60	Significant yield increase	Can endure soil and water salinity	Carbon sink increased
	2. Application of USG (urea super granular) as the N fertilizer for saving N and reducing N_2O emission	Small and medium	1.71	Slight increased yield	Less N-fertilizer need, sustained production	Reduced GHG emission
	3. Use of Axial Flow pump for irrigation to reduce irrigation cost by 30 - 40% in tidally flooded non-saline areas	Small and medium	1.80	Economic and increased yield	Better quality water, sustained yield	Reduced GHG emission
3. Aus rice (14)	1. Direct dry seeding for saving time, energy, and water	Small and medium	2.23	Slight increased yield	Reduces soil degradation, erosion	Reduced GHG emission
	2. Drought tolerant, short duration HY varieties	Small and medium	1.35	Increased yield	Tolerant to drought	C-sink increased
	3. Lodging tolerance taller varieties	Small and medium	2.29	Increased yield	Can cope with sudden water rise	C-sink increased

Table 1: *CSA practices of different rice crops for southern Bangladesh.*

HY: High yielding; GHG: Green House Gas.

Production system: Jute

Jute is an important fiber of Bangladesh covering nine percent area across most of the villages. It grows during summer to monsoon period (March to August). For crop rotation jute is regarded as an essential crop characterized by its deep root and luxurious leaves. Falling of these leaves on land helps to fertile next crop. But to remove the fiber from the stick is a cumbersome process and retting of it in water seriously pollutes water quality. Particularly in drought year jute fibers taking become a problem. Ribbon retting practice needs only a small amount of stored water for retting of stick less fiber. So, ribbon retting of jute fiber is a potential CSA for getting quality jute fiber. Though the climate smartness score of this CSA is only 0.71 (Table 2). It helps to reduce GHG emission.

For the southern Bangladesh dry season salinity is a problem for optimum crop growth. Thus, the CSA option- saline tolerant jute variety is a good alternative to grow it in saline affected areas. It is helpful to get increased and profitable yield of jute under saline conditions along with better sequestration of carbon. Its climate smartness score is only 0.60 (Table 2).

Production system: Spices crop

In Bangladeshi cuisine no food or curry could be prepared without Chili either it is fish, vegetable, meat or pulse. Spice crops cover about seven percent area. Both salinity and drought hampers it growth and economic production. The CSA practice saline and drought tolerant spice crop (Chili) ensures significant yield increase along with reduction of climatic risk. Through its cultivation C-sink increased and GHG emission reduced. Its climate smartness score is 1.61 (Table 2).

Production system: Oilseed crop

Vegetable oil particularly mustard oil is a part and parcel of Bangladeshi dishes and also it has some medicinal value. In five percent land oilseed is grown. But currently Bangladesh import bulk share of it vegetable oil need from different countries. But still the major oil seed crop is mustard. It often suffers pest attack at the end of crop season when the crop is late planted due to rise of temperature. Short duration mustard crop is also needed for growing next boro rice crop or switching to other options. Thus, the CSA practice- short duration high yielding (HY) mustard cultivation is important for multiple cropping systems and for escaping climatic hazard like early monsoon rain and pest. It also helps to increase C-sink and reduce emission of GHG. The climate smartness score of the practice is pretty good-2.90 (Table 2).

In the saline affected southern Bangladesh saline tolerant HY mustard variety is a potential CSA practice for achieving increased and economic yield. It can cope with winter and summer season soil salinity along with increased sequestration of carbon. Its climate smartness score is also good-2.21 (Table 2).

Production system/Crop name (% area)	CSA practice	Applicable farm category	Climate smart ness	Impact on		
				Productivity	Adaptation	Mitigation
4. Jute (9)	1. Ribbon retting for jute fiber management (drought management and avoids water pollution)	Small and medium	0.71	Better quality fiber and market price	Suitable for less water area and reduced water pollution	Reduction of GHG- emission
	2. Saline tolerant jute varieties	Small and medium	0.60	Increased and economic yield	Yield stability under saline condition	Carbon sink increased
5. Spices-Chilli (7)	1. Saline and drought tolerant Chilli cultivation in rabi and kharif I season	Small	1.61	Significant yield increase	Reduces climatic risk, so sustainable yield	Carbon sink increased and reduced GHG emission
6.Oilseed-Mustard (5)	1. Shorter duration and HY mustard 2. Saline tolerant HY mustard	Small	2.90	Increased yield and income	Use of soil moisture, and avoid late rainfall	More C- sequestration and reduction of GHG
		Small	2.21	Increased production stability and income	Cope with climatic risk	Better C- sequestration

Table 2: *CSA practices of jute, spices and oil seed crops for southern Bangladesh.*

Figure in parenthesis indicates percent cultivable area covered by the production systems in case of crop (Table 1-5) C-Carbon.

Production system: Vegetable

With rapid urbanization and growing of health sensitive middle class consumption of vegetable is increasing in Bangladesh. It is now cultivated in five percent land having huge commercial value as four to five vegetable crops could be cultivated in same piece of land in a year. As Bangladesh is a land hungry country all the available space must be utilized including water bodies, marshy land and trail system along with normal land. Thus, submergence tolerant aroid is grown in marshy land mainly for nutritious stolon having export value also. The CSA practice submergence tolerant aroid is grown by the smallholders having endured production and income. This is well adapted to marshy or water logged medium low land. By growing aroid C-sequestration is increased as it grows very profusely. The climate smartness of the practice is 1.39 (Table 3).

Gher is a Bengali word means surrounded by something. Here gher means excavated water body surrounded all sides by 1-2 meter height of polder made by soils mainly for shrimp/prawn culture, along with other fish and T.aman/boro rice cultivation. On the bank of 1 - 2 meter wide gher often vegetables are cultivated; also creeping vegetables are grown on trellis made on the water body by fixing bamboo [15]. The CSA practice growing tomato in winter season is a very productive and profitable enterprise applicable for all categories of farmers‟ of south-western Bangladesh and elsewhere. Through this CSA good women empowerment happens, as harvesting, cleaning, grading and packaging of tomato is done mainly by hired or own female labor. As a rapid growing high yielding plant it sink a good quantity of carbon. Its climate smartness score is 1.75 (Table 3).

Growing creeping vegetable on net/trail over pond/gher is typical example of using unused water space. Without disturbing fish cultivation of pond/gher it brings a good profit over the years. As seed/seedling is planted on bank of gher/pond, it can avoid extra rain or excessive tidal water surge having an increased and economic yield. It also increases women empowerment, as women mainly conduct harvesting and processing. It also increases the biodiversity of the area. As the creepers grow profusely, so C-sink is also higher. The climate smartness of the CSA practice is 1.95 (Table 3).

The CSA practice vegetable cultivation following tower system/sac in homestead area is technology suitable for the area where rainfall as well as tidal water entry hampers vegetable cultivation particularly in rainy season. It can fulfill the critical vegetable need of a family when it became scarce and costly due to inundation. It is one of the best practices to cope with rapidly growing rain and tidal water. Generally small farmers adapt this practice though applicable for others also. It also slightly increases C-sink. The climate smartness score of the practice is 0.51 (Table 3).

The CSA practice floating beds cultivation on water bodies is an age old highly productive and profitable practice of south-central Bangladesh, now increasingly adapted by other water logged areas. When vegetable seedlings are grown for selling, the farmers do it 4 - 5 cycles per year. Sometimes vegetable and spices are produced on those floating beds. Beds are made up of bamboo frame, water hyacinth, some aquatic weeds and coconut or saw dust.

Most of the operations are done on riding small boat, when needed also on foot within nee to waist deep water. It is a great adaptation measure against water logging where at best one low yielding floating aman rice could be grown. But by adapting this practice farmers have increased their productivity and profit markedly. It is also be great deterrent against future sea level rise due to climate change effect. The CSA practice capture carbon in an increasing rate has a climate smartness score of 1.19 (Table 3).

Kangkong (*Ipomoea aquatica*) is a nutritious green leafy vegetable can grow in any land having available moisture. It could be harvested number of times as after fertilization and irrigation it produce similar amount of leaves in several cuttings. Thus, the CSA practice cultivation of kangkong brings good production and income to famers and could be adapted in high to medium low land. Generally, smallholders adapt it and sold it to market, liked by all walks of people. By cultivating kangkong efficiency of water use, fertilizer and land use elevated significantly. It also quickly captures carbon. Its climate smartness score is 0.69 (Table 3).

In the tidally flooded area of southern Bangladesh where there is no embankment, it is not possible to grow vegetable or fruit during monsoon due to flooding by tidal and rain water. There farmers create ridged bed (1 - 1.5m height) and furrow (from where soil is given to bed). On the ridged bed farmers can successfully grow vegetable and quick growing fruits round the year on the bed. It is called sorjon method of cultivation. And in the furrow sometimes fish are being grown or aroids. After few years latter farmers also plant agroforestry species on the bed. The practice increases biodiversity against tidal surge along with safe cropping. It also increases C-sequestration. Its climate smartness score is high-2.17 (Table 3).

Production system/Crop name (5% area)	CSA practice	Applicable farm category	Climate smart ness score	Impact on		
				Productivity	Adaptation	Mitigation
7. Homestead/ commercial vegetable (5)	1. Submergence tolerant aroid for stolon mainly, having HY and market price	Small	1.39	Increased yield and income	Easy to adapt with marshy land	C-sequestration increased
	2. Tomato on the "gher" boundary dikes	Small, medium and large	1.75	Good yield and income	Women empowerment	C-sink increased
	3. Creeping vegetable on nets/ trail over ponds	Small and medium	1.95	Increased yield and income	Women empowerment and biodiversity	Carbon sink increased
	4. Vegetable cultivation following tower systems/using plastic sac for growing homestead crops under excessive water (tidal water and rainfall)	Small	0.51	Increased yield, family nutrition	Can cope with excess rain and tidal water	Slight increased C-sink
	5. Floating beds cultivation on water bodies	Small	1.19	Increased yield and income from wet land	Better utilization of land, water and space against water logging	Better C-capture, energy saving
	6. Kangkong cultivation on gher boundary/open land	Small	0.69	Increased yield and income	Land, fertilizer and water use efficiency increased	Quick C-capture
	7. Sorjon cultivation method	Small	2.17	Safer cropping and increased yield	Increased biodiversity against tidal surge	Increased C-sequestration

***Table 3:** CSA practices of homestead and commercial vegetable for southern Bangladesh.*

Production system: Wheat

Wheat is the second most important cereal crop in Bangladesh grown in five percent area. Each year Bangladesh import more than four million tons of wheat grain from different countries for meeting its growing demand along with urbanization, as diet for different diseases including diabetes, blood pressure and making bakery products and fast food items. As the winter period is becoming short with changing climate, wheat plants suffer heat, salinity, different diseases including deadly blast. So, switching to/developing CSA is so crucial for wheat crop. The CSA practice saline and heat tolerant variety ensures good yield and economic yield return even when planted in late season. The practice is adopted mainly by small farmers. It helps to maintain food security and increasing of C-sink. Climate smartness score of the practice is 3.41 (Table 4).

Conservation agriculture (CA) helps to establish wheat crop at early season without losing residual moisture in post- rainy season, thus helps to ensure better production. CA method reduces tillage cost and water requirement and lose of nitrogenous fertilizer. It also improves soil quality and reduces soil erosion. It is generally adopted by small and medium farmers. It also reduces GHG emission. The climate smartness of the CSA practice is 3.49 (Table 4).

Blast is deadly disease of wheat plant occurring in Bangladesh recent years. Due to this disease almost 100% yields is lost, so it is a serious threat to food security. It is a seed borne disease and visible at flowering stage, resistant to most of the fungicides. Hence planting of blast resistant wheat variety is so important, and key to ensuring production and farmers income. It minimizes crop vulnerability and climate smartness of the practice is high- 3.93 (Table 4).

As with the climate change effect the temperature of Bangladesh is gradually becoming high which affect grain filling in wheat plant. Also, at late stage of the crop rainfall and storm hampers the production of wheat, so planting of dwarf and early maturing wheat variety is needed to ensure yield and viable economic return. The CSA practice dwarf and early maturing wheat variety helps to avoid heat stress and seasonal storm and facilitates more sequestration of carbon. The climate smartness of the practice is 2.17 (Table 4).

Production system: Pulse crop

Bangladesh is a hugely deficit in pulse production, as it is grown just in four percent land mostly in winter and early summer, which is again affected by disease and pest. However, pulse is an almost essential part of everyday Bangladeshi dish, as it is a cheap source of protein. Summer mungbean (*Vigna radiata*) is a promising crop in the recent years having corporate business house investment, as roasted mung pulse fry (called mung dal fry) are marketed by them. The CSA practice short duration high yielding mungbean cultivation ensures yield and income increase. Mungbean gives high dividend as among the pulse crops mungbean is the costliest. It reduces climate shock and creates women employment. As harvesting and processing is done mostly by women and children. It increases C-sequestration and as legume crop improves soil health. Small and medium farmers often adopt this production practice. The climate smartness score of the practice is 1.41 (Table 4).

The production practice conservation agriculture in mungbean planting helps to reduce cost and increase profit. It improves soil quality and reduces erosion. Gradually small farmers are being accepting CA with the help of 2-wheel tractor operated Chinese seeder. It reduces GHG emission and increase C-sequestration. The climate smartness score of the practice is 0.85 (Table 4).

The CSA practice brown manuring mungbean biomass is a unique way to improve soil physical quality and soil fertility. Particularly in the next crop less nitrogenous fertilizer is required and production increased sustainably. It also reduces soil erosion and GHG emission having 1.34 climate smartness score (Table 4).

Production system/Crop name (% area)	CSA practice	Applicable farm category	Climate smartness score	Impact on		
				Productivity	Adaptation	Mitigation
8. Wheat (5)	1. Saline and heat tolerant late planting variety	Small	3.41	Yield increase	Tolerant to salinity and food security	Carbon sink increased
	2. Conservation agriculture (zero/ strip tillage/bed planting)	Small and medium	3.49	Yield and income increase	Efficient utilization of water, fertilizer, time. Reduce soil erosion	Reduced GHG emission
	3. Blast resistant wheat variety	Small, medium, large	3.93	Yield and income increase	Avoid crop vulnerability	Reduces GHG emission
	4. Dwarf and early maturing variety	Small	2.17	Ensured yield	Avoid seasonal storm and heat	More C- sequestration

9. Pulse-Mungbean (4)	1. Shorter duration HY mungbean	Small and medium	1.41	Yield and income increase	Reduces climate shock. Women empowerment	C-sequestration
	2. Conservation Agriculture (bed planting/strip tillage)	Small	0.85	Yield and income increase	Efficient water use, women empowerment	C-sequestration and reduced GHG emission
	3. Use of mungbean biomass as brown manuring	Small	1.34	Increased soil fertility, benefit to next crop	Reduced soil erosion, water and soil fertility improvement	Reduced GHG-emission

Table 4: *CSA practices of wheat and pulse crops for southern Bangladesh.*

CA-Conservation agriculture

Production system: Maize

In recent years maize has become an important and profitable cereal crop across the country due to its ensured high yield, less disease pest and multiple uses of maize grain including for poultry, animal and fish feed. Now maize is grown in three percent area. Among Asian countries Bangladesh maize has the highest average yield (6.64 t/ha), as largely different high yielding hybrid maize cultivars along with application of optimum irrigation and fertilizer it is cultivated in sunny winter season. Now a days Bangladesh can meet bulk parts of its maize requirement from its own production (2.7 million ton) (Ministry of Agriculture web site, Dhaka, 2017). It also helps to add to food security as people use it as roasted grain and millers/companies mixture some portion of milled flour with wheat flour. Also, it creates women employment, as for post-harvest operation women are popularly engaged. Being a C-4 crop it fixes more carbon to it canopy, grain and root systems. The climate smartness score of the practice is 2.12 (Table 5).

Conservation agriculture technique fits well for hybrid maize. It reduces cost, increase profit, conserves soil organic matter and reduces soil erosion. By using the practice maize is being planted in early of the winter season thus high yield is ensured, also early summer storm is avoided. It reduces GHG emission and increase C-sequestration (Table 5) having a good climate smartness score (3.38).

Maize is a long duration (about 150 days) spaced crop and its canopy is not closed until 40 - 50 days after planting. So, within this period any short duration vegetable crop could be grown efficiently without hampering maize yield. Thus, intercropping of vegetable like red amaranth, spinach, coriander sak (vegetable) could successfully be grown with quick cash income and family nutrition. Intercropping reduces risk of crop failure, space and time is scientifically utilized for production, creates women empowerment. It increases C-sink along with a moderate climate smartness score of 3.0 (Table 5).

White maize is new crop variety in Bangladesh, now being promoted for adoption for diversifying food security and directly for human consumption. It may be instrumental for production and income increase of small farmers (Table 5). As C-4 crop it will fix more carbon aboveground and underground. The climate smartness score of practice is 1.77.

Because Bangladesh acutely lacks pasture land, animal feed and grass is always a major problem for commercial livestock raring. Before harvesting of maize cob, leaves could be used as green fodder for animal. As huge maize biomass is produced each year farmers sometimes use it as fuel, but mostly thrown outside crop land without any economic use. But this maize Stover could be processed as nutritious animal fodder. It will increase farmers‟ income and reduce fodder cost along with reduction of GHG in livestock. The climate smartness score of the practice is 2.13 (Table 5).

Production practice: Banana

As a land hungry country Bangladesh spare a small area for fruit. But for nutrition and meeting the demand of growing rich and middle class it imports a huge amount of fruit from different countries round the year. Particularly for southern region available land for fruit crop/tree is scanty, as often affected by tidal water, submergence and cyclone. But by raising soil different varieties of banana is being cultivated for meeting the mineral and nutritional needs. Banana is also a costly and profitable fruit in southern Bangladesh as the area is largely deficit in major fruits due to environmental limitations. The CSA practice banana cultivation on ridged land ensure yield, reduces risk, decrease soil erosion and increase C-sink. The climate smartness score of the practice is 1.86 (Table 5).

Production system/ Crop name (% area)	CSA practice	Applicable farm category	Climate smart ness score	Impact on		
				Productivity	Adaptation	Mitigation
10. Maize (3)	1. HY hybrid varieties 2. Planting of maize following CA (strip tillage/bed planting) for energy saving and proper time planting 3. Intercropping with short duration vegetables 4. Cultivation of white maize for human consumption 5. Use of maize Stover as fodder for animal feed	Small, medium Medium Small Small Small	2.12 3.38 3.0 1.77 2.13	High yield High yield, reduced cost Total productivity increased Increased yield and income Increased income	Food security, women empowerment Efficient utilization of water, fertilizer, time, reduced soil erosion Utilization of time and space, reduce risk, women empowerment Food security, women empowerment Protein availability through livestock	As C4 crop more C-sequestration Reduced GHG emission and more C-sink Carbon sink increased Increased C-sequestration Reduced GHG for livestock
11. Fruit-Banana (1.75)	1. Banana cultivation on ridged soil	Small and medium	1.86	Yield, nutrition and income increase	Can cope with increasing tidal water and excessive rain, soil erosion decreased	C-sink increased

Table 5: *CSA practices of maize and fruit crops for southern Bangladesh.*

Production system: Pond and Floodplain aquaculture

From ancient time fish is being the major source of animal protein for common Bangladeshi people, however because of loss of rivers, water bodies, environmental pollution and over fishing the availability of hundreds of fish species have largely been lost or reduced. However, there is always a struggle to maintain the fish supply through aquaculture. Presently about 60 % animal protein is supplied from fisheries sector though it has become a bit costly item. The CSA practice rice-fish culture (Table 6) is a traditional way of getting fish from monsoon or aman rice field which occupy about 70 percent land, particularly in the medium low land or within polders where water remains for three to five months. It gives more fish production, income and family nutrition along with increasing total productivity of land. It also minimizes risk and generates women employment, as they watch and look after the rice-fish culture. It also increase the C-stock having a good climate smartness score (3.14).

The CSA practice culture of small indigenous fish species is a unique source of protein and minerals within low cost, as generally whole fish is taken including bones (Table 6). It is an additional fish with main cultivated larger fish species like intercropping of short duration vegetable with maize. So except the fish fry/small fish no other cost is required to get these small fish like, Mola, Dhela, Diankina, Puti etc. Thus, cultivation of small species increases productivity, economic return and nutrition. It also increases biodiversity and reduce risk and stock more carbon.

The climate smartness score of the practice is moderate (2.63) and adopted mainly by small fishers.

The CSA practice gher system cultivation of fish particularly giant tiger prawn or bagda chingri (*Penaeus monodo*) is the main target for maximum profit (Table 6). But additionally rice (boro or T.aman) is cultivated within gher for meeting cereal food demand. But with the advent of technology later on vegetables were being promoted by research institute (BARI) and were largely accepted by gher farmers to use fallow pond bank and to get additional production and income. It reduces the risk of failure of one enterprise against climatic shock, increases biodiversity and creates women empowerment. The practice also increases C-sequestration having a climate smartness score of 2.8. It is popularly adopted by medium and large farmers as capital intensive.

Crab fattening is a recently developed CSA practice (Table 6) as it bring good profit without facing major biotic risk (virus disease) as it often occurred for giant tiger prawn. However, it needs major investment and also labor intensive for getting the exportable marketing size and quality. So, the practice is mainly adopted by large farm and big businessmen/companies. It also stocks more carbon having a moderate climate smartness score of 2.34.

Year round aquaculture (Table 6) is a promising CSA practice for supply of cheap and quality animal protein in Bangladeshi people diet. It is accepted and liked by all categories of farmers for supplying of food, nutrition and cash income round the year. However, it fitted where water remains up to few feet round the year including in dry season. It also increases biodiversity and maintain/improve soil C-stock. Its climate smartness score is also good (3.04).

Production system: Livestock

Bangladesh is largely deficient in meat production, instead of 120 g/head/day requirement, availability is only 20g/head/day [17]. Popularity of cattle, goat meat is very high in Bangladesh though it is costly for common people. And the in the time of annual Muslim religious festival (Eid-ul-Azha) the demand of male cattle and goat is high along with buffalo and sheep. That's why young men and women take that opportunity and feed the cattle for quick fattening within 3 - 4 months for selling at the time of above festival. It brings good income within short time though investment is a bit high. However, it is suitable for small farm those who have no enough land, as limited number of livestock is reared within homestead and mainly cared by women and men. So, it creates women and men employment also. The CSA practice seasonal commercial livestock fattening helps to reduce climatic shock and methane gas emission (Table 7). It possesses climate smartness score of 1.58.

The CSA practice fodder crop production for saline affected area (Table 7) is important for southern Bangladesh, as high land is limited to grow it and also often it is affected by salinity in dry season. The health and number of livestock is less in southern region due to above limitation. Cultivation of any saline tolerant fodder crop will not only bring profit, but also it will reduce erosion, diversify farming along with increased sequestration of carbon. The climate smartness score of the practice is 1.55.

Because of limited forest area, crop residue and cow dung are used as fuel for household cooking in the country side. Bottled gas is rarely available. Fuel crisis is acute in southern region. As cow dung is used for fuel it rarely used in crop field for manuring. But with the government and donor agencies subsidy biogas could successfully be produced from cowdung, poultry litter and other crop residue. After

Production system/Fish culture (% production)	CSA practice	Applicable farm category	Climate smartness score	Impact on		
				Productivity	Adaptation	Mitigation
12. Pond and floodplain aquaculture (42% of total fish production)	1. Rice-fish culture within polder and adjoining canals, water bodies	Small, medium	3.14	More production, income and nutrition	Protein rich-food availability, reduce risk, women empowerment	Improve soil C stock
	2. Cultivation of small indigenous fish species	Small	2.63	Production, nutrition, income increase	Bio-diversity, food availability, extra income, women empowerment	Improve soil C stock
	3. Gher system cultivation for mixed Fish+rice+vegetable	Medium, large	2.8	Increased production, nutrition and income	Bio-diversity, food availability, reduces climatic risk, women empowerment	Increase C-sequestration
	4. Crab fattening	Large	2.34	Production, nutrition, income increased	Less disease, food availability, women empowerment	Increase soil C stock
	5. Year-round aquaculture	Small, medium, Large	3.04	Production, nutrition, income increase	Food availability round the year, women empowerment, bio-diversity	Improve soil C stock

Table 6: *CSA practices of pond and floodplain aquaculture for southern Bangladesh.*

Figure in parenthesis indicates percent of total fish production in a year.

producing gas the remaining material is used as good quality organic manure for growing crops. It reduces farmers‟ fuel and fertilizer cost, ease women health hazard for using crop residue/cowdung in cooking. It also greatly reduces GHG emission. The climate smartness score of CSA practice compost and biogas production is 1.89 (Table 7).

Production system/ livestock (% production)	CSA practice	Applicable farm category	Climate smartness score	Impact on		
				Productivity	Adaptation	Mitigation
13. Cattle/ Buff alo/ goat/shee p-meat (5)	1. Seasonal commercial cattle fattening	Small	1.58	Animal Protein, organic compost, fuel produced, income markedly increase	Women empowerment, food availability increased, increase farmer's resilience on climate shock	Reduced methane emission
	2. Fodder crop production for saline affected area	Small, Medium	1.55	Production and income increase	Soil erosion decrease, women empowerment, diversify land use	C-sequestration increased
	3. Compost and biogas production	Small, medium, large	1.89	Income increase, reduce fuel need	Organic fertilizer application increased, pressure on local resource reduced	GHG-emission decreased

Table 7: *CSA practices of commercial livestock fattening for southern Bangladesh.*

Figure in parenthesis indicates percent of total meat production per year.

Conclusions

Climate change and climatic variations are largely affecting agricultural productivity and livelihoods in southern coastal Bangladesh. And this devastating effect is becoming complex each year with the sea level rise, increase of salinity, onrush of excessive tidal water, soil and river bank erosion and decrease of soil fertility. As one of the most densely populated country of the world millions of Bangladesh people live near sea, big rivers and water bodies, so affected most with climatic hazards. In such a situation farmers and researchers have relentless efforts to innovate and develop technology, cultivars crops/fish species/livestock management for adapting with changing climate for maintaining and improving their productivity and profitability. Fortunately, most of the selected CSA practices have better impact on carbon sequestration as well as on mitigation. However, research based technology development activities is constantly needed to cope with changing climate and increase of population along with up-scaling and out-scaling. But poverty, dearth of information and poor knowledge about specific technology often hinder adoption of CSA practices. The documented CSA practices could be a base to conduct further research and development activities in southern coastal Bangladesh and elsewhere having similar environments and socio-economic conditions.

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