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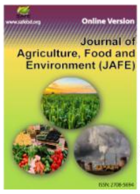

Original Article

Crop intensification with short-duration pulse crop (mungbean) using climate-smart agriculture technology in northeastern region of Bangladesh

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A B S T R A C T

Despite the economic progress in Bangladesh, a hot spot of hunger remained within the rapidly growing population and even the Covid-19 Pandemic made the hunger more intensive. Increasing the cropping intensity by replacing fallow with a short-duration pulse crop using climate-smart agriculture (CSA) technology in the northeastern area of Bangladesh might increase food security and the livelihood of poor farmers. Therefore, the objective of the study was to investigate short-duration mungbean crop in between the two rice-based cropping systems following CSA technology. The study was conducted at two locations following Randomized Complete Block Design (RCBD) in the farmers' field of Netrokona and Sunamganj Districts of Bangladesh during the period from March to May 2021. Results from both the study areas showed that CSA technology had substantially increased the total yield of mungbean, and BINA-8 variety performed the best results of 1061 kg/ha yield in the Sunamganj area. In mungbean cultivation, the lower tillage, 50% less fertilization, manuring, crop residues and efficient irrigation of CSA technology had a positive impact on water infiltration, soil nutrient status and water use efficiency of more than 40% compared to traditional cultivation systems. Nevertheless, the CSA in mungbean cultivation had enhanced carbon sequestration and reduces GHG emissions. The results also revealed that mungbean plant residues add an average 4.35 ton/ha green mass to the soil and saved more than 25% labor costs for mungbean cultivation. Therefore, crop intensification with mungbean using CSA technology in the disasters pruned area would be a good approach to combat food security and income generation of farmers. The study also argues that there is an immediate need for more intensive research to better quantify the mitigation effects of CSA technology.

Introduction

Agriculture production and food security throughout the world are facing challenges by the projected increase in climatic variability and change (Wheeler and von Braun, 2013; Thierfelder *et al.*, 2017). Climate change is the key problem to feed 9 billion people by 2050 and the survival of the whole of mankind (Godfray *et al.*, 2010; IPCC, 2014). Accordingly, FAO suggested that to keep pace with the increasing population and to feed those huge populations by 2050, agricultural production will need to increase 70 to 100% (Godfray *et al.*, 2010; Thiefelder *et al.*, 2017). In the tropics and sub-tropics, the smallholder farmers will be the most affected people and unable to cope with the adaptation process of climate changes compares to the farmers in the temperate zones (Brown and Funk, 2008; Thierfelder *et al.*, 2017). Nevertheless, the result is more profound for smallholder farmers of Bangladesh due to the increase of sea level and population, decline of soil fertility and soil degradation, and large-scale dependency on agriculture will also increase vulnerability to climate change (IPCC 2014).

Agriculture is the key of the Bangladesh economy, and the GDP contribution of agriculture in Bangladesh is 16.5% but more than 87% of the rural people are relying on agriculture directly or indirectly (CIAT: World Bank, 2017; Islam *et al.*, 2021). About 99% of farms of Bangladesh are considered as small-scale with an average area of less than 1 hectare (CIAT: World Bank, 2017; Islam and Hyakumura, 2021). Bangladesh is said to be self-sufficient in food production (e.g., rice) country but the reality is that the country has faced enormous challenges on food-sufficiency to feed its poor population (Tuong *et al.*, 2014; Mondal *et al.*, 2015). The picture was worst in the resource poor area of Bangladesh which includes the northern border region of Bangladesh. The local people of the northeastern border of Bangladesh have faced severe scarcity of water in the dry season and flash flood in the rainy season to cultivate their crops. These challenges would affect the agricultural production and livelihood of the poor people living in the northeastern border of the Netrokona and Sunamganj districts of Bangladesh. The cropping pattern in those areas depends on traditional rainfed rice (Transplanted Aus and Aman rice) cultivation mainly. However, some rich farmers can manage irrigation facilities and cultivate Boro rice and therefore, the cropping intensity is mainly two (Fallow-Aus rice-Aman rice) or in some extent three (Boro rice-Aus rice-Aman rice) crops (Khatun *et al.*, 2017).

On the contrary, Bangladesh is the most climate change the vulnerable country in the world as per the Global Climate Risk Index, and thus, climate-smart agriculture (CSA) is an effective approach for transforming and integration of agricultural development and climate responsiveness (CIAT: World Bank, 2017; FAO, 2013). The CSA concept is new which can successfully address the challenges in economic, social and environmental dimensions. It can sustainably increase productivity, enhance resilience and reduce greenhouse gases, which means synergies among productivity, adaptation and mitigation (CIAT: World Bank 2017). Therefore, crop intensification with CSA technology would be an effective approach to face the food security of poor farmers and climatic change impacts in Bangladesh.

Crop intensification with proper rotation would be a good strategy to boost up agricultural production which will concurrently improve the resource-poor farmers' livelihood and diets. Pulses are considered as being readily available sources of protein, carbohydrates, vitamins, fibres and minerals. Moreover, pulse crops contribute to diversification plus fixing atmospheric nitrogen and improve soil fertility thus, overall system productivity has been augmented. On the contrary, the legume production of the country has fallen below to meet the consumer demands and become a major concern for maintaining food security and nutritional balance (ACIAR, 2016). Pulses are also said to be susceptible to biotic stress and required minimum input for cultivation. Therefore, to fit the cropping pattern and reinvigorate the national pulse production, this study planned to introduce short-duration mungbean into the early Kharif season with a rice-based cropping pattern of the Netrokona and Sunamganj border region of Bangladesh. Most pulses are grown in western Bangladesh and have ample scope for expansion of mungbean in other parts of Bangladesh including the resources poor areas (ACIAR, 2016). More than 16 varieties of mungbean were tested in Bangladesh and the BARI-6 and BINA-8 were reported to be the best varieties in the farmers' field (Islam *et al.*, 2020). So, the study was introduced BARI-6 and BINA-8 varieties in the northeastern parts of Bangladesh as part of crop intensification with the existing Aus-Aman rice pattern. Therefore, the objective of the study was to test and promote short-duration mungbean in the existing Aus-Aman rice crop following climate-smart agriculture technology in the Netrokona and Sunamganj region of Bangladesh.

Theoretical Framework: The study introduced short-duration mungbean crop using climate-smart agriculture (CSA) technology in the resource-poor Netrokona and Sunamganj border region of Bangladesh. Improving the integration of agriculture development and resource conservation through climate responsiveness are the main theme of climate-smart agriculture technologies. Food security throughout the world under the changing climatic condition is the main consideration of scientists' and thus, climate-smart agriculture has already been popular in the world. CSA technologies can generate both public and private benefits and thus creates a potentially important means of generating win-win solutions to address food security and environmental issues (Pretty *et al.*, 2006; Branca *et al.*, 2011). CSA refers to increase the productivity of agricultural systems with enhanced resilience (adaptation) and reduce greenhouse gases (mitigation) (FAO, 2013) (Figure 1).

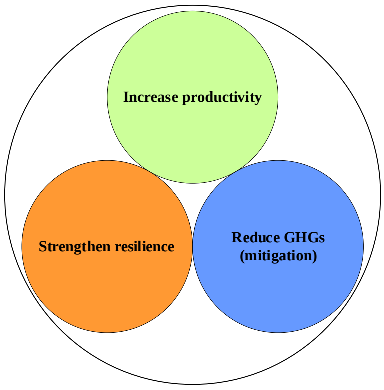

Figure 1. Three pillars of Climate-Smart Agriculture (CSA) technology.

The key theme of the CSA concept is defined as food security and development (Lipper *et al.*, 2014; FAO, 2013), while productivity, adaptation and mitigation are representing as the three interlinked pillars necessary to achieving this goal. Sustainably increase agricultural productivity and income from crops without having any negative impact on the environment is the key concept of the CSA approach. This will ensure food and nutritional security towards sustainable intensification as well.

While CSA also reduces the exposure of farmers to short-term risks and strengthening their capacity in the long-term stresses. Particular emphasis is to give protection of ecosystems that provides services to farmers and others, and these services are important to adapt to climate change. Finally, CSA helps to reduce and or remove greenhouse gas (GHG) emissions. That means we reduce emission for each calorie of food, fibre and fuel that we produced and also avoid deforestation from agriculture. In this way, the soils and crops act as a carbon sink and absorb CO2 from the atmosphere to mitigate GHG. The study would cultivate mungbean and practice all sorts of strategies to ensure productivity, adapt reliance and mitigate GHG from the atmosphere.

Materials and Methods

Study Location

The study was conducted in the farmers' field of Kalmakanda and Dharmapasha Upazilla of Netrokona and Sunamganj district of Bangladesh (Figure 1) under the agroecological zone of AEZ-22 (northern and eastern piedmont plains). This region is situated in the Bangladesh-India border occurring as a narrow strip of land at the foot of the northern and eastern hills. The soil of this area is characterized by the grey piedmont and non-calcareous grey floodplains, also loam to dry, slightly acidic to strong acidic in reaction and lower fertility status (UNDP, 1998). The study areas soil p^H ranges from 5.48 to 6.06 (acidic) and lower organic matter content (2.16 to 2.69%) (soil tested in BAU laboratory). The field research was set up in the March to May (early Kharif season) of 2021. Early Kharif season is featured by high temperature and low moisture content in the soil. Due to a shortage of soil moisture and lack of precipitation, the farmer could not cultivate any crops and in some cases, Boro rice has been cultivated within irrigation facilities. Moreover, the study farmers were poor and cannot manage irrigation facilities and thus, short-duration mungbean is a suitable crop for these areas.

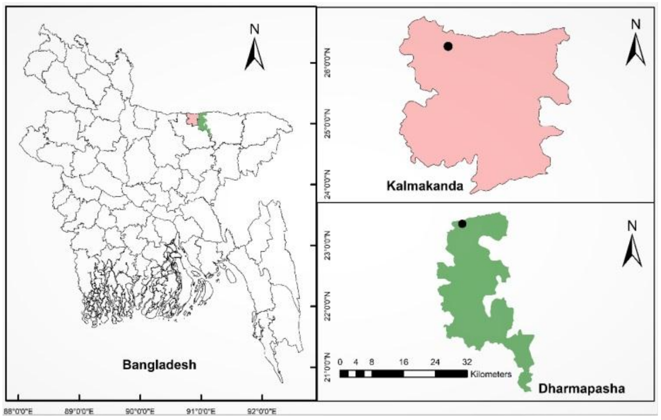

Figure 2. Study area map showing Bangladesh, Kalmakanda and Dharmapasha Upazilla.

Mungbean Variety

The study used the high-yielding and short-duration tested mungbean varieties in the study area. The two varieties in Bangladesh namely, BARI Mung-6 and BINA Mung-8 have tested the best verity among the 16 different varieties in Bangladesh (Islam *et al*., 2020). Bangladesh Agriculture Research Institute (BARI-6) variety is medium plant structure, photo insensitive and resistant to major diseases. Seed size bold with green seed coat and deep green seed color. Crop duration is about 60 days and seed yield around 1.6 ton/ha and also recommended for entire Bangladesh (Islam *et al*., 2020). While the Bangladesh Institute of Nuclear Agriculture (BINA-8) variety is good for the summer season and was introduced in 2010. BINA-8 mungbean crop duration is about 65 days and the average seed yield 1.6 ton/ha. Seed is medium size with green shiny color, contain higher protein (23%), plants are medium to short and resistant to mosaic virus and suitable for all over Bangladesh (Islam *et al*., 2020).

Experimental Design and Layout

Two experiments were conducted in the Randomized Complete Block Design (RCBD) with four treatments (T1=BARI-6 CSA, T2=BARI-6 Traditional, T3=BINA-8 CSA and T4=BINA-8 traditional) and three replications in two different locations (Kalmakanda and Dharmapasha). Each plot size has 5m × 4m size, therefore, 12 plots in Kalmakhanda and another 12 plots in Dharmopasha Upazilla were carried out for the study. The CSA (climate-smart agriculture) technology followed organic manuring plus 50% less recommended doses of fertilizers, minimum irrigation with hand application methods, line seed sowing, no insecticides/pesticides and use mungbean crop residues as green biomass for the next crop. While the traditional technology uses conventional chemical-based producing technologies in both areas.

Land Preparation, Seed Sowing and Intercultural Operations

The farmer's field was prepared by plowing and cross plowing three times followed by laddering until the desired tilth occurred. The traditional plot was mixed by the recommended doses of fertilizers- Urea, TSP, MoP at the rate of 50, 85, 35 kg/ha (BARI 2011); however, the CSA plots were mixed with 50% recommended doses of fertilizers with 10 ton/ha cow dung/vermicompost at the time of land preparation. The mungbean seeds were sown 30kg/ha rate in the traditional plot with hand broadcasting methods and line sowing (30cm × 10cm) methods on March 19, 2021. In line sowing methods, about 30% less seed was required compared to the broadcasting method. Line sowing was done at a depth of 6cm and covered by losing soil, other intercultural operation was done accordingly.

Growth and Yield Parameters of Mungbean

Data on plant height (cm), number of branches per plant, number of leaves per plant, number of pods per plant, pod length (cm), number of seeds per pod, 1000 seeds weight (g) and seed yield (kg/ha) were recorded. Five mature plants from each plot were collected to measure those parameters and for total yield, we converted each plot yield to a hectare basis. The mean value of those parameters was recorded and seed weight was collected after proper sundry, both mungbean varieties were harvested after 65 days of sowing.

Statistical Analysis

The collected data were analyzed using the statistical package of Web Agri Stat Package (WASP) and the mean difference was measured at a 5% level of significance.

Results and Discussions

Production

The growth and yield data of the BARI and BINA mungbean varieties in CSA and traditional technologies showed that plant height (cm), number of branches per plant, number of leaves per plant, pod length (cm) was statistically non-significant at 5% level of significance. That means there was no significant variation among the two varieties in both CSA and traditional cultivation technologies (Table 1). However, the BINA-8 variety in climate-smart agriculture technology showed the best results among the other treatments (Table1).

Table 1. Seed yield and yield contributing parameters of mungbean in CSA and traditional cultivation technologies.

Location	Treatments	Plant ht. (cm)	No of branch/ plant	No of leaves/ plant	No of pods/ plant	Pod length (cm)	No of seeds/ pod	1000 seeds wt. (g)	Seed yield (kg/ha)
Kalmakanda	T_1 BARI-CSA	38.33	3.33	11.67	14.22 b	7.50	9.70	42.01 b	1035 ab
	T_2 BARI-Trad	39.67	3.0	11.33	13.99 b	6.933	9.17	40.98 b	983 c
	T_3 BINA-CSA	43.67	3.67	12.0	18.78 a	8.57	11.37	46.55 a	1047 a
	T_4 BINA-Trad	45.33	3.33	11.0	15.72 b	7.43	10.43	43.89 ab	1013 b
	CV (%)	10.896	16.583	17.691	7.722	7.344	9,924	3.866	1.190
	CD (0.05)	NS	NS	NS	**	NS	NS	**	**
Darmapasha	T_1 BARI-CSA	38.33	2.67	11.67	12.43 b	7.67	8.87 b	40.61 c	1039 a
	T_2 BARI-Trad	39.33	2.67	11.00	12.87 b	7.23	8.53 b	41.77bc	945 b
	T_3 BINA-CSA	43.67	3.33	12.00	16.98 a	8.57	10.93 a	45.99 a	1061 a
	T_4 BINA-Trad	45.33	3.0	10.00	14.11 b	7.50	10.13 ab	42.89 b	995 ab
	CV (%)	11.193	12.778	13.433	8.556	6.770	8.643	2.064	3.687
	CD (0.05)	NS	NS	NS	**	NS	**	**	**

Note: NS=Non significance, CV= Coefficient of Variation, CD= Critical difference at 5% level of probability (**).

The number of pods per plant was 18.78 in the BINA-8 variety in CSA technology in the Kalmakanda area which was the highest among others and the lowest pods per plant were recorded in BARI-6 CSA treatment. Mungbean 1000 seed weight and seed yield were the main parameters that indicated total production, and the study found out that the highest yield (1061 kg/ha) was recorded in BINA-8 CSA treatment at the Darmapasha area. The lowest yield (983 kg/ha) was observed in the BARI-6 variety in traditional cultivation technology at the Kalmakanda area (Figure 3).

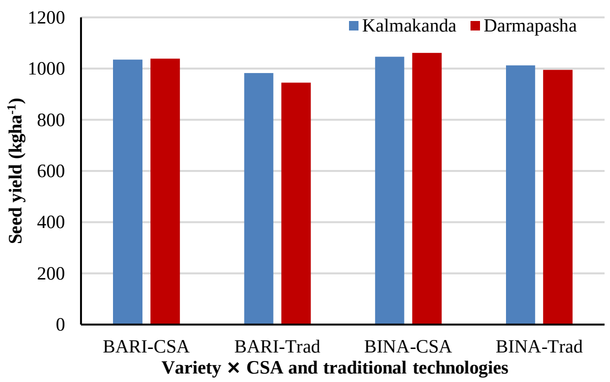

Figure 3. Mungbean yield in the CSA and traditional cultivation technologies.

The results also indicated that the mungbean yield was better in CSA technology compare to traditional cultivation methods and the total yield of BINA-8 variety performed well both in Kalmakanda and Darmapasha area. It was mentioned here that the CSA technology also used 50% fewer fertilizers and also manures were added at the rate of 10 ton/ha rate. These two varieties have already proved to be the best production ability in Bangladesh (Islam *et al*., 2020), and the present study also found that mungbean production had quite better (1065 and 1047 kg/ha) in the disaster pruned Northeastern border region of Bangladesh. The results of the present study also supported the study of Islam *et al.* (2020) in the mungbean production of Bangladesh. However, the mungbean average standard yield is about 1.4 ton/ha (Islam *et al.*, 2020), and due to disaster pruned and lower soil fertility status the study area revealed a slightly lower total yield than the national average yield. Nevertheless, the study found that every plant had formed root nodule through symbiotic association with Rhizobium bacteria which in turn enhanced soil nitrogen-fixing, and the soil analysis results showed that the total N (nitrogen) of the study area's soil has been augmented at 0.34 %. The sign of increasing soil N showed that the CSA technology had an impact on soil fertility status, nutrient cycling and thus improve crop productivity. However, the soil fertility status towards increases productivity and yield is not immediate and there is a time lag of 2-5 cropping seasons until significant yield benefit occurs.

Resilience/Adaptation

The most important crop-related limitation in the winter and summer seasons of the study area is water scarcity or lack of soil moisture for crop germination, development and yield. In considering that stress, the study introduced low water requirement, short-duration and high-yielding pulse crop like mungbean. Production of mungbean crop used minimum tillage, residues retention and crop rotation that can maintain a higher rate of water infiltration; a similar finding was recorded by Thierfelder and Wall (2009) in their study in Africa. Climate-Smart Agriculture (CSA) has already been proved to be a good approach to conserve soil moisture, reduce erosion, increase soil fertility status, enhance soil organic carbon, reducing GHG and also deducting the cost of production (Kassam *et al.*, 2009; Derpsch *et al.*, 2010; Johnson *et al.*, 2005; Johansen *et al.*, 2012). The result revealed that the CSA technique had gained more than 4.39 tons of mungbean biomass as crop residues in the soil. That means at the time of final harvesting the mungbean crop was cut above 6cm height and allowed those crop green (room and shoot) residues/ biomass to the soil. This would be a substantial amount of organic matter added to the soil through CSA technology. The mungbean residues provide feed and conserve moisture to enhance soil organism proliferation (Table 2). Moreover, the mungbean has a deep-rooted crop and was rotated with rice crop that improves soil structure and porosity, these in turn increase soil moisture and groundwater recharge.

Table 2. Possible CSA indicators in mungbean cultivation.

Theme	Sub-theme	Indicators
Productivity	Growth	Increase crop growth contributing parameters compare to traditional methods
	Yield	Increase total yield
	Soil fertility	Enhance soil fertility through soil N_2 fixation and addition of green biomass, increase soil total N at 0.34%.
Resilience	Robustness	Promote crop and income diversification, incorporate site-specific CSA knowledge, productivity continue
	Water use efficiency	Save at least 30% irrigation water use efficiency, increase resilience to drought
	Water infiltration	Increase soil moisture and water retention ability of the soil
	Drought	Increase resilience to drought
	Surface erosion	Crop residues protected soil surface erosion and run-off
	Labor saving	Decrease irrigation and overall labor requirement
	Soil quality	Improve soil fertility and organic matter content
Mitigation	Emission	Reduced GHG emission through lower tillage and fertilizations
	Carbon storage	Increase soil carbon sequestration

Together with water infiltration, the mungbean green biomass had maintained soil moisture due to reducing evaporation and heat stress, which was also mentioned by Thierfelder *et al.* (2017). Allowing mungbean crop residue at least 6cm from the ground would also reduce the risk of wind erosion, surface run-off and soil erosion in heavy rain/flash flood of the study area. Water use efficiency was another important aspect of mungbean production in CSA technology. In the CSA technique, the study used hand irrigation systems instead of traditional flooded irrigation techniques. This technique of hand irrigation had saved more than 40% water loss and reduced irrigation costs for the farmers (Table 2). The short-duration mungbean could tolerate drought stress and require a minimum water supply to cultivate the crop, it can build resilience to drought as well. Finally, the short duration and lower water requirement ability of the mungbean would reduce the agricultural labor quantity and farmer production costs. The result revealed that mungbean cultivation required less than 25% labor compare to rice cultivation in the study area. Therefore, adaptation to CSA cultivation technology in resource-poor areas with negative climate variability had improved soil water infiltration, increased soil moisture retention, increased drought resilience, efficient water utilization and saving labor which was also documented by the researchers in the world (IPCC, 2014; Ngwira *et al*., 2014; Thierfelder *et al*., 2017; Thierfelder and Wall, 2009).

Mitigation

Besides production and resilience, mitigation is also the key to making the mungbean cultivation system climate-smart. There are two main elements of mitigation strategy which are sequestration of soil carbon and reduction of greenhouse gas emission. The management of soil can significantly impact carbon stocks in the soil pool and the atmosphere. Mungbean cultivation had augmented soil organic matter decomposition and reduce the loss of C from the soil through lower tillage and nitrogen fixation. This was greater in the traditional cultivation of mungbean with higher tillage and left no green mass to the soil. Baker *et al*. (2007) and Powlson *et al.* (2014) reported that soil organic carbon sequestered only in the topsoil under zero or lower tillage conditions. Globally, there are few studies on GHG emission under CSA technologies, but it was evident that different fertilizers application has contributed to GHG emission (Gentile *et al*., 2011; Mapanda *et al*., 2011). Mungbean cultivation with CSA technologies had been used 50% fewer fertilizers compare to traditional ones, therefore, the GHG emission has reduced significantly (Table 2). Lower tillage and N fertilizers application on soil surfaced to cultivate mungbean had reduced the GHG emission, similar findings were documented by Liu *et al*. (2006). In addition, CH4 emission has greater in traditional cultivation with heavy tillage (Liu *et al.*, 2006), also resulted in greater CO_2 and N_2O emission (Linn and Doran 1984). Therefore, lower tillage and lower fertilizers application in mungbean cultivation with the CSA approach had reduced GHG emission compared to traditional cultivation methods.

Conclusion

Cropping patterns are highly variable in Bangladesh and crop intensification depends on many local and climatic factors. Crop intensification with short-duration mungbean within the existing rice-based cropping pattern was the main focus of this study. Farmers in the Kalmakanda and Darmapasha Upazillas of the northeastern border region of Bangladesh are cultivated transplanted Aman and Aus rice throughout the year as the irrigation facility has limited in winter to summer seasons to incorporate another crop. Considering this limitation of available water and early disasters, the study introduced short-duration and high-yielding mungbean crops in between the Aman and Aus rice production. The study also introduced climate-smart agriculture (CSA) technology in cultivating mungbean varieties in the resource poor and disaster-pruned areas of Bangladesh. The CSA technology has introduced lower tillage and efficient water utilization mechanism in which the farmer can cope with the adverse climatic situation. The results showed that farmers used hand irrigation with a watering can and successfully saved more than 40% irrigation water. The growth and yield of both BARI-6 and BINA-8 mungbean varieties showed that they produced a good yield in CSA technology comparing to traditional methods, and in both cases, the yield was the highest in CSA treatments. The CSA techniques allow crop residue as a source of green biomass which would be a key source for soil organic matter and also protect soil surface erosion during early flashflood/heavy rain in the study area. The lower tillage and crop residues also enhanced the water infiltration ability of the soil and farmer could easily adapt those techniques in their field to sustain crop productivity. The results also showed that mungbean as a Leguminosae family crop had enhanced soil fertility through nitrogen fixation with the symbiotic association and improved soil fertility. Regarding the mitigation, the lower tillage, crop residues and 50% less fertilization was reduced the GHG emission to the atmosphere and enhanced soil carbon sequestration. Moreover, crop rotation with mungbean had positively impacted both carbon sequestration and reduces GHG emissions to the atmosphere. The CSA technology had reduced the labor and fertilizers towards production costs for the farmers as well. Finally, CSA technology has proved to increase productivity and farmers' profitability towards food security in various ways; however, the productivity benefit does not achieve immediately and it takes more than 2-5 years until the yield benefit becomes sustainable.

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References

ACIAR (2016). Introduction of short duration pulses into rice-based cropping systems in Bangladesh. Australian Center for International Agricultural Research (ACIAR) Project Report, Canbera, Australia. p 6.

Baker J M, Ochsner TE, Venterea RT & Griffis TJ (2007). Tillage and soil carbon sequestration-what do we really know? Agriculture, Ecosystems and Environment, 118:1–5.

BARI (2011) Krishi Projukti Handbook (in Bengali), Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh. pp.164-165.

Branca G, McCarthy N, Lipper L & Joleiole MC (2011). Climate smart agriculture: a synthesis of empirical evidence of food security and mitigation benefits from improved cropland management. Working Paper, FAO, Rome. p.5.

Brown ME & Funk CC (2008). Climate: Food security under climate change. Science, 319(5863): 580–581.

CIAT; World Bank (2017). Climate-Smart Agriculture in Bangladesh. CSA Country Profiles for Asia Series. International Center for Tropical Agriculture (CIAT); World Bank. Washington, D.C. 28 p.

Derpsch R, Friedrich T, Kassam A & Hongwen L (2010). Current status of adoption of no till farming in the world and some of its main benefits. International Journal of Agriculture and Biological Engineering, 3(1): 1–25.

FAO (2013). Climate-Smart Agriculture: Sourcebook. Rome, Italy: Food and Agriculture Organization (FAO) of the United Nations. p. 570.

Gentile R, Vanlauwe B, Chivenge P & Six J (2011). Trade-offs between the short-and long-term effects of residue quality on soil C and N dynamics. Plant and Soil, 338(1–2): 159–169.

Godfray HC J, Beddington J R, Crute IR, Haddad L, Lawrence D, Muir JF, *et al*. (2010). Food security: the challenge of feeding 9 billion people. Science, 327(5967): 812–818.

IPCC (2014). Intergovernmental panel of climate change. Fifth assessment report (AR5) (online). Geneva: WMO, UNEP. Available at: http://www.ipcc.ch/report/ar5/ (accessed June 10, 2021).

Islam KK & Hyakumura K (2021). The potential perils of Sal forests land grabbing in Bangladesh: An analysis of economic, social and ecological perspectives. Environmental, Development and Sustainability. Online first, Doi.org/10.1007/s10668-021-01301-7.

Islam KK, Saifullah M & Hyakumura K (2921). Does traditional agroforestry a sustainable production system in Bangladesh? An analysis of socioeconomic and ecological perspectives. Conservation, 1(1): 21-35.

Islam KN, Khan MMH, Islam MM, Uddin MM & Katif MA (2020). Performance of different cultivars of mungbean in coastal region of Bangladesh. SAARC Journal of Agriculture, 18(1): 161-172.

Johansen C, Haque M, Bell R, Thierfelder C & Esdaile R (2012). Conservation agriculture for small holder rainfed farming: opportunities and constraints of new mechanized seeding systems. Field Crops Research, 132: 18–32.

Johnson JMF, Reicosky DC, Allmaras RR, Sauer TJ, Venterea RT & Dell CJ (2005). Greenhouse gas contributions and mitigation potential of agriculture in the Central USA. Soil and Tillage Research, 83(1): 73–94.

Kassam A, Friedrich T, Shaxson F & Pretty J (2009). The spread of conservation agriculture: justification, sustainability and uptake. International Journal of Agricultural Sustainability, 7(4): 292–320.

Khatun A, Parvin N, Dewan MMR & Saha A (2017). Cropping pattern in Mymensingh region: diversity, constraints and potential. Bangladesh Rice Journal, 21(2): 217-235.

Linn D & Doran J (1984). Effect of water-filled pore space on carbon dioxide and nitrous oxide production in tilled and nontilled soils. Soil Science Society of America Journal, 48(6): 1267-1272.

Lipper L *et al*. (2014). Climate-smart agriculture for food security. Nature Climate Change, 4: 1068-1072.

Liu XJ, Mosier AR, Halvorson AD & Zhang F S (2006). The impact of nitrogen placement and tillage on NO, N_2O, CH_4 and CO_2 fluxes from a clay loam soil. Plant and Soil, 280(1–2): 177–188.

Mapanda F, Wuta M, Nyamangara J & Rees R (2011). Effects of organic and mineral fertilizer nitrogen on greenhouse gas emissions and plant-captured carbon under maize cropping in Zimbabwe. Plant and Soil, 343(1): 67–81.

Mondal MK, Paul PLC, Humphreys E, Tuong TP, Ritu SP & Rashid MA (2015). *In* Humphreys E, Tuong TP, Buisson MC, Pukinskis I, Phillips M (eds.). Revitalizing the Ganges Coastal Zone: Turning Science into Policy and Practices Conference Proceedings. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food (CPWF). 600pp.

Ngwira AR, Johnsen FH, Aune JB, Mekuria M & Thierfelder C (2014). Adoption and extent of conservation agriculture practices among smallholder farmers in Malawi. Journal of Soil and Water Conservation, 69(2): 107–119.

Powlson DS, Stirling CM, Jat M *et al*. (2014). Limited potential of no-till agriculture for climate change mitigation. Nature Climate Change, 4(8): 678–683.

Pretty JN, Noble AD, Bossio D, Dixon J, Hine RE, Penning de Vries FWT & Morison JI L (2006). Resource-conserving agriculture increases yields in developing countries. Environmental Science & Technology, 40(4): 1114–1119.

Thierfelder C & Wall PC (2009). Effects of conservation agriculture techniques on infiltration and soil water content in Zambia and Zimbabwe. Soil and Tillage Research, 105(2): 217–227.

Thierfelder C, Chivenge P, Mupangwa W, Rosenstock TS, Lamanna C & Eyre JX (2017). How climate-smart is conservation agriculture (CA)? -its potential to deliver on adaptation, mitigation and productivity on smallholder farms in southern Africa. Food Science, 9: 537-560.

Tuong TP, Humphreys E, Khan ZH, Nelson A, Mondal M, Buisson MC & George P (2014). Messages from the Ganges basin development challenge: Unlocking the production potential of the polders of the coastal zone of Bangladesh through water management investment and reform (online). CPWF Research for Development Series 9. Available at: https://cgspace.cgiar.org/bitstream/handle/10568/41708/CPWF%20Ganges%20basin%20messages%20Sept%2014.pdf?sequence=5 (accessed May 24, 2021).

UNDP (1998). Land Resources Appraisal of Bangladesh for Agricultural Development Report-2: Agroecological Region of Bangladesh. Published by United Nation Development program of the Food and Agricultural Organization.

Wheeler T & von Braun J (2013). Climate change impacts on global food security. Science, 341(6145): 508–513.