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AGRONOMIC MANAGEMENT OPTIONS FOR CLIMATE CHANGE ADAPTATION AND MITIGATION

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Abstract

Over exploitation of the natural resources viz., soil, water, natural gases and gasoline for growing foods and producing industrial commodities contributes to the global warming and climate change. Unless proper adaptation and mitigation strategies are followed, long-term effect of climate change might appear as a catastrophe for the global population. Many countries of the world are vulnerable to climate change, while the situation of Bangladesh is severe. Hence, this study discusses a good number of agronomic management tactics which are suitable to adapt crops under drought, prolonged submergence, salinity, extreme high and low temperature, and elevated carbon dioxide conditions. Furthermore, the study has identified strategies to reduce greenhouse gas emission, increase carbon sequestration, maintain soil biodiversity, reduce soil erosion and nutrient losses, increase nutrient use efficiency and improve soil health. The best set of soil and crop management practices are recommended as guiding tools for agricultural and environmental sustainability. These are no-till, retention of crop residues, urea deep placement, biochar application, improved manure management, anaerobic composting of organic materials, afforestation and reforestation, cover crops, legume-based agroforestry system, crop rotations, floating agriculture, adjustment of planting dates, genetic improvement of stress tolerant crop varieties etc. Carbon trading scheme could help improve livelihoods of the concerned stakeholders and further help sequester carbon and emit less greenhouse gases. Ultimately, such attempt might ensure the earth green and sustainable.

Keywords: Biochar, Carbon sequestration; Carbon trading, Floating agriculture, No-till.

1. Introduction

It is obvious that the climate from tropical to temperate even in the polar regions is continuously changing because of temperature rise and elevated carbon dioxide (CO_2) in the atmosphere. Such changes of the global climate caused tremendous effects on all living beings (Agrimonti *et al.,* 2020). Anthropogenic activities like burning fossil fuels, cutting and clearing forests, industrializations, intensive agriculture are the contributors of greenhouse gas (GHG) emission and rising earth's temperature (Rahman, 2014; Bisht *et al.,* 2020). Even though global warming and climate change are habitually used interchangeably but they have different meanings. Global warming refers to the upward temperature trend across the entire earth since the early 20th century, and most notably since the late 1970s. This is due to the increase in fossil fuel emissions since the industrial revolution. On the other hand, climate change denotes to a broad range of global scenario shaped mostly by burning fossil fuels, which add heat-trapping gases to earth's atmosphere. These include the increased temperature trends, cover sea level rise, ice mass loss (in Greenland, Antarctica, the Arctic and mountain glaciers worldwide), shift in blooming of plants and experience extreme weather events.

The warming of the globe and changing the climate are the greatest environmental challenges facing the world today (Rahman *et al.,* 2022). The world becoming warmer at a faster rate than any time of recorded history. The major GHGs are CO_2, methane (CH_4) and nitrous oxide (N_2O) which are responsible for rising sea level, disintegrating ecosystem functions, and impacting human health (Filonchyk *et al.,* 2024). The projected global warming because of emission of GHGs, especially CO_2 will result temperature rise between 1.8 ^{0}C and 4 ^{0}C by 2100 and sea level rise between 180 mm and 590 mm (IPCC, 2007). Changes in global climate contribute to change the weather patterns of climate vulnerable countries and thus have serious consequences on crop production (Islam *et al.,* 2022). Increase in CO_2 concentration may increase the photosynthetic efficiency of rice, wheat etc., thereby may increase their yields. Hu *et al.* (2021) reported that rice grain yield increased by 16% under free air CO_2 enrichment, while increase in temperature will mask the effect of elevated CO_2 and reduce crop production. This is a great dilemma in agriculture to sustain crop production under changing climate.

Bangladesh is recognized as one of the most climate vulnerable countries in the world. The higher temperature and changing rainfall pattern, coupled with increased flooding, rising salinity in the coastal belt and droughts are likely to reduce crop yields and crop production in Bangladesh. Because of climate change and use of imbalanced fertilizers solely depending on inorganic sources it is estimated that by 2050, rice production in Bangladesh will be declined by 8% and wheat by 32% against a base year yield of 1990 (MoEF, 2008). Thus, in 2050, there will be a deficit of 1.93 million metric tons (MMT) of wheat and 6.85 MMT of rice in Bangladesh (Bokhtiar *et al.,* 2022). Loss of agricultural land, lack of sustainable agronomic management options, imbalanced fertilization, climate vulnerability etc. severely hinder sustainable crop production. At present N fertilizer alone constitutes about 55% of the total nutrients used in crop fields of Bangladesh. Excess N may enhance mineralization of OM which may decrease C content in soil and increase CO_2 emission (Alam *et al.,* 2019; Rahman *et al.,* 2024; Islam *et al.,* 2024a). Overuse of N enhances its loss as NO_3^- leaching, NH_3 volatilization and denitrification as N_2O and NO (Huang *et al.,* 2017; Islam *et al.,* 2024b). Therefore, crop production under changing climate in Bangladesh is a great challenge, which needs to be addressed following sustainable land and crop husbandry promising to reduce C emission and enhance its sequestration in soils (Alam *et al.,* 2023; Al-Amin *et al.,* 2024). Carbon is the subject of a great deal of research but very little is known to date. The global concerns about the effect of current climate change demand information on carbon cycling, its transformation under different crops and soil management practices, and stability of carbon compounds in soils (Rahman, 2010). Emission of C from the soil results in lessening of soil organic pool and thus exerts effects on soil structure, soil fertility and crop productivity (Bhattacharya *et al.,* 2016). It is challenging to grow more foods for the global population while climate change is a barrier to progress. It is crucial to adopt crops and maintain their production under changing climate. Mitigation strategies are also to be applied for agriculture and environmental sustainability. Management practice like diversified cropping systems, application of organic residues, biochar, conservation tillage operation, adjustment of sowing and transplanting time, water management, mulching, optimum and balanced fertilization using organic and inorganic sources etc. are believed to offer higher potential to increase carbon level in soils (Islam *et al.,* 2018; Rahman *et al.,* 2020). Crop and soil management practices can affect the formation and stabilization of soil aggregates through changes in SOC levels and soil microclimate (Kelly *et al.,* 2017; Lal, 2019). Conservation and reduced tillage have the capacity to increase the size of soil carbon, and reduce GHG emission. Therefore, the present study aimed to identify a series of agronomic strategies of climate change adaptation and mitigation and recommend for farmers' practice which might be contributing towards achieving several UN Sustainable Development Goals (SDGs) viz., SDG 1 (No poverty), SDG 13 (Climate action), SDG 14 (Life below water) and SDG 15 (Life on land).

2. Adaptation and Mitigation of Climate Change

Climate adaptation refers to the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damage, to take advantage of opportunities, or to cope with the consequences. The IPCC defines adaptation as the, "adjustment in natural or human systems to a new or changing environment. Adaptation to climate change refers to adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Adaptation means adjustment of behaviors/activities/crop production in a changing climate which involves adjusting to actual or expected future climate. The goal is to reduce our vulnerability to the harmful effects of climate change (like sea-level encroachment, more intense extreme weather events or food insecurity). It also encompasses making the most of any potential beneficial opportunities associated with climate change.

Climate mitigation is any action taken to permanently eliminate or reduce the long-term risk and hazards of climate change to human life, property. The International Panel on Climate Change (IPCC) defines mitigation as 'An anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases.' Mitigation means reducing of climate change effect which involves reducing the flow of heat-trapping greenhouse gases into the atmosphere, either by reducing sources of these gases (for example, the burning of fossil fuels for electricity, heat or transport) or enhancing the 'sinks' that accumulate and store these gases (such as the oceans, forests and soil). The goal of mitigation is to avoid significant human interference with the climate system, and 'stabilize greenhouse gas levels in a timeframe sufficient to allow ecosystems to adapt naturally to climate change, ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.'

2.1 Adaptation plans for climate-resilient soil and crop management

As climate change continues to affect agricultural systems, the need for effective adaptation strategies to preserve soil health and ensure food security is critical. Climate-related challenges such as rising temperatures, erratic rainfall, and more frequent extreme weather events place agricultural productivity at risk. To address these challenges, adaptation strategies must be implemented to promote resilient, sustainable farming systems (Table 1). Climate induced soil risks and their adaptive counter measures are depicted in the Fig. 1. These strategies aim not only to protect the soil but also to improve productivity, making it essential for long-term agricultural stability. One effective approach to soil adaptation is enhancing soil carbon sequestration. Increasing soil organic carbon through the use of biochar, compost, and cover crops can improve soil structure and fertility, while also boosting water retention.

Table 1. Adaptation strategies for soil health and fertility management

Strategy name	Brief description	Key benefits
Enhance soil carbon sequestration	Apply biochar, compost, and cover crops to store carbon.	Biochar increases soil organic carbon by 11–40% in rice fields (Gaihre *et al*., 2015), leading to a 15–30% increase in yield for both rice and wheat (Kumar *et al*., 2020).
Reduce tillage	Minimize soil disturbance to prevent CO_2 loss.	No-till farming increased microbial activity by 40% (Ghosh *et al*., 2020), leading to a 25% increase in nitrogen uptake in wheat and rice fields (Kumar *et al*., 2022).
Use of green manure	Plant cover crops for fertility and microbial health.	Green manure improved maize yields by 13% (Singh *et al.*, 2015), with better nutrient cycling and enhanced microbial activity (Ghosh *et al.*, 2020).
Improve grazing management	Implement sustainable grazing practices to promote soil health and productivity.	Proper grazing management improved pasture productivity by 22% (Alam *et al.*, 2023), resulting in better soil fertility for subsequent maize crops (Kumar *et al.*, 2020).
Water-efficient irrigation	Install drip irrigation systems and rainwater harvesting to optimize water usage.	Drip irrigation improved water efficiency by 45% in maize cultivation (Alam *et al.*, 2023), leading to a 25% increase in yield (Kumar *et al.*, 2020).

Cover cropping	Use of legumes and other crops to improve soil fertility and prevent erosion.	Legume cover crops increased soil nitrogen by 18% (Singh *et al.*, 2012), enhancing maize yield by 22% (Thind *et al.*, 2012).
Optimize organic fertilizers	Apply organic fertilizers to enhance soil nutrient cycling and reduce dependency on synthetic fertilizers.	Organic fertilizers boosted rice yields (Singh *et al.*, 2020), reducing the need for synthetic fertilizers by 30% (Meena *et al.*, 2022).

Biochar, for example, has been found to increase soil organic carbon by up to 40%, resulting in improved crop yields and reduced greenhouse gas emissions (IPCC, 2019). Alongside this, reducing tillage practices such as no-till farming helps preserve soil structure and microbial activity. By minimizing soil disturbance, no-till practices can enhance nitrogen uptake in crops, thereby increasing productivity and promoting long-term soil health (Ghosh *et al.,* 2020). Another key strategy is the use of green manure, primarily through leguminous cover crops, which enhances nitrogen cycling in the soil. This approach not only boosts soil fertility but also increases productivity. For example, the incorporation of green manure into agricultural practices can improve maize yields by as much as 22%, as it enhances the nitrogen levels necessary for crop growth (Singh *et al.,* 2015). Sustainable grazing management is similarly beneficial, increasing pasture productivity and promoting nutrient cycling that benefits subsequent crops. Properly managed grazing systems can improve pasture yield by up to 22%, directly contributing to soil health (Alam et al., 2023).

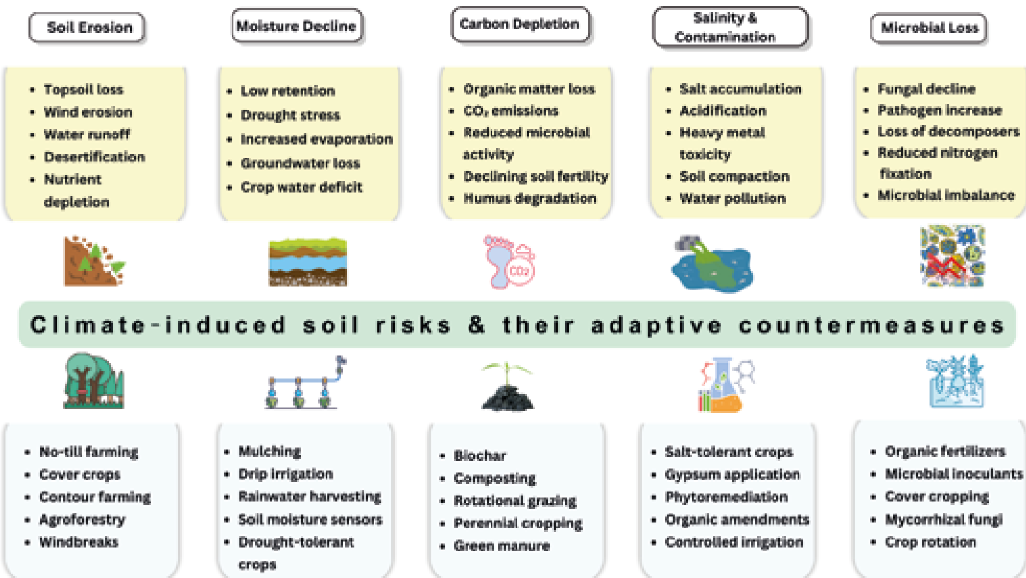

Fig. 1 Impact driven adaptation strategies for sustainable soil health and agriculture

Bangladesh is a flood prone country where crop loss is common because of prolonged submergence. Although different research institutes of the country developed a good number of submergence tolerance crop varieties but their field level performance is poor in many cases. Lack of farmers' awareness and reluctant engagement of different stakeholders also are the barriers of adopting such technologies. However, development of submergence tolerance crop varieties and the technology dissemination among the farmers might solve the situation. During extreme climatic events like extreme low temperature seed germination is a serious concern. Mulching using rice straw, plastics and others are recommended to get seedlings of different crops within a short period of time under low temperature condition (Fig. 2). At temperature of $12\text{-}14^{\circ C}$ and without mulch, to get 50-60% of germination of soybean and chickpea seeds need longer time of about 7-9 days. While at the same temperature, rice mulch and white plastic mulch contributed to about 85-90% and 95-98% germination, respectively (Unpublished data from research of Gazipur Agricultural University). In the coastal saline regions, floating agriculture is a promising technology for growing different vegetables (Fig. 3). Growing crops in earthen or plastic bowls placed on a structure above rice fields in the saline region is also a very good adaptation strategy.

Fig. 2 Mulching for seed germination during extreme cold temperature: control (left) *i.e.*, without mulch, rice straw mulch (middle), and white plastic mulch (right)

Fig. 3 Floating agriculture growing different vegetables in ponds (left), and brinjal cultivation in plastic bowls over the rice field in the saline region (right)

Water-efficient irrigation systems are increasingly important, especially in areas prone to water scarcity. Drip irrigation systems, which enhance water use efficiency, have been proven to increase maize yields by 25% while simultaneously reducing water wastage. These systems are particularly effective in regions where water availability is limited, ensuring that crops receive optimal moisture without causing soil erosion or nutrient leaching (Kumar *et al.,* 2020). Complementary practices such as rainwater harvesting and mulching can further mitigate water stress, enabling soil to retain moisture even during periods of drought. Cover cropping plays a vital role in enhancing soil resilience by preventing erosion and increasing organic matter in the soil. By using leguminous crops that fix nitrogen, cover cropping can boost soil nitrogen content by up to 18%, leading to significant yield improvements, particularly in maize (Singh *et al.,* 2012). Additionally, the use of organic fertilizers such as compost and farmyard manure can improve moisture retention and soil structure, enhancing crop yields by up to 15-20% while reducing reliance on synthetic fertilizers significantly (Meena *et al.,* 2022, Al-Amin *et al.,* 2024b; Al-Amin *et al.,* 2025).

Despite these benefits, implementing these adaptation strategies faces significant challenges. Knowledge gaps, limited access to technology, and high upfront costs are common barriers. Smallholder farmers, especially in developing regions, may lack the necessary resources or education to adopt these climate-smart practices. Additionally, policies and infrastructure needed to support widespread adoption are often insufficient, limiting the scalability of these practices. To overcome these barriers, it is crucial to create enabling policies that provide financial support, training, and access to technology. Governments, NGOs, and research institutions must collaborate to provide farmers with the tools and knowledge necessary to implement these adaptation strategies. Supportive policies, such as subsidies for implementing sustainable practices and investment in infrastructure, will help scale climate-resilient practices, ensuring that soil management is adapted to the challenges of climate change.

2.2 Mitigation strategies for agriculture and environmental sustainability

Mitigation refers to actions that aim to reduce the causes of climate change, specifically GHG emissions, and enhance carbon storage within agricultural systems (Fig. 4). Unlike adaptation, which deals with adjusting agricultural practices to cope with existing climatic changes, mitigation strategies seek to address the underlying factors contributing to climate change (Table 2). In the context of soil management, these strategies aim to reduce emissions, promote carbon sequestration, and improve resource efficiency, contributing to both global climate goals and local agricultural resilience (FAO, 2022).

Among the most significant methods are those that focus on increasing soil organic carbon storage and reducing GHG emissions from agricultural activities. Practices like agroforestry and no-till farming are key to carbon sequestration, as they not only store carbon but also improve soil fertility and structure, contributing to long-term productivity. These methods reduce soil erosion, enhance water retention, and support biodiversity, all of which are essential for soil health and productivity. By reducing nitrogen losses through volatilization or leaching, these practices also enhance soil health and reduce fertilizer dependency, promoting a more sustainable farming system (Zhang *et al.,* 2019).

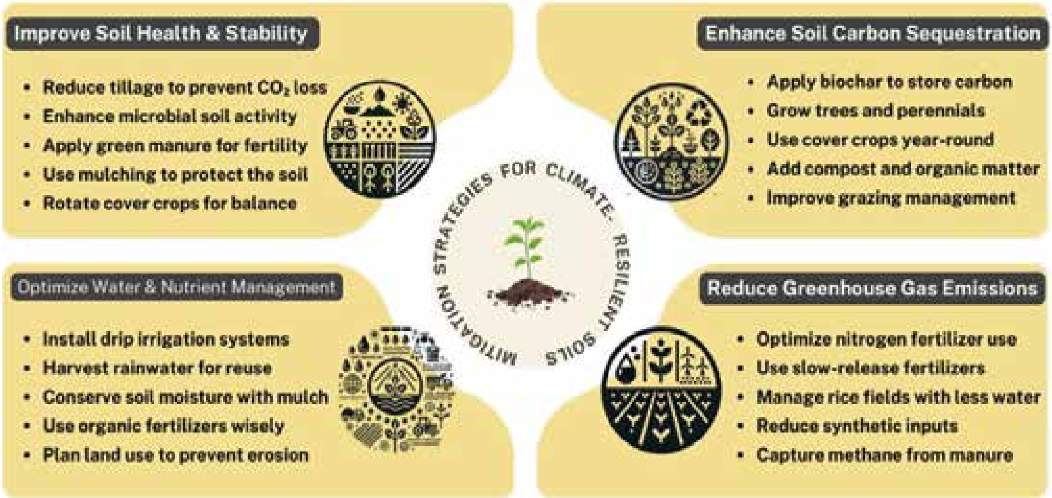

Fig. 4 Mitigation strategies for improving carbon sequestration, nutrient management, soil health improvement and greenhouse gas emission reduction

Despite their effectiveness, there are substantial barriers to the widespread adoption of these mitigation strategies. One of the primary challenges is the high initial cost of implementing technologies such as controlled-release fertilizers, agroforestry systems, or advanced irrigation techniques. Smallholder farmers, especially those in developing regions, often lack the financial resources to adopt these practices, which are seen as capital-intensive. Additionally, there is a lack of knowledge and technical support among farmers regarding the implementation of these practices. Limited access to training, modern tools, and expertise makes it difficult for farmers to implement and sustain these practices effectively. Policy barriers also hinder adoption, as there is often insufficient financial incentive or lack of support structures for farmers transitioning to climate-smart practices.

Overcoming these barriers requires comprehensive policy support and the creation of enabling environments that promote the adoption of mitigation strategies. Governments and international organizations must develop policies that provide financial incentives, such as subsidies or tax breaks, to reduce the cost of implementing sustainable practices. Furthermore, education and training are essential to increase farmer awareness and knowledge of the benefits and methods of mitigation strategies (Rahman, 2024). Policy frameworks must also foster the development of markets for carbon credits, allowing farmers to gain financial rewards for engaging in carbon sequestration practices like agroforestry and no-till farming. Additionally, public-private partnerships can play a key role in providing access to the necessary resources and technologies, thereby supporting farmers in adopting and scaling mitigation practices.

Table 2. Mitigation strategies for climate-resilient soil management

Strategy name	Brief description	Key benefits
Carbon-smart farming	Adopt no-till, agroforestry, and manure management practices.	Agroforestry and no-till farming reduced CO_2 emissions by 3.5–4.5 t ha^{-1} (FAO, 2022), enhanced rice yields by 15% on average (Gaihre *et al.*, 2015).
Use of controlled-release fertilizers	Fertilizers that release nutrients gradually.	Controlled-release fertilizers improved nitrogen use efficiency by 28% in wheat (Thind *et al.*, 2010) and 20% in rice, which also reduced N leaching (Jiang *et al.*, 2022).
Nitrification inhibitors	Reduce nitrogen losses by inhibiting nitrification processes.	Nitrification inhibitors reduced N_2O emissions by 25% (Guo *et al.*, 2022) and improved maize yield by 17%, while increased nitrogen retention by 18% (Wallace *et al.*, 2020).
Integrate organic & inorganic fertilizers	Combine organic fertilizers with traditional methods.	Integration of farmyard manure with inorganic fertilizers increased rice yields by 30% (Dwivedi *et al.*, 2016) and improved nitrogen efficiency by 21% (Singh *et al.*, 2020).
Agroforestry systems	Grow trees alongside crops to improve soil and climate resilience.	Agroforestry systems increased soil fertility by 10–15% (Chen *et al.*, 2017), while improving maize yield by 20% (Singh *et al.*, 2015).
Cover cropping	Use of diverse crops like legumes to fix nitrogen and improve soil.	Cover cropping with legumes reduced the need for synthetic fertilizers, increasing yields by 12% in rice (Singh *et al.*, 2012) and 18% in maize (Bhatia *et al.*, 2015).
Water-efficient rice cultivation	Reduce water usage in rice fields.	Water-saving practices in rice cultivation increased yields by 25% (Bhatia *et al.*, 2012) and reduced water use by 30% (Meena *et al.*, 2022).

It is found that soil and crop management practices that focus on mitigation provide a dual benefit: they reduce the agricultural sector's contribution to climate change while simultaneously enhancing the resilience of agricultural systems (Fig. 5). Effective implementation of these strategies requires a coordinated effort among farmers, policymakers, and researchers, ensuring that mitigation practices are accessible, affordable, and effective in addressing the challenges posed by climate change.

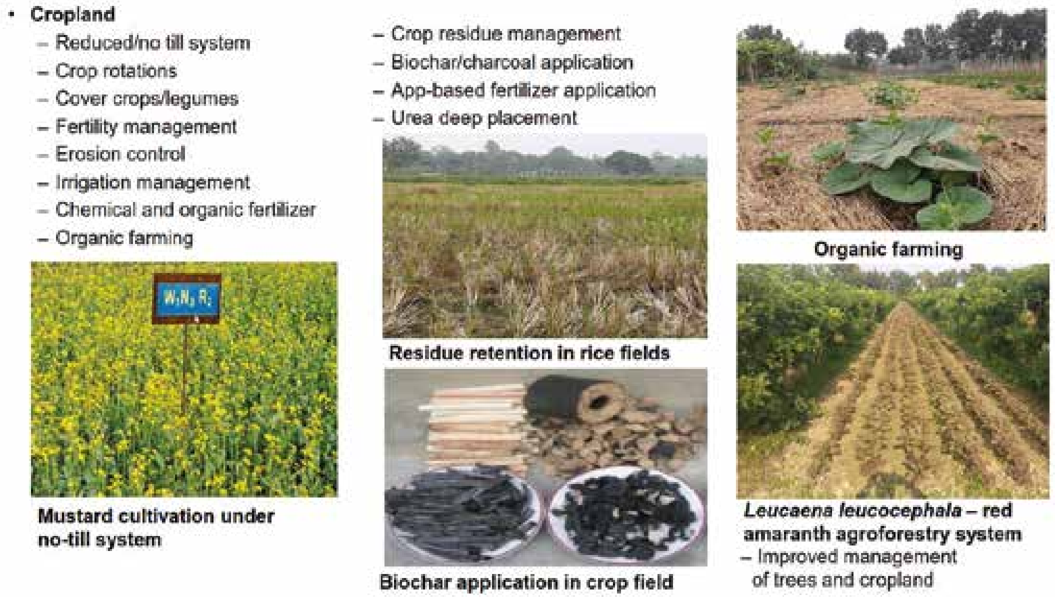

Fig. 5 Some efficient adaptation and mitigation strategies practiced in Bangladesh

Soil organic matter is of paramount importance with respect to availability of plant nutrients and improvement of physical, chemical and biological properties of soils (Rahman et al., 2022). Maintenance of SOC is essential for the sustainable agricultural production as declining soil C generally decreases crop productivity (Hasnat et al., 2022). The SOC pool in agricultural land-uses is capable of enhancing agricultural sustainability and serving as a potential sink of atmospheric CO_2. Carbon stocks are not only critical for the soil to perform its productivity and environmental functions but also play an important role in the global C cycle. Carbon sequestration is essential to improve soil quality, increase agronomic productivity, and use efficiencies of different production inputs like fertilizers, water etc. Thus, sequestration of carbon in soils helps maintain or restore the capacity of soil to perform its production and environmental functions on a sustained basis (Urmi et al., 2022). From a study of two consecutive years (four crop seasons) Rahman et al. (2016) reported that poultry manure sequestered more carbon compared to cowdung and soil test-based fertilizer application (Table 3). Soil carbon or organic matter in general, is important because it affects and governs all soil quality functions. Organic matter is the key to soil health which sustains biological activity, diversity, and crop productivity. It facilitates regulation and partition of water and solute transport within soil systems. Soil organic matter upon decomposition produces humus which is a colloidal particle that regulates cation exchange capacity of soil (Alemayehu and Teshome, 2021).

Table 3. Effect of organic manure and chemical fertilizers on carbon stock and carbon sequestration of post-harvest soil after four consecutive rice seasons (Rahman *et al.*, 2016)

Treatment	Initial soil			Post-harvest soil			Carbon sequestration ($t\ ha^{-1}$)
	OC (%)	BD ($g\ c.c^{-1}$)	C Stock ($t\ ha^{-1}$)	OC (%)	BD ($g\ c.c^{-1}$)	C Stock ($t\ ha^{-1}$)	
T_1 =Control	1.13	1.38	23.39	1.08	1.36	22.03	-1.36
T_2 =CD +IPNS	1.13	1.38	23.39	1.39	1.27	26.42	3.03
T_3 =PM +IPNS	1.13	1.38	23.39	1.45	1.30	28.30	4.90
T_4 =RS +IPNS	1.13	1.38	23.39	1.32	1.24	24.43	1.04
T_5 =STB	1.13	1.38	23.39	1.18	1.32	23.43	0.04
LSD (*0.05*)	0.00	0.00	0.0	0.08	0.046	2.78	2.31
CV (%)	0.00	0.00	0.0	3.3	1.9	4.8	8.01

CD = Cowdung, PM = Poultry manure, RS = Rice straw, STB = Soil test-based fertilizer, IPNS = Integrated plant nutrition systems (Organic materials were applied considering 2 t C ha^{-1} $season^{-1}$)

Reliance on inorganic fertilizers with less or no use of organic fertilizers impaired the productivity of soils in Bangladesh. From a study conducted in a farmer's field at Kapasia, Gazipur, Bangladesh found that contents of organic carbon, total carbon and C sequestration in post-harvest soil were increased due to application of organic fertilizer, which indicated enhancement of soil fertility (Urmi et al., 2022). The soil bulk density decreased slightly as compared to control, which indicated the improvement of soil physical properties of soil using organic manures. Regular nourishment of soil with organic and inorganic fertilizers might help rejuvenate our soils and ensure agricultural sustainability.

4. Carbon Trading

Carbon trading denotes to the trading of emission of six GHGs viz., CO_2, CH_4, N_2O, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF6). Trading of emission of GHGs is set out in the Article 17 of the Kyoto Protocol. Later, the Paris Agreement provided a robust but ambitious basis for the use of international markets and reinforces international targets. The Article 6 of the agreement allows Parties to use international trading of emission allowances to help achieve emissions reduction targets, establishes a framework for common robust accounting rules, and creates a new, more ambitious market mechanism. The countries that have extra emission units i.e., they are not emitting they are allowed to sell their limit. Therefore, these countries can sell quotas to other countries who are over their targets. Thus, GHG commodity has been created in the form of emission reductions or removals.

As CO_2 is the principal GHG, it is simply called or known as carbon trading. Therefore, carbon is now tracked and traded like any other commodity which is called as the 'carbon market'. The industrially developed countries emit a huge amount of GHGs, while the sufferers are the least developed countries from such emissions. Thus, carbon credit schemes might be a safe gourd for the lower income countries. This carbon market offers financial incentives to the countries of low emission but higher carbon sequestration (Fig. 6). By participating in the carbon markets, farmers of low-income countries can make additional source of income while contributing to climate change mitigation (Fig. 7). A good example of carbon trading is the Pilot projects in Punjab of Pakistan where smallholders are linked to carbon markets (Ali et al., 2023).

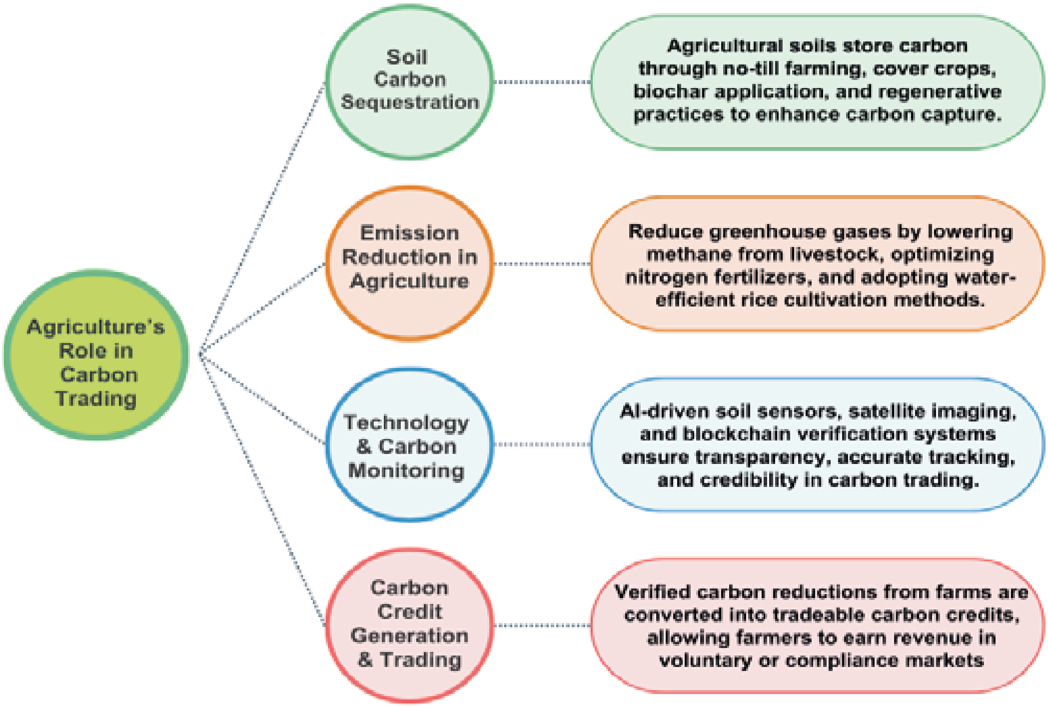

Fig. 6 Pathways to carbon sequestration, emission reduction and market integration

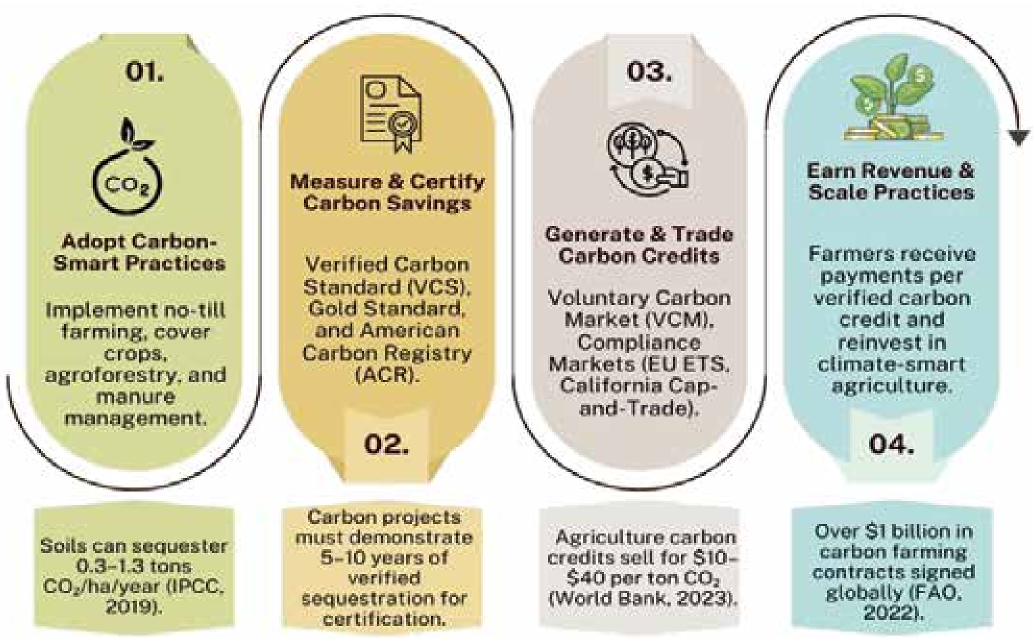

Fig. 7 Carbon trading process in agriculture: from soil to market

5. Conclusions and Way Forward

Climate change is obvious which is evinced through global temperature rise, warming oceans, shrinking ice sheets, sea level rice, salinity intrusion, loss of soil fertility, extreme climatic events etc. There are sets of adaptation and mitigation strategies from which location and region-specific suitable technologies need to be identified and adopted together for reducing the negative effects of climate change. It is commonly believed that the more mitigation there is, the less will be the impacts to which we need to adapt. A set of suitable adaptation and mitigation strategies provided below with their expected impacts in agriculture and environment are recommended for farmers' practice:

- Zero till/minimum or reduced tillage - increase C sequestration, reduce GHGs emission
- Retention of crop residues and organic fertilizers application – increase C sequestration, reduce N fertilizer application and thereby reduce N_2O & CO_2 emission, improve soil health
- Alternate wetting & drying – reduces CH_4 emission, increase nutrient use efficiency
- Deep placement and slow-release fertilizer management (urea super granule/urea mega granule) – reduces N_2O emission, increase nutrient use efficiency
- Anaerobic composting of crop residues and different organic materials - reduces CO_2 emission
- Restoration of cultivated and degraded lands – increases carbon sequestration

- Improved manure & waste management – reduces CH_4 and N_2O emissions
- Improved energy use efficiency – reduces GHGs emission
- Afforestation and reforestation - reduce deforestation and increase carbon sequestration
- Harvested wood product management – increases C stock
- Legume-based agroforestry - increases biomass & C sequestration, reduces CO_2 emission, ensures biodiversity, and improves soil health
- Adjustment of planting dates – avoids adverse production environment like drought, flood etc.
- Floating agriculture – climate smart technology in the coastal areas and long-term submerged soils which ensures nutritional security
- Genetic improvement of stress (drought/salinity/submergence etc.) tolerant crop varieties – helps adapt crops under changing climatic conditions
- Relay cropping – efficient utilization of soil moisture
- Alley cropping - increases C sequestration, reduces N fertilizer application and thereby reduces N_2O & CO_2 emissions, ensures biodiversity, improves soil health and crop yields,
- Crop rotation – increases nutrient use efficiency, ensures biodiversity, improves soil health, increases C sequestration and reduces GHGs emission
- Improved land management and erosion control – ensure sustainable agriculture for future generation.

Conflicts of Interest

The authors declare no conflicts of interest regarding publication of this paper.

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