Carbon Farming to Carbon Credit- An Agricultural Approach to Minimize the Risk of Global Warming and Scope of Economic Solace to the Farmers: A Review

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ABSTRACT

Mitigation of GHGs emissions is a great global survival disquiet for today's world. This mitigation mostly revolves around industrial sectors. Agriculture sector has always been judged as the crop and livestock based economic system. Soil carbon (C) has only been considered within the budget of soil carbon (C) pool, but sequestrated C is yet to be judged as the marketable unit in large scale. Increasing "C-sequestration" can simultaneously offer alleviation of GHGs emission hitch, an additional economic benefit to the farmers as well as the growing industrial involvement in agriculture for corporate sustainability in terms of carbon marketing.

Key words: Agriculture, Carbon credit, Carbon farming, GHGs emissions.

Global warming, the current inextinguishable threat to the planet, is haunting the entire human race. Since the 19th century the average temperature of the earth has increased by 0.6°C whereas that is believed to be rising to 1.1 to 6.4°C by 2100 (Pathak and Aggarwal, 2012). The primary reason for this increase is emission of heat absorbing gases from escalating industrialization, fossil fuel burning, urbanization, deforestation and improper farming practices. These entire activities are responsible for the increase of "Greenhouse Gases (GHGs)" especially carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). These gases have the characteristics to absorb the solar heat to maintain the earth's atmospheric temperature, but an excess quantity in the atmosphere leads to an artificial increase in temperature results the "Global Warming".

The responsible sectors for GHGs emission (GHGE) mostly includes energy sector, industrial process and product use (IPPU) sector, agriculture, land use-land use change and forestry (LULUCF) sector and waste management sector (Fig 1). Without LULUCF, as per Third Biennial Update Report to the United Nations, India's GHG emissions in 2016 were 2,838,889 Gigagram of CO_2-equivalent (CO_2e), out of which energy sector contributed 75% of emissions, followed by 14% from agriculture, 8% from IPPU and 3% from waste (Fig 2). Among different GHGs, mainly CH_4 and N_2O emission by agriculture boosts the GHGs sink in the atmosphere throughout the world, however, it is more relevant in developing countries due to improved agricultural practices (Fig 3).

Globally agriculture sector accounts for about 24% of greenhouse gas emissions (GHGs) and in India it contributes 14.37% of the total net CO_2e emissions (MoEFCC, 2021). The major sources of CO_2e emission in Indian agriculture includes enteric fermentation from livestock, paddy cultivation, manure management, burning of crop residues, indiscriminate use of nitrogen fertilizers (Subbian, 2022) and excess tillage of the fields leading to the atmospheric carbon loss (Fig 4). Thus, the crop production sector (rice cultivation, soils and field burning of crop residues) contributes 35.9% of the total emissions from agriculture (Pathak and Aggarwal, 2012; INCCA, 2010). The emission from enteric fermentation in livestock was 2,22,655 Gg CO_2e, from manure management was 27227 Gg CO_2e and from rice cultivation was 71322 Gg CO_2e, respectively. According to third Biennial Update Report, GOI, in terms of CO_2e, total N_2O and CH_4 emissions from agricultural soils and crop residue (rice, wheat, cotton, maize, millet, sugarcane, jute, rapeseed and mustard) burning is about 86617 Gg CO_2e. The 2.88% increase of the CO_2e emission by crop residue burning was recorded (2014 to 2016) that turns agricultural sector as marking contributor for climate change. Since CH_4 emission is a

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major concern for its Global Warming Potential, the loss rate of CH_4 through simulation models has been estimated over India at 5.5 Tg·yr^{-1} in year 2000 and 5.8 Tg·yr^{-1} in 2016 (Fig 5).

This current scenario clearly reflects that the emission spectrum is mounting and it is quite tough to reduce GHG emissions below the safe limit. Since, different assessments are suggesting that maximizing the carbon storage into soil can be a weapon against the war of GHGE. The practicality of the reduction of GHGs by the potential contributory sectors is quite infeasible because of its complex relation with social, economic, political and geographical dependency; however, alternatively carbon agri-farming not only improves the soil health but also drives the global warming mitigation and its resonance by reducing the carbon content in atmosphere (Singh *et al.*, 2023). Thus, agriculture sector can play a path breaking role for GHGE reduction that bridges the farmers to the

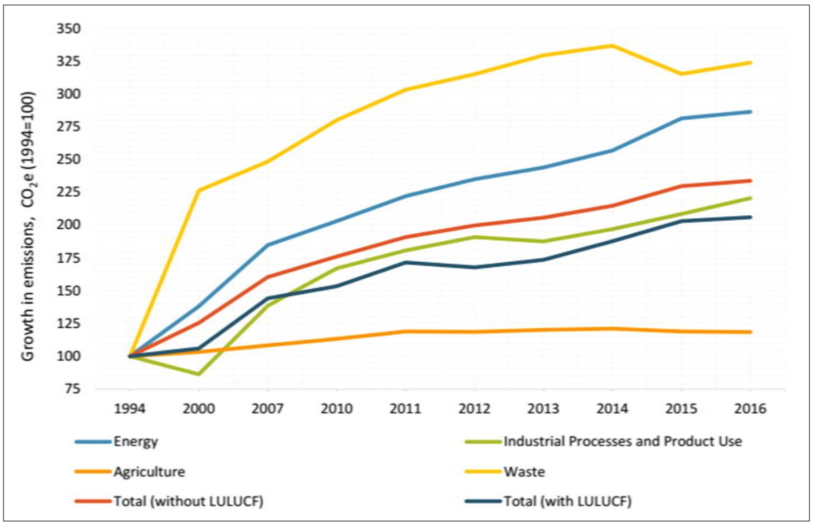

Fig 1: Dynamics of emissions of GHGs by different sectors over the period of 1994 to 2016 (Source: MoEFCC, 2021).

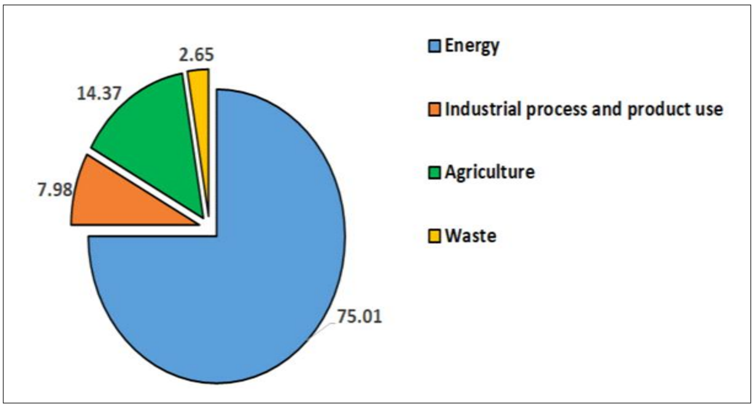

Fig 2: Distribution of GHGs emissions (Gg CO_2e) by sectors, 2016 (Source: MoEFCC, 2021).

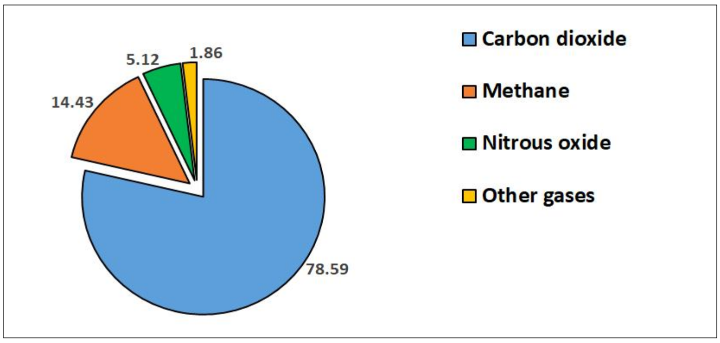

Fig 3: Contribution of different gases on GHGs emission (Source: MoEFCC, 2021).

industrial magnates through ensured business tie-up and generates the additional economic returns for the farming community.

India has committed itself to voluntarily reduce its emissions intensity (*i.e.*, emissions per unit gross domestic product or GDP) by 33 to 35% below the 2005 levels by 2030 (Centre for Science and Environment, 2021). In February 2021, in its Third Biennial Update Report (BUR-3) to the United Nations Framework Convention on Climate Change (UNFCCC) (MoEFCC, 2021), India stated that it had reduced emission intensity of its GDP by 24% between 2005 and 2016. This marks progress compared to its achievement of reducing emission intensity by 21% by 2014, as stated in BUR-2. This initiative can be more successful by giving more emphasis on the contribution from agricultural sector in scaling up the mitigation strategies. In this context, India is undertaking the following mitigation strategies to meet its emission intensity reduction targets:

a. Increase the share of non-fossil fuels in overall energy mix.
b. Improve energy efficiency measures.
c. Increase forest and tree cover to enhance CO_2 removal.

Moreover, low carbon development pathways (regenerative agriculture) or more utilization of the natural resources to sequestrate the carbon offers opportunities for achieving GHGE as the indirect effective way to reduce the green house gas by sequestering more carbon to the soil. In this regard, agriculture sector can help by taking an approach of "climate smart" agriculture involving technologies for productivity increase, income generation and GHGE reduction simultaneously.

Carbon sequestration

Carbon sequestration, defines the long-term storage of carbon in plants, soils, geologic formations and the ocean by naturally and as a result of anthropogenic activities. Soil carbon sequestration is a plant mediated process in which CO_2 is removed from the atmosphere and stored in the soil organic carbon pool (Lal, 2004). According to the Intergovernmental Panel on Climate Change in 2007, improved agricultural practices and forestation can significantly contribute in CO_2 sequestration to keep the carbon in soil (Nizamedinkhodjayeva and Mehmood-Ul-Hassan, 2019). These activities could include reduced tillage, improved crop and pasture management, increased fertilizer use efficiency to minimize loss, minimized soil erosion, restoration of soil quality, uses of cover crops, incorporation of organic amendments *etc*. (Ontl and Schulte, 2012).

How carbon sequestration helps agriculture

The efficient way to minimize the atmospheric C pool is the return pathway of C from atmosphere to soil via crop system. Some 18 metric tonnes of atmospheric CO_2 can be arrested by opting the agricultural technologies that will increase the SOC of 1-acre land by 1% (Vijayakumar *et al*., 2021). It was predicted that increment of global top soil (30-40 cm) OC by 0.4% per year can remove approximately 3-4 Gigatons of atmospheric C along with an estimated increase of crop yields by 1.3% without escalating the cultivation cost (Dignac *et al*., 2017). This fact will boost soil health and also stop annual increase of atmospheric CO_2. Moreover, the carbon sequestration technologies improve the ecosystem services including soil quality upgrades by improving soil organic matter and total nitrogen, retention of water and nutrients, increasing agricultural productivity, improving soil aggregate stability and soil structure, control of erosion and enhancing surface and subsurface water quality (Chahal Singh and Singh, 2020; Gorooei *et al*., 2022). Since climate is playing a driven role for agriculture, the changes of climate significantly influence the total agriculture and imbalance the food security. Thus, instead of imposing law and restrictions on the industrial GHGs emission, it may be an alternative decision to emphasize on the climate change mitigating strategies through agricultural management practices.

A suitable interventions for promoting low carbon agriculture such as: no-till (zero-till) and minimum tillage systems to increase soil organic carbon pool and minimize fuel consumption; sustainable forest management and restoration; introduction of superior livestock breeds to reduce numbers (especially unproductive cattle) and increase yield; proper livestock waste management to reduce GHGs emission, save electricity consumption and production and use of composts for the buildup of carbon

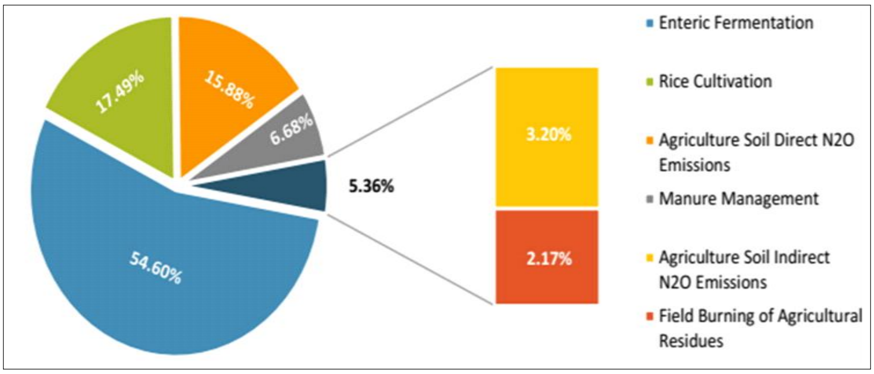

Fig 4: Contribution of different agricultural sectors on GHGs emission (Source: MoEFCC, 2021).

in soil and introduction of carbon credits and exploration of domestic carbon markets might be the best strategies for this mission.

Carbon farming

A system of agricultural management technologies that promotes the means of carbon sequestration in soil and vegetation with provisions of atmospheric carbon status minimization. The management practices include land management, soil conservation, stubble retention, agro-forestry and utilization of organic fertilizers are the effective approaches for carbon farming. At the other end of the scale, it promotes development of an integrated farm system to reduce emissions and maximize carbon capture.

Current intensive agricultural practices include soil tillage by fuel used tractors, over-grazing practices, use of fertilizers and pesticides (manufactured in cost of fossil fuel) and all other aspects that may ultimately result in significant carbon release into the atmosphere. Alternatively, carbon farming can be a successful approach to return the atmospheric carbon to the soil resulting the reduction of carbon quantum in atmosphere.

The main target of carbon farming is the build up of carbon in the soil along with the possibilities of GHGE reduction that helps to minimize the effect of global warming and mitigates the climate change. Moreover, considering the farmers' welfare, carbon farming will not only improve the soil health and crop yield; but also append a monitory incentive to the farmers from individuals, private companies and NGOs concerned about climate change.

Only one target, *i.e.* carbon sequestration, will earn two benefits-contribution of the non-agricultural sector in agriculture for their own interest and new possibility of income generation for farming communities.

Carbon farming approaches

For successful carbon farming, the integrated approach of soil, livestock, plant, fertilizer and energy use can be executed to increase soil organic carbon, enhance productivity and reduce the possibilities of GHGs emissions (GHGE).

Soil based carbon farming

The increase in SOC helps to augment the soil health by improving soil structure-soil organic matter-soil microbial community, conserving the soil biodiversity, improving soil borne disease resistance ability, limiting soil nutrient losses, increasing the nutrient use efficiency and ultimately the soil productivity. The following management practices can cover the carbon farming as an effective means-

- No-tillage/zero tillage or conservation tillage for maintaining soil structure.
- Scientific stubble management instead of stubble/crop residues burning.
- Intensification of fallow land by cover/legume/fodder cropping to protect SOC and nutrients.
- Adoption of soil erosion checking management practices (developing bunds, maintaining slope, covering of the soil by crop *etc*).
- Increase cultivated land area by crop intensification and crop rotation.
- Restricting the conversion of cultivable land to shallow water fishery/hatchery.
- Green and brown manuring for *in-situ* organic matter incorporating manuring crops (*Sesbania* sp., sunnhemp, pulse crops *etc*).
- Effective soil-based irrigation schedule and techniques (sprinkler, drip irrigation).
- Adoption of mulching (preferably using natural residue) technology for conserving the soil moisture, SOC build up and reducing the irrigation requirements.
- Nutrient and energy efficient rice variety cultivation technologies (site-specific integrated nutrient management, aerobic rice cultivation, system of rice intensification; direct-seeded rice cultivation *etc*.).
- Scientific composting technology for animal waste management to minimize N_2O/CO_2 emission.
- Use of good quality organic compost instead of dried cattle waste, undecomposed or poorly fermented organic waste to the soil.

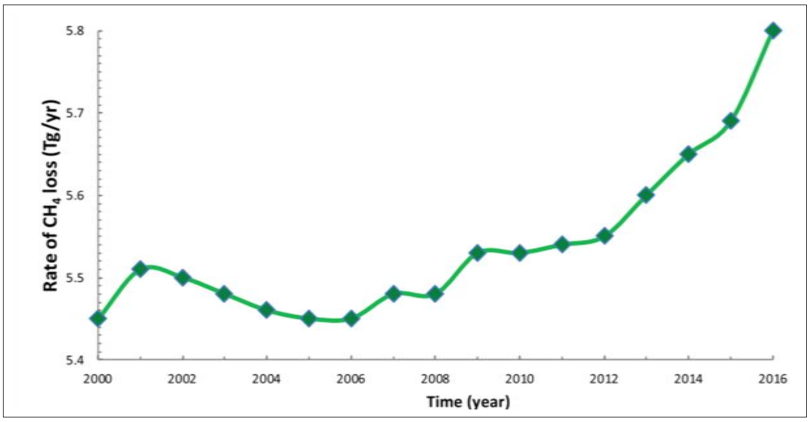

Fig 5: Rate of CH_4 loss approximately over the Indian domain covering an area of 3.71 M km (Source: MoEFCC, 2018).

- Amelioration of problematic soil (acidic, saline and sodic soil) based on Soil Test Crop Response system recommendation.
- Conserve and promote the soil microbial community structure.

Livestock based carbon farming

Unmanaged animal wastes are a major problem in livestock sector due to significant CH_4 emission. About 6-10% of livestock gross energy intake is lost as methane. A substantial amount of nitrogen is lost through ammonia and nitrous oxide volatilization from the excreted waste by the ruminants due to improper waste management. Complying proper waste management process can turn the waste to an effective nutrient supplying substrates which boost the crop growth and building up of SOC. The following practices can reduce these losses:

- Supply of easily digestible feed with green fodders.
- Use improved breeds for better reproductive efficiencies.
- Avoiding the open dumping of waste for long periods.
- Manage livestock waste (dung and urine) by bio-digestion process (composting) to minimize N_2O emissions and capture methane.

Plant based carbon farming

Naturally carbon is sequestrated by the plant system through photosynthesis process. Basically, wood and litter store significant amount of carbon until they are going to decomposed into soil. Apart from the crop cultivation, effective carbon sequestration can be promoted through plantation programme in integrated farm system with increment of farm productivity, soil and water conservation, animal habitation and ecosystem biodiversity. The plant-based carbon farming includes:

- Utilization of poorly productive/degraded soils for wildlife, woodlots or shelterbelt's purpose.
- Promotion of forestation.
- Plantation and conservation of location- and climate-specific trees to ensure their better survival and growth.
- Establishment of multipurpose tree species (MPTs).
- Intensification of the plantation programme through conservation of plant biodiversity.

Fertilizer based carbon farming

Achieving high yield through over use of nitrogenous fertilizers as easy return is the main driven force to the farmers for injudicious use of nitrogenous fertilizers over the reality of soil and plant health degradation. This practice doesn't follow the real N demand by crop, moreover increases cost of cultivation, limits crop yield, leads nitrogen losses to the atmosphere and ultimately climate change. With crop yield, agriculture contributes a significant amount of ammonia (NH_3) through volatilization and denitrification processes. The calculated median NH_3 loss from global application of synthetic N fertilizers is about 78 million tonnes N per year. Particularly urea, is responsible for 19.0-20.3% of total ammonia emissions from agricultural practice during fertilization that facilitates the global warming and ozone layer depletion in the stratosphere via N_2O production. Moreover, high N fertilization influences the CO_2 emission during urea hydrolysis in soil. Thus, N fertilizer management based on real time demand, application methods and site specificity can efficiently reduce the threats of global warming, soil-water pollution, cultivation cost and maximize the N use efficiency (NUE) of plants resulting high yield. The approach can be achieved through:

- Planning of N fertilization should follow the real time crop N demand technology (leaf colour chart, SPAD meter, different AI based optical sensors).
- Nitrogen fertilization should consider the soil nitrogen status, soil condition, climate specific suitable N fertilizer.
- Nitrogen fertilization schedule should follow splitting dose, placing below soil-surface, avoiding broadcasting for higher NUE.
- Application of nitrogenous fertilizers in dry or waterlogged condition should be avoided.
- Use slow-release N fertilizer (coated or super granule urea) and nitrification inhibitor (nitrapyrin and dicyandiamide) to minimize N loss.

Energy based carbon farming

Mechanical involvements of farming practice mostly depend on electricity and fuel. The improper management practices waste excess electrical or fuel energy for every agricultural activity related to machinery or equipment's during sowing to harvesting. Thus, consumable energy should be use-efficient and optimum to the management practice related to cropping, storage or handling of the end product.

- Minimization of electric/fuel energy by proper irrigation scheduling through evaluation of soil type, plant and climate factors.
- Adoption of energy saving structural (natural light source, ventilation) and operational techniques (automatic paddy transplanter, combined harvester).
- Proper and energy efficient post-harvest storage techniques (proper insulation of the buildings, temperature conserving approaches, optimization of the storage quantity, automated access techniques).
- Effective and productive use of animal wastes to produce green energy (bio energy) and green nutrients (composts).

Low carbon farming (LCF) strategy

Low carbon farming is a target specific and precise strategy to maximize the GHGs reduction in agricultural management practices by removing the common sources of GHGs in agriculture. This approach promotes the maintenance of ecological sustainability as well as the building up of SOC. The strategy includes the natural organic resource utilization for site-crop specific nutrient and pest management, soil and water conservation techniques, diversified cropping practices and soil-plant biodiversity conservation processes (Table 1).

The direct benefits from the low carbon technologies are diversified that includes significant reduction of GHGs, adoption of improved nutrient/plant protection/irrigation management, better nutrient use efficiency, incentives/ subsidies for natural resource management related to soil-water-energy conservation techniques, better abiotic stress resistance characteristics, carbon marketing, income generation, development of skill and knowledge at village level through trainings/awareness programmes, accurate weather forecasting, development of post-harvest facilities *etc*. The introduction of carbon credits not only will encourage the farmers to adopt low carbon technology options, also opens a broad possibilities domestic carbon markets towards a new economic scenario.

Opportunities in carbon farming

Carbon farming initiative has two strong profitable goals *i.e.* voluntary carbon offset by the farmers with an economic returns and indirect mitigation approach of GHGs emissions. Through carbon farming, there are huge scopes of multidimensional benefits for the farming community as well as the environment as it simultaneously restores the soil organic and generates the scope of agriculture-industry collaboration. This carbon farming approach can bring the possibilities of economic return from the sequestrated carbon as an investment by the farmers and that buildup carbon can be marketed as a credit to the industries who are in need to reduce their GHGs emission magnitude in terms of carbon capture. Under carbon farming initiatives scheme, the farmers may be able to earn carbon credits from activities such as:

- Enhancing carbon in agricultural soil.
- Reducing livestock emissions.
- Increasing efficiency of fertilizer use.
- Storing carbon through re-vegetation and re-forestation.

Transformation of 'C' to 'C': Carbon to credit

Approach towards the organic farming is based on the more and more utilization of the natural resources to make the soil healthy, improve the soil quality, productivity and also to reduce the pollutions resulted from the modern agriculture. But due to several bottlenecks the approach of organic farming is still either limited or not being able to flourish as a huge income generating opportunity, rather is restricted within the boundaries of class dependent market. The farmers have to dependent solely on the marketing return from the harvested products which is also fluctuated depending on the socio-economic conditions. Moreover, contribution of agriculture to mitigate the climate change is usually not considered with great concern. But in case of carbon farming, there is a wide possibility of economic upliftment by converting the

Table 1: Agronomic practices improving carbon sequestration.

Name of practice	Management practice	Sequestrated Soil Organic Carbon (SOC)
Conservation tillage practices	No tillage or minimum tillage practices; minimum soil disturbances, crop rotation	• Sequestration rate 0.43 tonne C ha^{-1} yr^{-1} (Yadav *et al.*, 2019)· Sequestration rate 2.69 and retention of crop residues tonne C ha^{-1} yr^{-1} (Lu *et al.*, 2018)
Inclusion of cover crops	Legumes, pasture grasses for soil improvement; provides soil protection and has huge potential as global carbon sink	• Sequestration rate 0.32 tonne C ha^{-1} yr^{-1} (Poeplau and Don, 2015) • Sequestration rate 0.92 tonne C ha^{-1} yr^{-1} (Blanco-Canqui, 2022)
Mulching	Organic mulching improves soil environment and plant growth, increases crop biomass and soil microbial ecosystem	• Sequestration rate 0.43 tonne C ha^{-1} yr^{-1} (Yadav *et al.*, 2019) • Sequester 2.3 tonne extra C ha^{-1} than inorganic nutrient management practices Padbhushan *et al.*, 2021)·
Integrated nutrient management practices	Utilization of organic and inorganic resources, improves the quality of soils and crops, increases microbial biomass carbon (MBC) and SOC	• Sequestration rate 0.18 tonne C ha^{-1} yr^{-1} (Anandakumar *et al.*, 2022)
Agroforestry	Greater canopy enables greater utilization of available natural resources, higher contribution to C sequestration, higher range of ecosystem services	• Sequestration rate 15.21 tonne C ha^{-1} yr^{-1} (Nair *et al.*, 2010) • Average 95 tonne ha^{-1} carbon sequestration potential (Albrecht and Kandji, 2003)· • Agroforestry, if increase the income of incentivized with carbon revenue, can farmers up to Rs. 25,000 ha^{-1} yr^{-1} (Singh *et al.*, 2024) • Carbon sequestration potential of coconut trees range between 37 kg $tree^{-1}$ yr^{-1} (dwarf variety) up to 56 kg $tree^{-1}$ yr^{-1} (tall variety) (Namitha *et al.*, 2025)

farming into a new credit system *i.e.* not only agricultural product provides the monetary return, also the incorporation of the carbon to the soil can be considered as the economic contributor to the farmers.

Carbon credits

Carbon credits are a medium of exchange used to "offset" CO_2 emissions under the Cap-and-Trade guidelines set by the Paris Agreement

Carbon credits also known as "cap and trade regimes", wherein participants can emit a set amount of carbon dioxide over the course of a given time period. If they manage to emit less than that, they get credits which they can sell to those who are unable to get emission down to the capped level; money for the credits goes to the participants. CO_2 producers unable to meet the limits and unable to buy credits are penalized. Every sector which are involved in carbon emission process must have a limit of carbon emission and if they are succeeded to produce lower amount of carbon emission against the limit or 'cap', they can market their remaining carbon amount on the calculation of carbon credit to the buyers. This exchange of credits between businesses has encouraged carbon trading globally. From agricultural point of view, the idea of "Carbon credit" is that companies responsible for emitting CO_2 have to reduce their emissions (cap) or pay for the efforts of farmers or others who can prove that they are doing the work of removing CO_2 from the air (trade). In particular, carbon credits are created based on the amount of carbon you draw down into the soil.

Approaches like carbon credits simultaneously force and drive the carbon emitting sectors to reduce the carbon emission in terms of monetary benefit, also adapting environment friendly approaches. These credits can be exchanged between businesses or can be bought and sold in international markets at prevailing market price at two exchanges, namely the Chicago Climate Exchange and the European Climate Exchange. The Multi-Commodity Exchange of India (MCX) may soon become the third exchange in the world to trade in carbon credits.

What are carbon markets?

Carbon markets aim to reduce GHGs emissions enabling the trading of emission units (carbon credits), which are certificates representing emission reductions. Trading enables entities that can reduce emissions at a lower cost to be paid to do so by higher-cost emitters. By putting a price on carbon emissions, carbon market mechanisms raise awareness of the environmental and social costs of carbon pollution, encouraging investors and consumers to choose lower- carbon paths. There are two main categories of carbon markets: cap-and-trade and voluntary. Cap-and-trade sets a mandatory limit (cap) on GHG emissions and organizations that exceed these limits can purchase excess allowances to fill the gap or pay a fine. Voluntary markets enable the trading of carbon credits outside of the regulatory environment.

It was estimated that demand for carbon credits could increase by 15x or more by 2030 and up to 100x by 2050 as per the assessment of International Finance (IIF) with knowledge support from McKinsey. Overall, the global market for carbon credits could be worth upward of $50 billion in 2030 (Blaufelder *et al*., 2021).

Role of agriculture in carbon credit

In this carbon credit marketing process, agriculture sector has recently become easy and successful means for achieving the prime objectives of mitigating the of GHGs emission and crediting of carbon. For a carbon emitting industry or sector, arresting the atmospheric carbon in soil and plant is the best and financially viable approach in comparison to minimizing the carbon emission. A huge financial expenditure for technological scaling up is necessary to cut down or restrict the carbon emission below the cap, but carbon farming can be the alternative way to limit their excess carbon emission. At this point agriculture can play a business-driven role to the non-agriculture sectors for the interest of the later and in return farmers can be benefitted with an additional income. In wholesome, the entire system motivates carbon emitters to promote environment friendly processes that reduce greenhouse gas emission.

From the agricultural point of view, carbon credit also deals with the concept of the initiation of a project by farmers or individuals to reduce the atmospheric carbon in terms of sequestering the carbon in soil by carbon farming process. The amount of the carbon incorporated will be then considered as a credit and can be used for marketing to the parties who are in need to minimize their carbon emission. A single carbon credit represents ownership of the equivalent of one metric tonne (MT) of carbon that can be traded, sold or retired. Carbon credits are measured in CO_2 equivalence and expressed in MT and compared to the carbon status of situation with no carbon farming initiative.

Carbon credit monetization can be the nudge

Since the improvement of soil health is innately linked with the ability to increase soil carbon levels, achieving it demands on continuous monitoring of soil carbon levels and the incentivization of its improvement.

Monetizing soil carbon requires a good understanding of carbon credits. Carbon credits are certificates that represent quantities of greenhouse gases that have been kept out of the air or removed from it. One carbon credit certifies that one metric tonne of carbon dioxide has been removed from the atmosphere. Advancements in remote sensing data and artificial intelligence (AI) have enabled the prediction of carbon levels through satellite data and this serves as one of the methods through which carbon credits are calculated. Companies and governments purchase carbon credits to meet the cleaner-climate commitments that they make.

The benefits to the farmers through carbon market

The direct benefit is that farmers receive cash-based incentives for the carbon they have managed to sequestrate in their lands. A farmer who manages to sequester one carbon credit can earn approximately INR 780 at current market prices, but large corporations are likely to provide better rates as high as INR 2,000 to the farmers when directly purchasing large chunks of carbon credits. It was observed that, farmers who follow regenerative practices are able to sequester one to four carbon credits per acre.

The indirect benefit that farmers experience is the improvement in soil health due to the carbon captured in the soil. This improvement can be gauged by determining whether the soil displays any of the following characteristics: Increased water-holding capacity, lower soil density, increased water infiltration, increased nutrient availability and decreased soil surface temperature.

How does carbon credit programmes work for the farmers?

While it isn't easy for individual farmers to go down this route, non-profit and farmer producer organizations (FPOs) can help them avail the benefits of the carbon credit programmes.

1. Follow regenerative agriculture practices as a group

The first step for non-profits/FPOs is to promote regenerative agriculture practices among their farmer groups, especially focusing on increasing soil organic matter and soil carbon. Since this can take time and initially lead to lower yields, it is important to handhold and support the farmers during the initial years. Showing that these regenerative practices were adopted is a key step in the process of availing carbon credits.

2. Onboarding and third-party verification of carbon credits

Once the projects are identified and listed, third-party agencies verify these projects. After verification and approval, these credits are sold in credit markets and the incentives are distributed to the FPOs as well as the farmers.

What is regenerative farming?

Regenerative farming practices hand degraded land back to nature. They let ecosystems store planet-warming CO_2 by using soil as a carbon sink, literally. This farming approach also helps boost wildlife and promote biodiversity. Many regenerative farming methods follow the traditional ways of farming that were used for thousands of years. These include:

- Reducing soil disturbance due to tillage (no-till farming).
- Ending the use of synthetic pesticides and fertilizers through mob grazing and manure/compost application.
- Maximizing soil coverage through living roots and mulching (covering the soil with mulch).
- Promoting crop rotation by moving away from mono-cultures and growing cover crops, which improves biodiversity.
- Combining livestock rearing with crops and other plants.

Regenerative farming and carbon credits

As farmers and ranchers embrace regenerative farming, their land goes from being a net-emitter of GHG to sequestering carbon. In other words, becoming a carbon sink.

The reduction or sequestration of CO_2 by regenerative farming methods can lead to the creation of carbon credits. These credits are created and brought to market by project developers. They then sell the credits to big companies seeking to offset their own emissions while supporting farmers.

In return, farmers receive additional revenue for every tonne of CO_2 reduced or sequestered in their farmlands. This is why a third-party body has to measure and verify the claim by the farmers to ensure whether there is any evidence of sequestration or not. Soil tests, for instance, are one part of carbon credit programs. Validation of conservation practices is also done by way of federal crop records and field data.

On the buyers' side, investors and companies have committed to promote farming methods that regenerate the soil by buying carbon credits from farmers. Through various regenerative farming techniques, corporations can invest to improve soil health and help grow farmers' income. They can support growers today and drive the regenerative agricultural revolution. And on top of that these techniques can reduce GHGs emission significantly.

Carbon credit as an economic benefit

In the concept of carbon credits, the reduction of one tonne of CO_2 production is considered as the one carbon credit that may be taken for economical market consideration. In developing countries, the implementation of the new technologies to cut down the GHGs emission is quite tough depending upon their socio-economic or policy related issues, but they can earn carbon credit by implementing the carbon farming under clean development mechanism (CDM). Companies in developed countries which had emission reduction targets till 2012 can partner with farms in developing countries through financial stakes or sharing of technology.

Agricultural sector

Within the agricultural sector, credits may be generated in two ways:

Reduction of GHGs

Reduction of the use of fossil fuels, fertilizers and adoption of improved livestock management to reduce GHGs emissions.

Removal of GHGs

Sequestration of CO_2 into terrestrial processes by developing biological sinks.

However, reduction and removal of GHGs should be in compliance with the Kyoto Protocol:

- Credits should be given based on net atmospheric reductions- that means, there should be a net reduction of greenhouse gas emissions. Reduction or removal of one greenhouse gas should not lead to an increase in another greenhouse gas.

- Efforts to remove or reduce GHG emissions cannot result in increased emissions elsewhere-either in space or time.

Forestry

Afforestation

Intensification of the plantation at non-forest land.

Reforestation

Recreation of the forest or woodland areas at deforested land/affected land.

Consideration of agriculture for carbon trading

Since the industrialization is totally unavoidable on the basis of the existence of civilization, this is also quite unrealistic to reduce the GHGs emission pool to the level as expected to keep the planet cool. But the alternative approach that cannot directly counterattack the emissions, but can drive the carbon return back from the atmospheric source to the soil sink, may significantly contribute to the climate change stabilization. Soils are a major server for storage of carbon, the second-largest pool after the oceans, that can be used as the arrester or sequester of carbon depending upon how they are used for agricultural practices. When run properly, agricultural farms can be powerful tools in the fight against climate change. Estimates of the "technical potential" of agricultural soils to absorb the carbon range from 3 to 8 Gigatonnes (billion metric tons) of CO_2 equivalent per year for 20 to 30 years, enough to close the gap between what is achievable with emissions reductions and what is necessary to stabilize the climate. The boosting of the soil organic carbon can be a potential planet survival tools by conserving the climate, environment and the living ecosystem of the entire world. Moreover, advocating of the carbon credits in terms of carbon farming, a new economic world can be opened up as carbon trading where agriculture directly steps a strong and directive consideration compared to other sectors. India has pledged net-zero carbon emissions by 2070 and that target cannot be completed without considering the initiatives like eliminating stubble burning, equipping farmers with digital tools and other regenerative agricultural practices as top priorities. New technologies and digital connectivity are already pairing with carbon credit systems to unlock opportunities for farming communities that harness the power of climate-positive agriculture and boost their livelihoods as a result.

CONCLUSION

Due to the trending and more focused consciousness over the country regarding the detrimental effects of GHGs upon climate and more importantly agriculture, the initiatives from government and different sectors are giving more emphasis on the carbon farming. The approaches provide the scope of utilization of the organic matter along with the conservation of the natural resources and soil-water ecosystem and generates the additional economic incentives to the farmers. Besides this, it may also allow landholders to generate offset credits from activities that reduce emissions or sequester carbon. The carbon emitters will be in track either by reducing their emissions or investing their budgets to procure the carbon credits from the agricultural sectors. As a whole, there will be a sustainable improvement in both the sectors that may offer financial and environmental benefits. Considering the imperative need to mitigate the climate change, it is suggested to accelerate the carbon farming initiative in the work plan of GHGs emission mitigation strategies. The carbon farming may serve as a promising mitigation strategy deserving higher attention as many other geo-engineering options.

Conflict of interest

All authors declared that there is no conflict of interest.

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