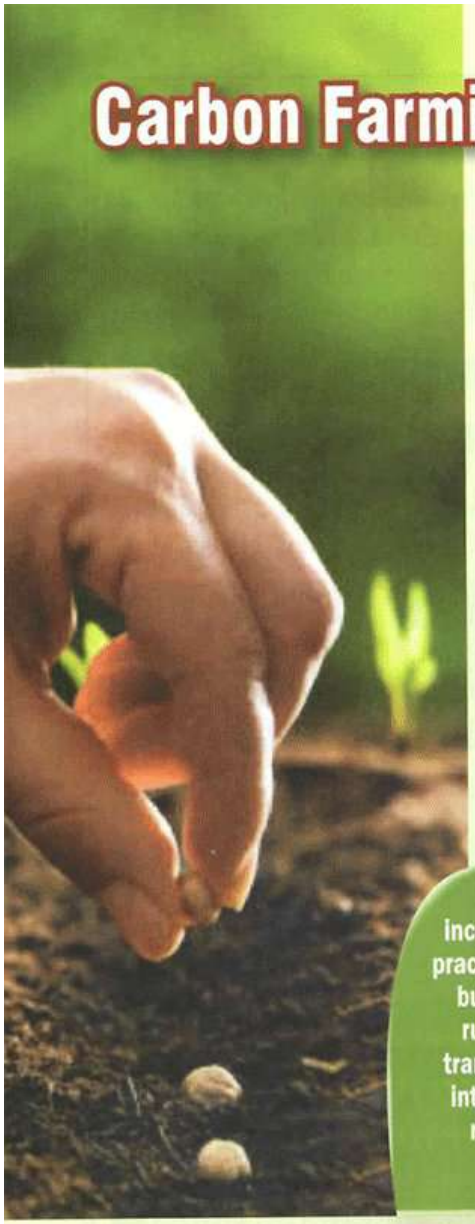
Carbon Farming for Climate-Smart Agriculture



Carbon farming offers a sustainable solution to climate challenges in agriculture by enhancing soil carbon sequestration, improving productivity, and reducing emissions.

With the 2022 amendment to the Energy Conservation Act, India's emerging carbon market enables farmers to earn carbon credits through eco-friendly practices like zero tillage and agroforestry.

Its potential remains underutilised in India, where smallholders dominate carbon farming can transform Indian agriculture into a climate mitigation tool while creating new income opportunities for farmers through carbon credits.

Carbon farming incentivises sustainable practices, reduces stubble burning, and supports rural development by transforming agriculture into a climate-resilient, revenue-generating sector.

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Agriculture, one of the main sectors directly and indirectly linked to the Sustainable Development Goals (SDGs), requires a holistic approach to develop production models that sustain both people and the planet. Climate change exacerbates the environmental impacts of agriculture by reducing crop yields, intensifying soil erosion, and increasing greenhouse gas (GHG) emissions, underscoring the urgent need for sustainable and climate-resilient agricultural practices. Hence, to ensure food security, life on earth, and address climate challenges, agricultural innovation must prioritise improving water retention and filtration, increasing biomass production and promoting carbon sequestration capabilities. In the global climate system, agriculture plays a dual role, like the two sides of a coin. On one side, it is a huge source of GHG emissions,

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contributing to 20% of emissions globally (FAO, 2020). On the other side, it holds immense potential for carbon sequestration, where sustainable practices can transform farms into effective carbon sinks, having the potential to mitigate climate change while presenting farmers with additional income avenues through carbon credits.

Carbon Farming

Carbon farming refers to the adoption of agricultural practices that increase the sequestration of atmospheric carbon dioxide in soils and vegetation. These practices not only mitigate climate change but also enhance soil fertility, water retention, and crop resilience. Carbon farming is a system of agricultural management that helps the land accumulate and store more greenhouse gases instead of releasing those gases into the atmosphere. Carbon farming transforms agriculture from being a net emitter of carbon dioxide (CO_2) to a net sequester of CO_2. Because carbon farming uses the natural process of photosynthesis in conjunction with the improvement of soil organic matter to capture and store carbon, it is incredibly effective at sequestering CO_2. But in India, where 85% of the farming population are smallholder farmers (GOI, 2021), carbon farming remains underutilised. Farmers receive one carbon credit for removing one tonne of carbon emissions. They can trade these for additional revenue while also benefiting from increased soil fertility and crop productivity. With an estimated potential of $63 billion from about 170 million hectares of arable land, India's vast agricultural base offers substantial economic opportunities through the implementation of carbon farming technologies. India's agricultural soils have the capacity to store 3-8 billion tonnes of CO_2 equivalent per year for 20–30 years, which would allow farmers to take part in carbon trading markets.

Core Carbon Farming Practices

- **Forest Management**

Healthy forests are important in reducing climate change by serving as natural carbon sinks, capturing and sequestering carbon dioxide (CO_2) from the atmosphere. Sustainable forest management interventions help in sequestering GHG through avoided deforestation, reforestation, afforestation, and enhanced forest conservation measures. Also, agroforestry, the combination of trees and shrubs in agricultural landscapes, sequesters carbon while offering co-benefits like biodiversity conservation, soil improvement, and diversified farmer income in the form of timber, fruits, and non-timber forest products. Trees sequester CO_2 through photosynthesis, locking carbon in their biomass (trunks, roots, leaves) and the soil. By integrating traditional forestry with climate-smart agriculture, India can increase its carbon sequestration capacity while sustaining rural livelihoods and ecosystem resilience.

- **Grasslands Conservation**

Natural sources of greenhouse gas (GHG) absorption and sequestration include native grasses and other vegetation. Carbon offsets from this category focus on maintaining native plant life through permanent land conservation and avoiding conversion for commercial development or intensive agriculture.

- **Reduced Fertiliser Application**

Excessive use of chemical fertilisers undermines soil health and reduces its capacity to sequester carbon, while their energy-intensive production contributes significantly to greenhouse gas emissions. With increasing fertiliser costs, improving nutrient utilisation through lower application rates, precision farming practices, and newer fertiliser technologies offers farmers a cost-saving route. Recent innovations such as controlled-release fertilisers and fertigation systems improve the use of nutrients with even distribution throughout the crop cycle, reduced waste, and inhibited environmental runoff. These methods not only lower input costs but also improve soil carbon retention, crop resilience, and long-term agricultural sustainability. By adopting balanced fertilisation practices, farmers can maintain yields while reducing their carbon footprint, aligning climate action with economic viability.

- **Biochar Application**

Biochar (biological charcoal) draws carbon from the atmosphere, providing a carbon sink on agricultural lands. Biochar is biologically unavailable, sequestering fixed carbon in the soil for centuries to millennia, providing a tool to absorb net carbon from the atmosphere. Biochar also lowers the need for fertiliser and slows down water runoff.

- **Reduced Tillage**

Traditional tillage practices promote the rapid release of CO_2 from soils and lead to soil structural

degradation, increased erosion risk, and lower long-term productivity of agricultural lands. In contrast, conservation tillage (e.g. no-till and reduced-till) systems reduce disturbance, and can allow maintenance of soil organic matter (SOM) levels, improve water retention and provide significant carbon storage benefits. Reduced or no-tillage systems are sustainable approaches that conserve soil carbon and increase crop yields and long-term sustainability. Using minimum tillage, farmers can shrink their carbon footprint, cut fuel expenses and help establish more resilient agriculture, which can handle climate variation.

- **Cover Cropping**

Cover crops play a key role in carbon sequestration and assist in preventing soil erosion, increasing nitrogen fixation in legumes, leading to improved fertility and add, as it is decomposed, organic matter into the soil, which increases organic carbon levels. They also help to reduce weeds, and in a chemical herbicide-free manner, also protect against nutrient runoff through their thick, ground-covering growth and maintain soil moisture. And by keeping fields productively covered throughout the year, cover crops disrupt pest cycles, contribute to nutrient cycling and reduce carbon losses from bare soils, all of which makes them a low-cost strategy for building resilient farming systems. For example, green manuring with *Dhaincha* in rice-wheat systems indicate that cover cropping could be a win-win intervention for increasing yields and contributing to climate change mitigation while decreasing input costs to farmers.

- **Crop Rotation**

The health of the soil is influenced by the diversity of the plants and microbes. One way to increase this diversity and reduce the burden of pests and disease that accumulates when planting the same crops is through the practice of crop rotation. Root depth of crops and type of crop rotation could do a favour in fully utilising soil nutrients at different depths and in enhancing soil structure.

- **4Rs Approach for Nutrient Management**

The 4Rs of nutrient management include the right time, the right rate, the right source, and the right place. The goal of the 4Rs is to keep nutrients where they are needed, on and in the field. The right time means matching the application of nutrients with crop demand. The right rate refers to aligning the amount of fertiliser with crop nutrient uptake. The right source takes into account the type of fertiliser chosen and whether it has an improved efficiency technology, such as inhibitors, slow or controlled release. And right place is the precise placement of fertiliser such that crops can successfully access nutrients.

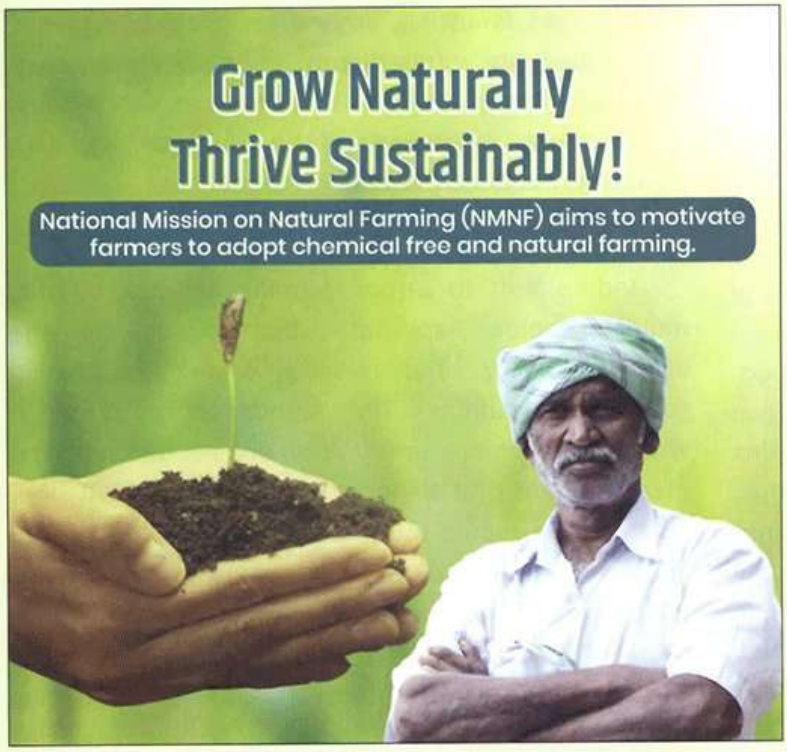
The Government of India passed an amendment in 2022 to the Energy Conservation Act 2001, which lays the foundation for the Indian Carbon Market. The Carbon Market can play a crucial role in generating revenue as well as combating climate change using Agricultural technology. The carbon market can also be used to reduce stubble burning. It will incentivise farmers and can help them in sustainable development. Farmers play a critical role in carbon markets by implementing practices that sequester carbon or reduce emissions, such as cover cropping, zero tillage, agroforestry, and improved manure management.

- **Eliminating Bare Fallows**

Leaving a cultivated land idle and fallow for long periods of time exposes it to loss of carbon brought on by exposures to heat (summer), wind, and rain while enhancing the risk of erosion or weed pressure. Instead, replacing bare fallows with nitrogen-fixing cover crops like clover or vetch has been shown to maintain continuous groundcover, store soil-C, and achieve biological N-fixation to naturally enrich soil-fertility without 'fiddling' (i.e., biologically prepare soil for a more productive subsequent crop while decreasing the requirement of synthetic feeds). By eliminating bare fallow periods, farmers can convert idle land into a carbon-capturing asset that improves the health of soils over the long term and makes them more resilient to climate extremes.

- **Sowing Companion Crops**

By planting two or more crops within proximity to each other, companion planting increases diversity and can be very beneficial to crops and soil. To maximise crop



development and yield, one must be knowledgeable about complementary crops. For example, companion planting is when one crop is planted to repel insects or prevent pests from the main crop.

- **Rotational Grazing**

It involves moving animals to fresh grazing areas at regular intervals. This method allows grazed areas to recover faster by minimising erosion and maximising stump regrowth. In return, the flourishing vegetation harnesses the process of photosynthesis to sequester carbon dioxide into the ground, where it is absorbed from the atmosphere.

- **Silvopasture**

Silvopasture is the combination of trees and pastures used for livestock grazing. As such, it unites the ecological benefits of forestry and the economic benefits of livestock husbandry. Silvopasture systems increase carbon stored by trees as well as in the soil; they also increase pasture productivity and animal welfare.

- **Improved Residue Management**

In agriculture, it is further possible to maintain soil cover by keeping crop residues in the field. It is not only beneficial to soil fertility and reducing moisture, but also covers the land with mulch or agricultural residues (such as straws) and, in combination with organisms to develop a better soil composition.

- **Improved Water Management**

Excess water causes erosion and washes away nutrients. Optimal irrigation, when watered at the proper times, at appropriate rates and the correct depth and distance from the crop, has the potential to maximise crop growth and minimise water loss of the resources.

- **Data-driven Decision Support System**

Taking important decisions on plant protection and fertilisation based on a data-led support system ensures the use of the right types and rates of inputs on the farm. Growers can compare alternatives, increase the visibility of processes and identify sources of variability with the use of a data-driven support system. As a result, data and the resources we employ are invested in a way that strengthens sustainable agriculture.

Carbon Market and its Role in Promoting Carbon Farming

The carbon market refers to the market in which carbon credits, in other words, carbon certificates or emission reductions (ERs)/ emission reduction units (ERUs), are obtained and sold within defined standards for the prevention or reduction of GHGs *(Ministry of Environment, Forest and Climate Change, 2020*). The concept of emission trading through Carbon Markets came into existence because of greater awareness of the need for mitigating greenhouse gas emissions. Carbon Markets play an important role in engaging governments and the private sector effectively in climate change mitigation.

Carbon credit is an instrument used to decrease the degree of carbon dioxide or ozone-depleting substance emissions, which are brought about by an undertaking or the products of any industry. As indicated by the Kyoto Convention, the worth of one carbon credit was identical to one ton of Carbon Dioxide Reduction. *(UNFCC-2021).*There are currently no established emission reduction targets in the Indian agriculture sector, thus farmers can earn additional revenue by trading their carbon credits in voluntary carbon markets.

The Kyoto Protocol required country-specific caps or reductions in greenhouse gas (GHG) emissions. It established targets, allowing emission reductions to

have economic value. The trade of ERs/ERUs enabled the creation of carbon markets. Carbon markets contribute to the reduction of GHG emissions by allowing for the trade of emission units, as well as lowering the economic cost of emission reduction. India is one of the few countries that responded to the carbon market mechanism early on, establishing the system in accordance with the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC). India now has the second-highest number of projects registered under the clean development mechanism (CDM), following China (*Ministry of Environment, Forest and Climate Change, 2020).* The *Paris Agreement (2015) Article 6.4* outlines the establishment of a voluntary mechanism under the authority of the Conference of the Parties to mitigate greenhouse gas emissions and promote sustainable development. This mechanism aims to encourage participation from public and private entities authorised by Parties, facilitating emission reduction efforts. It also seeks to reduce emission levels in host Parties, which can benefit other Parties in fulfilling their nationally determined contributions, ultimately contributing to a global reduction in emissions.

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Way Forward

India's shift to carbon farming needs a holistic, multistakeholder approach that builds on the existing policy frameworks while introducing specific innovations. The foundation must begin with strengthening policy frameworks through the establishment of a National Carbon Farming Mission. This mission would integrate and expand successful initiatives like the Soil Health Card Scheme (DAC&FW, 2015) and National Mission for Sustainable Agriculture (MoA&FW, 2010), while developing standardised carbon measurement protocols and region-specific farming packages. In addition, these policies should offer superior financial incentives, technical handholding, and market linkages to incentivise the majority of India's smallholder farmers to adopt.

At the same time, emphasis must be given to research and development that can bring context-specific innovations. This necessitates significant investments to develop and disseminate new carbon farming technologies suitable for India's varied agro-climatic zones. Institutions involved in research should prioritise the development of low-cost carbon measuring instruments, and crop-specific sequestration through certain intensified programmes like National Innovations in Climate Resilient Agriculture (NICRA), in association with establishing demonstration farms in all agro-ecological regions. These technological advancements must be complemented by robust capacity building and education initiatives. India's extensive Krishi Vigyan Kendra (KVK) network should be mobilised to conduct comprehensive training programmes for farmers and extension workers, combining workshops, field demonstrations, and information campaigns to build expertise in carbon farming techniques and their economic benefits.

The creation of accessible carbon markets represents another critical pillar. We need to develop transparent trading platforms with efficient pricing mechanisms that allow farmers to fairly monetise their carbon sequestration efforts. The successful Farmer Producers

Organisation (FPO) model can be adapted to form specialised Carbon Farmer Producer Organisations that aggregate credits and enhance farmers' bargaining power. These market systems must be supported by credible Measuring, Reporting and Verification (MRV) systems to allow sound and transparent accounting of carbon sequestered according to internationally agreed-upon rules.

A robust monitoring system featuring annual progress reports and district-level carbon targets will ensure accountability. The implementation of these, following our Net Zero 2070 objective, and the application of global best practices will enable the development of a farmer-centric, technology-driven approach in India, which will lead to green agriculture in India and, at the same time, will help meet both – food security and emission reduction – objectives. The convergence of robust policies, advanced research, comprehensive education, and equitable markets will enable smallholders to undertake carbon farming in a manner that is economically attractive and contributes significantly to India's sustainable development goals.

Conclusion

Carbon farming is a game-changing revolution in how agriculture interacts with the climate system. Through carbon farming practices, Indian farmers can help increase productivity and climate resilience while also participating in global carbon mitigation efforts. But it requires a joint effort by policymakers, scientists, private players, and farmers to make this vision a reality. A robust carbon market, supported by strong institutions and farmers-focused policies, can help to unleash the full potential of carbon farming, allowing India's agriculture to flourish in a warming world while undermining a strong sustainable future for generations ahead. ❑