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CARBON FARMING 2.0: UNLOCKING INDIA'S GREEN WEALTH THROUGH SCALABLE SEQUESTRATION AND CLIMATE FINANCE INTEGRATION- A STUDY BY HIGH SCHOOL STUDENT

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Abstract
Carbon farming is a sustainable and new farming practice that helps farmers fight against climate change, and also brings new financial rewards to farmers. By agroforestry—growing trees with crops—cover cropping, no-till agriculture, and planting perennial crops, farmers can sequester atmospheric carbon dioxide and store it in vegetation and soil. This process is known as carbon sequestration. By these farming practices, not only is soil quality and biodiversity increased, but farmers can also earn carbon credits that they can sell to companies wanting to offset their carbon footprint. This paper addresses how carbon farming can generate measurable ecological effects and carbon credits that are tradable. Second, the paper addresses how government regulations and nongovernmental programs can support and scale up these enterprises. Third, the analysis connects carbon farming to broader innovation in sustainable food systems, for instance, clean cooking technology like solar cookers and biogas systems, and thus an integrated "farm-to-fork" sustainable vision. Although the strategy has substantial potential for improving the financial sustainability of farms and rural economies, there are some challenges related to verification systems, equitable payment and permanency of carbon storage to consider. If done transparently and with economic considerations, public-private partnerships in carbon farming can create real change towards a more sustainable and equitable future.

Keywords: Carbon Farming, Carbon Credits, Sustainable Agriculture, Green Cooking, Carbon Sequestration, Economy

1. Introduction

Climate change is possibly the most critical, global, human-made problem we currently face as a civilization, and agriculture is a major contributor to climate change and a potential contributor to its mitigation. Agricultural practices that have historically produced greenhouse gases (GHGs) such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are attributed to soil erosion, livestock/manure/applications of synthetic fertilizers, and land conversion associated with deforestation.[1] Additionally, cooking equipment used in rural and semi-urban regions—still using firewood, coal, or energy-inefficient gas burners—add to carbon emissions, indoor air pollution, as well. Agriculture and cooking together constitute a vital but under-tapped component of climate policy.

In this paradigm, carbon farming—a project that integrates sustainable agriculture with carbon sequestration—has proven to be a viable approach. Carbon farming enables farmers to develop soil health and enhance productivity while, concurrently, buying carbon credits, which are tradable permits granted for every metric ton of CO_2 taken out of the atmosphere.[2] These credits are subsequently sold in voluntary or compliant carbon markets, thereby providing farmers with an incentive-based revenue stream. Carbon farming therefore presents a distinctive model that combines ecological renewal with economic empowerment, particularly for small-scale and marginal farmers.

The concept is carried a step further when we introduce green cooking systems in this paradigm. The transition to clean energy alternatives such as solar cookers, biogas plants, and energy-efficient stoves can significantly reduce emissions at the household level. This article proposes a "crop-to-cooking" model that address sustainable food production while evaluating the impact on the environment from production and processing through consumption.[3] This holistic model has the potential to transform rural livelihoods while fighting climate change from both sides of the value chain of food.

India, being its extensive agricultural foundation and vulnerability to climate change, stands at a juncture today. Agriculture contributes to nearly 14% of the country's total greenhouse gas emissions.[4] Indian farmers, on the other hand, are faced with increasing threats of climate-related disasters—more than 12 extreme weather occurrences per year since the year 2015, with damages billion dollars in few years alone. Realizing this fact, the Indian government has launched the Carbon Credit Trading Scheme (2023) and a Voluntary Carbon Market (VCM) under the umbrella of the Ministry of Agriculture. The rationale behind the above policies is to empower farmers to benefit from their green interventions. For instance, 25,140 smallholder farmers of Uttar Pradesh have been able to earn ₹202 crore through carbon financing programs, with vast potential for scaling up.[5][6]

In addition, India's new Nationally Determined Contribution (NDC) also focuses on lowering emissions intensity by 45% by 2030 with a major focus on market-conformant and sustainable agriculture. This policy context, coupled with enhanced views on climate-related risks and the availability of green energy technology, creates the best possible context for the deployment of integrated models with regard to addressing both environmental needs and farmers' interests.[7]

This research paper begins by explaining the concept of carbon farming and its core techniques—such as agroforestry, no-till farming, and cover cropping—and their role in enhancing soil health and carbon sequestration. It then explores how carbon credits are generated and examines supportive policy frameworks globally and in India. The paper next connects carbon farming with green cooking technologies to build a holistic “farm-to-fork” strategy. Subsequent sections analyse economic incentives, discuss key implementation challenges, and conclude with actionable policy recommendations for sustainable scaling.

2. Climate Change, Agriculture, and Carbon Emissions

World is at the heart of the climate challenge. In India, Agriculture plays a significant role as a greenhouse gas (GHG) producer but also provides a considerable opportunity for solutions to climate impact. At the national level, agriculture is the second biggest producer of GHG emissions after energy, at approximately 13.4% of total emissions as of 2019, having increased absolute emissions to 421 million tonnes CO_2 equivalent. The key sources of emissions from Indian agriculture are through animal enteric fermentation (54.6%), paddy rice cultivation (17.5%), fertilizer utilization (19.1%), manure management (6.7%), and burns of residue in fields (2.2%).[8][9]

While enteric fermentation from livestock regularly produce greenhouse gases through the methane emitted through its digestion (cattle mostly), rice paddies produce a lot of methane, which is the result of anaerobic decay from field flooding.[10] The higher application of nitrogenous fertilizers has resulted in a significant increase in the emission of nitrous oxide, a very powerful greenhouse gas, increasing 13.6% between 2016 and 2019. Residue burning, although displaying some trend decline, continues to contribute to the burden of emissions.[11]

Conventional farming practices defined by intensive monoculture, excessive tillage, and dependency on chemical inputs have not only increased emissions but also compromised soil quality, drained groundwater, and lowered biodiversity. This has exposed Indian agriculture to climate variability, including unpredictable monsoons, droughts, floods, and heatwaves, that are increasingly undermining food security and livelihoods in rural areas.[12] For example, it is estimated that without adaptation, rain-fed productivity of rice, wheat, and maize may decline 18%-20% by 2050 due to climate change.[13]

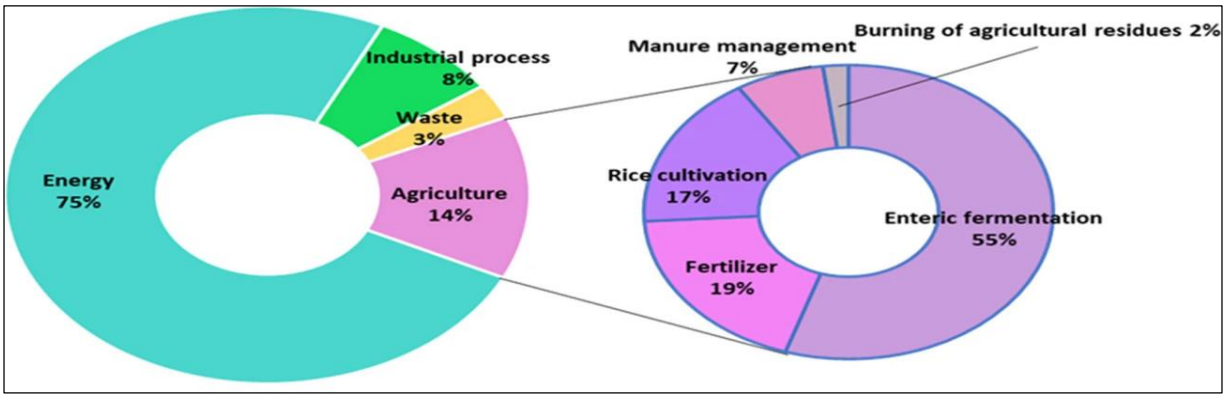


Fig. 1. Percentage of various sectors producing GHG emissions in India (Left), and Percentage of various agricultural sub-sectors producing GHG emissions (Right).[14]

To confront these challenges, India has begun to support climate-smart and regenerative agricultural practices. Crop diversification, zero-tillage, mulching, integrated pest management, and agroforestry, among others, are starting to be adopted in various Indian States.[15] These practices have the potential to decrease emissions, expand the amount of soil carbon sequestration, and improve resistance to climate shocks. For example, direct-seeding of rice can decrease emissions of methane by about 40% relative to convention wet-system rice systems.[16]

Although Indian agriculture is still primarily exempt from mandatory emissions reductions, the support for voluntary carbon markets and green credit schemes is growing, which may provide farmer incentives to adopt more sustainable agricultural practices to reduce emissions, and as new sources of income. Therefore, transitioning Indian agriculture through the pathway of carbon farming and regenerative practices is critical to mitigating greenhouse gas emissions, providing livelihoods to millions, and ensuring national food security in an uncertain future.

3. Carbon Farming Practices and Their Sequestration Potential

Agriculture in India is at a crossroads. Dealing with climate change, the impacts tend to put food security and rural livelihood safety at risk. Farmers and policy-makers look for different pathways for the future of farming that is sustainable, productive, and climate-friendly. Carbon farming, which encompasses a range of agricultural practices that remove and store carbon in the soil and/or plants, can provide a low-risk pathway for India to consider. In this part, we outline, highlight, and discuss key carbon farming practices, the scientific basis of practices, as well as some examples of these practices in India, in the context of activities to improve soil health, crop productivity, and sequester carbon to address climate change.

Agroforestry: Agroforestry refers to the practice of growing trees or shrubs in association with crops and/or livestock on the same tract of land.[17] Agroforestry is practiced traditionally in many regions of India; for example mango, neem, or tamarind trees growing alongside fields of wheat, rice, or pulses. Trees help mitigate climate change by taking up carbon dioxide (CO2) from the atmosphere and storing it in their wood, leaves and roots. Trees store carbon in their deep roots and soil around those roots too.

- Providing shade, reducing wind and water erosion, and better moisture within the soil.
- Allowing for additional income from fruit, timber, fodder and fuelwood.
- Encouraging farming households to plant trees on their fields under the National Agroforestry Policy (2014) and in states such as Haryana and Uttar Pradesh, where agroforestry is promoted at a large scale. [18]
- At present, agroforestry systems in India can sequester (store) 2 - 10 tonne of carbon per hectare of land in a year, depending on tree species and management.[19]

Cover crops: Cover crops are defined as plants that are grown primarily to cover the soil and not for harvesting purposes. Some examples of cover crops in India include Dhaincha (Sesbania), Sunhemp, and Cowpea. These crops are generally planted in the time between the main crop or in the time of fallow.[20]

- Cover crops offer protection to the soil from the effects of soil erosion by wind and water.
- Roots will build organic matter in the soil which can contribute to an increase in soil carbon.
- Many cover crops are legumes, which is a plant group that can fix nitrogen from the atmosphere reducing dependence upon synthetic fertilizers.[21]

The cover cropping practice widely promoted in Punjab and Maharashtra is seen to improve soil fertility and reduce the cost of fertilizers. This cropping can add soil organic carbon of 0.2–0.5 tonnes per hectare per year. [22]

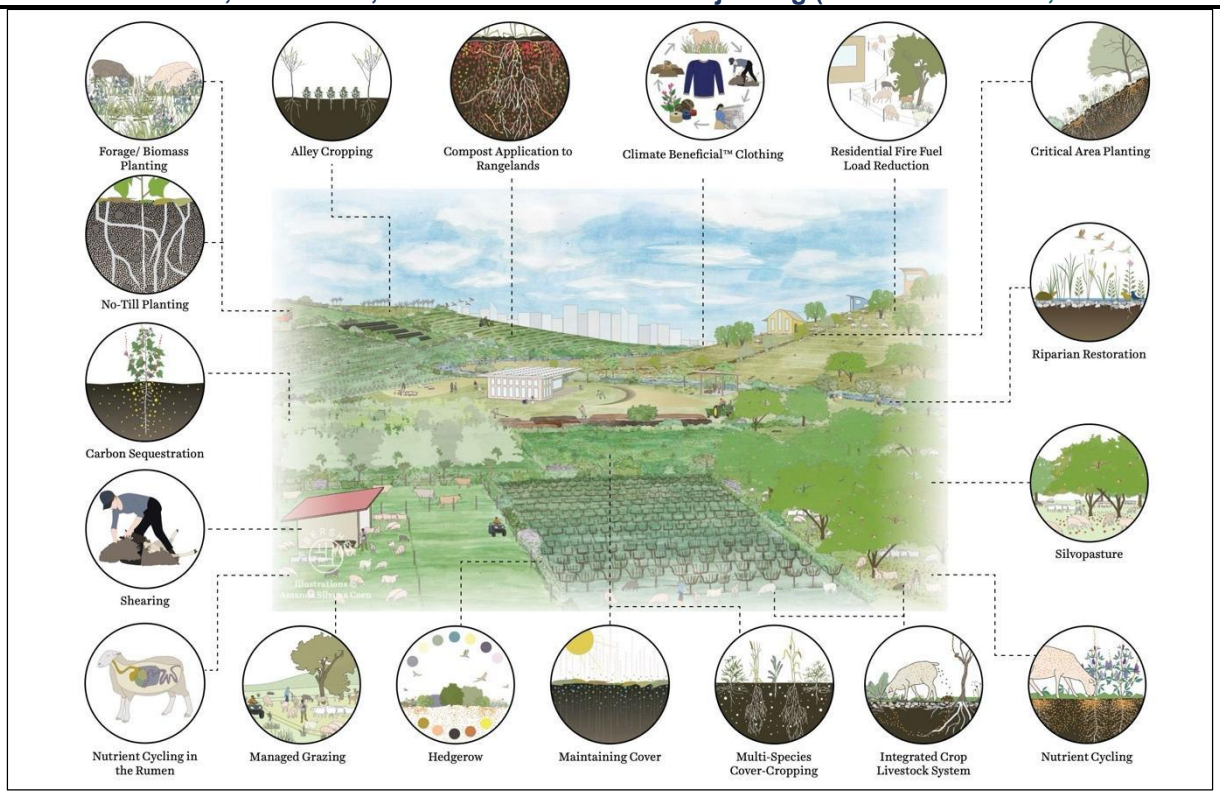


Fig.2. Carbon farming practices known to sequester carbon and/or reduce GHG emissions as identified by the Natural Resource Conservation Service (NRCS).[23]

No-till farming: No-till farming (or zero tillage) describes growing crops without ploughing or overturning soil, no-till relies on planting seeds directly into the residues of the previous crop. No-till farming conserves soil structure, reduces soil erosion and conserves soil carbon. Soil organic matter is decomposed when oxidized to air through traditional tillage practices.[24]

- No-till wheat following rice harvest is done in Haryana and Punjab and reduces water input and labour time costs.[22]
- Several studies support that no-till can increase soil carbon stocks by 0.3 - 0.6 tonnes per hectare per year, while reducing greenhouse gas emissions by mitigative actions related to burning.[25]

Biochar is a charcoal-like product produced by the burning of crop residues (e.g., rice husks, sugarcane bagasse) in a low-oxygen environment. When added to soil, biochar adds another element, as it can act like a sponge and holds water and nutrients, and stores carbon for hundreds of years.[26]

- Biochar, when we add to the soils, enhances the fertility and productivity of the soil, and adds carbon. This effect is especially significant for poor or degraded soils.
- Biochar prevents carbon release to the atmosphere as when included in soils it locks up carbon.
- In India, biochar is being tested in different states (e.g. Karnataka, West Bengal, etc.) and preliminary results suggest that providing appropriate amounts of biochar will contribute to crop yield and carbon sequestration.[27]

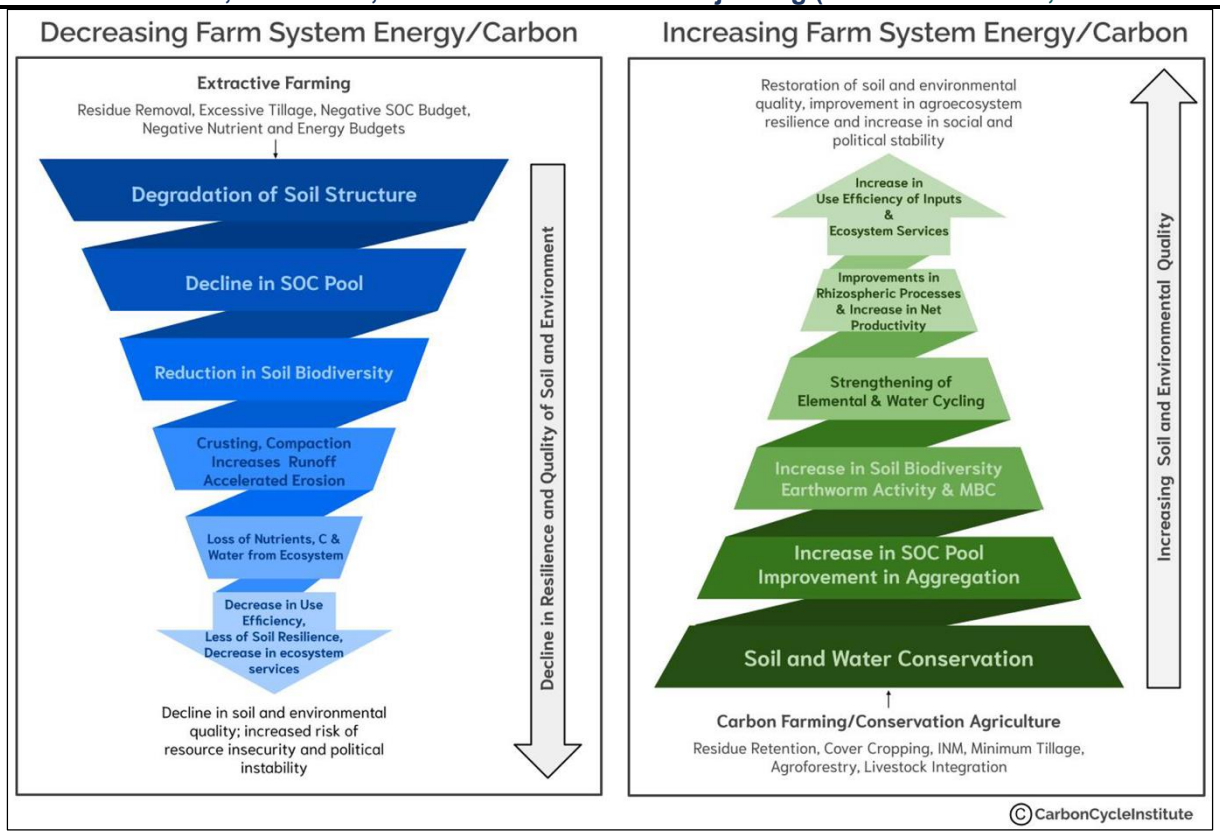


Fig.3. Comparison of Extractive Farming, and Carbon farming.[23]

Organic farming and Regenerative agriculture: Organic farming avoids synthetic fertilizers and pesticides to emphasize using natural fertilizers, such as compost and farm yard manure and practices such as crop rotation.[28][29] In contrast, regenerative agriculture aims to restore the health of soil, increase biodiversity, and improve ecosystem services. Regenerative agriculture also includes practices that put the health of the soil on a path of improvement and environmental impacts on a path of reduction.[30] Many of these practices focus on composting farm waste and animal manure to add nutrients to the soil, crop rotation to control pest life cycles and improve nutrients in the soil profile, and livestock integration to build soils, support pasture health, increase biodiversity, impact animal health through grazing, and speed action of naturally cycling organic matter as natural fertilization.[31][32] Regenerative agriculture also works towards natural pest controls, while using ecological means rather than chemical ones. Overall, regenerative agricultural practices help build soil, improve biodiversity, increase carbon storage on farm, and bring more sustainability and resilience to farming, and ultimately better solutions to climate change.[33]

- Andhra Pradesh has the Community Managed Natural Farming (CMNF) program that covers millions of hectares across the state and employing organic and regenerative agricultural practices.[34]
- Re-generative farming methods can improve soil carbon by 0.5 - 1 tonne per hectare per year and improve the resilience of crops to droughts and flooding.[35]

When carbon is sequestered into plant and soil carbon, these practices are helping reduce greenhouse gases. For India, if these practices widely adopted, we may sequester 100-200 million tonnes CO_2 each year, or to the equivalent of taking millions of cars off the road.[36][37]

Table 1: Key Carbon Farming Practices, Methods, and Benefits in the Agriculture

Practice	What It Involves	Main Benefits for Soil & Climate	Ref.
Agroforestry	Growing trees alongside crops and/or livestock	• Stores carbon in trees and soil • Improves soil fertility and water retention • Offers income from fruits, timber	38
Cover Cropping	Growing legumes or grasses between main crops to protect soil	• Adds organic matter • Fixes nitrogen, reducing need for fertilizers • Prevents erosion	39
No-Till Farming	Planting without ploughing; crop residues left on the field	• Preserves soil structure • Reduces carbon release • Minimizes erosion	40
Biochar	Burning crop waste in low-oxygen conditions to create charcoal and mixing with soil	• Stores carbon long-term • Improves soil's nutrient and water retention	41
Organic / Regenerative	Using compost, natural manure, crop rotation, minimal chemicals	• Boosts biodiversity • Improves soil health • Enhances carbon in soil	42,43

4. Carbon Credit Markets: How Indian Farmers Can Participate

Agriculture being a key part of India's economy, is also a major source of greenhouse gas (GHG) emissions, and it accounted for about 12.7% of global agricultural CO2 equivalent emissions in 2021. India was also the largest emitter of agricultural CO2 equivalent emissions in the world.[44] The leading sources of GHG emissions associated with land use in India are methane emissions from paddies and livestock, nitrous oxide emissions from fertilizers, and carbon dioxide emissions from soil tillage and residue burning.[45] These emissions not contribute to climate change, but also threaten the long-term productivity of the agricultural sector and the livelihoods of millions of Indians. An economic and market-based mechanism to support efforts towards reducing global emissions is the Carbon Credit system, which is currently being developed and adopted around the world. A carbon credit is a transferable certificate to represent the removal or reduction of one metric ton of carbon dioxide (CO_2) or chemically equivalent greenhouse gases from the earth's atmosphere. Carbon credits are generated by a project that show measurable and verifiable emissions reductions.[46][47] For example sustainable farming, planting trees, and improving soil carbon storage to demonstrate carbon credits. The carbon credits may be sold to companies or countries attempting to offset their own emissions, thus providing organizations the SAPs to conduct climate-friendly activities celebrated by their consumers.

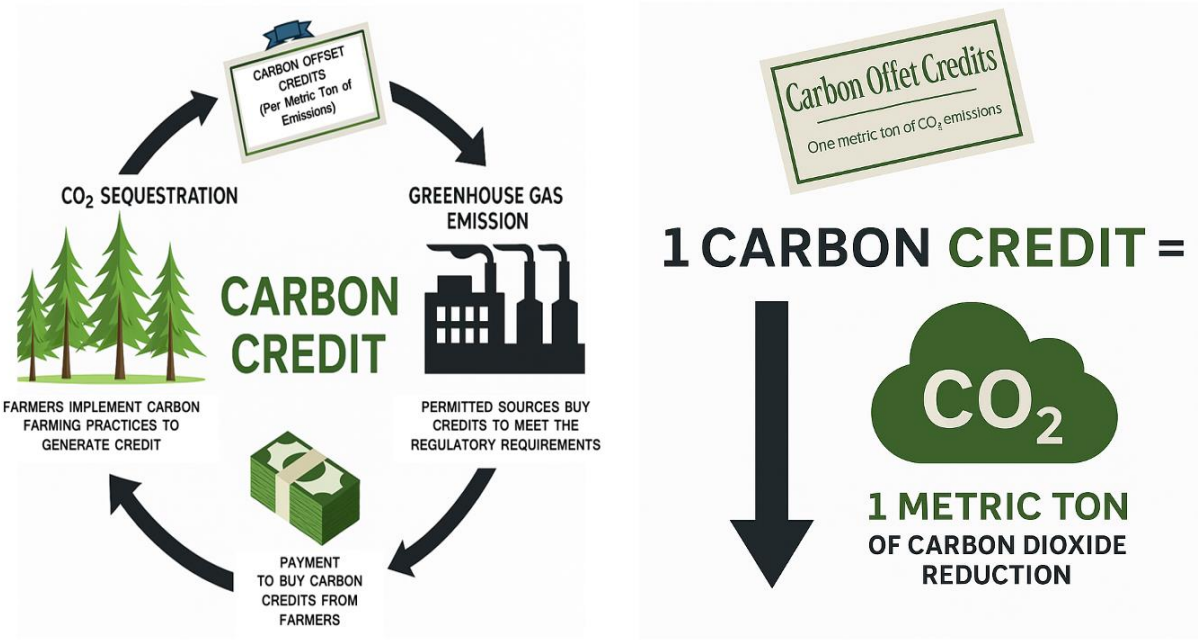


Fig. 4. Carbon Trading offers opportunity for the Farmers to generate the Carbon Credits and sell those to earn money in return. (1 Carbon Credit = 1 metric ton of CO_2 Reduction)

Carbon credits can be obtained by a farmer by using beneficial agricultural practices which limits greenhouse gas emissions or carbon storing in the soils, and crops.[48] The practices are discussed earlier, and also listed in Table 1. Once these practices are monitored, reported, validated (ensuring someone verifies the practice), farmers can earn a carbon credit (a certificate that represents the reduction or the removal of one metric ton of carbon dioxide equivalent). When they earn carbon credits, the farmer can sell them to companies and organizations to offset their unwanted emissions and the farmer will earn another income source from their management of the soil while improving soil health and farm production.

4.1 The Process: MRV (Monitoring, Reporting, Verification)

The MRV (Monitoring, Reporting, and Verification) process is critical for farmers to issue credible carbon credits in India's agricultural carbon markets. The MRV process consists of three steps. [49][50]

1. Monitoring: This step involves farmers or project developers systematically monitoring changes in their agricultural practices (for example, whether they have implemented changes to no-till farming, cover crops, or changes to fertilizer application) and measuring the tangible impacts of these practices (for example, soil carbon content, changes in greenhouse gas emissions). As a monitoring process, farmers will be creating observable and measurable data to support future carbon credit reporting. This process is often accompanied by digital reporting processes or precision agriculture technologies to collect or report this data as well as satellite imagery for support as needed.
2. Reporting: In this step, farmers will organize and report information that has been gathered during the monitoring phase following standardized methodologies approved by carbon credit registries. This stage is important because it will provide transparency, consistency, and verifiability of information regarding the practices carried out and their associated environmental impacts. Reporting also demonstrates that emission reductions or carbon sequestration were delivered as intended and according to the eligibility and requirements of other carbon credit registries like Verra, Gold Standard, or platforms in the Indian Carbon Market.[51]
3. Verification: Independently accredited third party agencies, which in India are known as Accredited Carbon Verification Agencies (ACVAs), audit the relevant data and verify a farmer's practise was "real", "additional" (that is, beyond what would have happened anyway), and "permanent" before issuing carbon credits. Farmers can then trade the credits they receive from their successful verification in either domestic or international markets. Maintaining rigorous measurement, reporting, and verification (MRV) of offsets is critical if the integrity of carbon credits and the economic value of credit are to be maintained. If buyers or regulators cannot trust that the environmental benefits of the agricultural project are real then the public's confidence in carbon credits will be compromised.

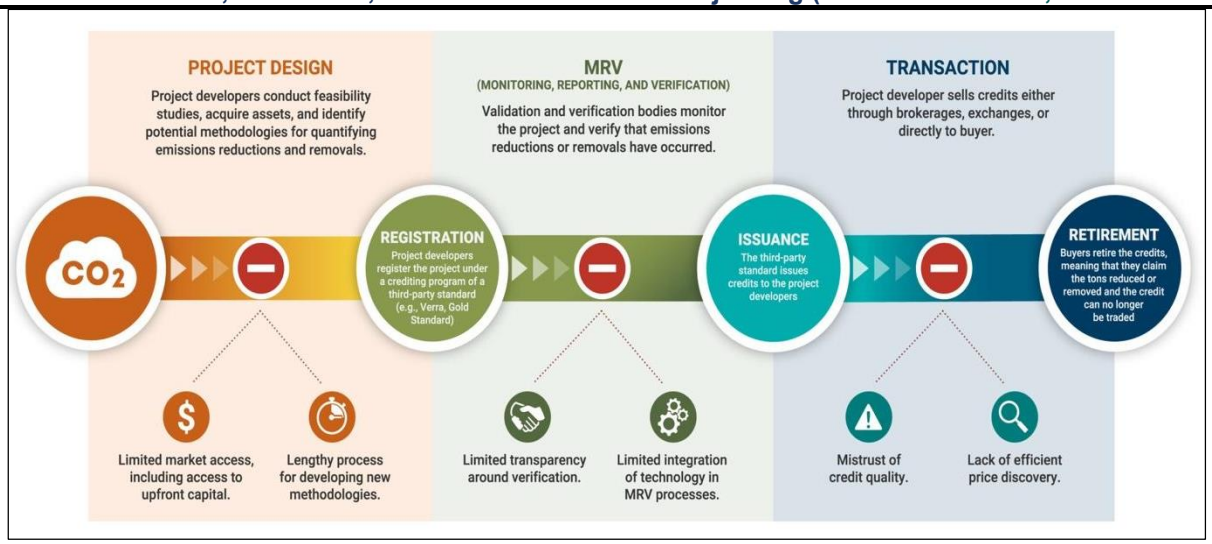


Fig. 5. Lifecycle of a Carbon Credits from project design to retirement highlighting key steps and market challenges.[52]

4.2 Participation of the Farmers and Benefits

Farmers in India, who are keen to access carbon credit markets, now have a range of global and domestic opportunities to benefit from climate-friendly agricultural procedures. On the global stage, Verra (Verified Carbon Standard) and Gold Standard are two of the more established registries with verified processes and reputational credibility. Verra has issued more than 1.1 billion credits based on more than 2,000 projects across 88 countries including a large number focused on agricultural and forestry activities. Gold Standard projects additionally highlight their emission reductions with social and environmental co-benefits.[53][54][55] For Indian farmers, these benefactors share some potential opportunities for sale of credits at an international level, especially given that their particular projects can demonstrate quantifiable carbon reductions compared to its baseline and its associated community benefits.

Inside the country, the Carbon Credit Trading Scheme tries to facilitate the Indian Carbon Market that is managed by the Bureau of Energy Efficiency (BEE) and the Central Electricity Regulatory Commission (CERC).[56][57] The cap on the registry is the Grid Controller of India and the process of verification is carried out by Accredited Carbon Verification Agencies (ACVAs). GCP recognizes planting trees and soil conservation as credit-earning activities. Currently, India has more-than-5,000 carbon offset projects registered both at the international level and the domestic level, which shows a fast-growing infrastructure for carbon trading.

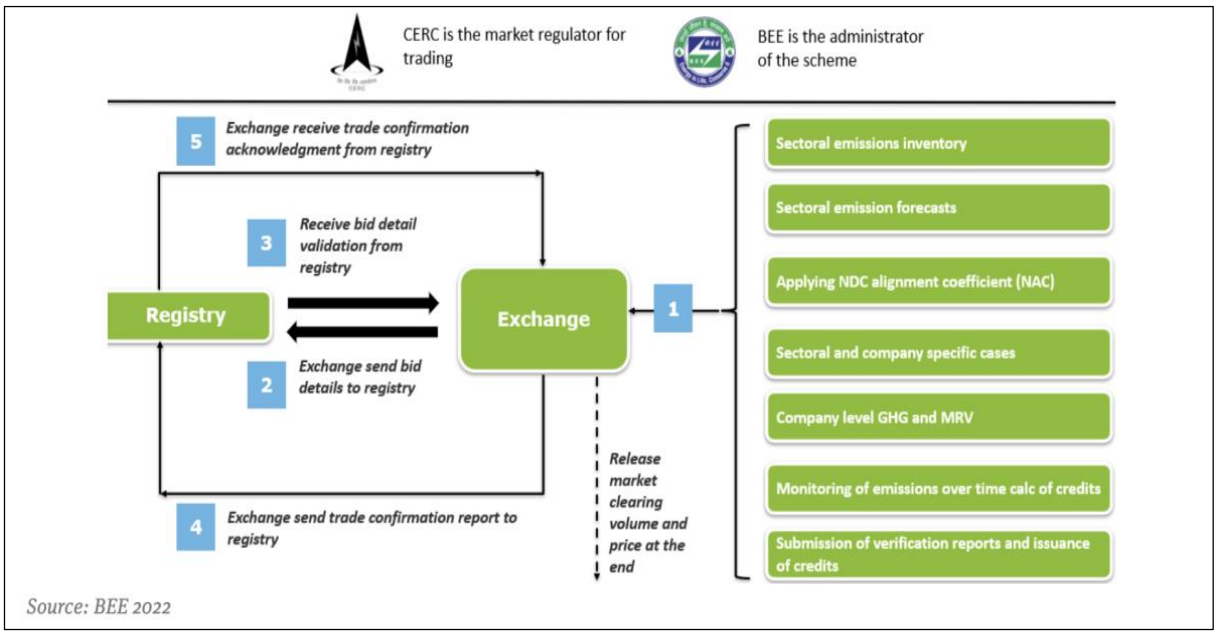


Fig. 6. India's PAT scheme is transitioning into an Emissions Trading System (ETS) in three phases: Phase 1 opens voluntary carbon markets to more buyers; Phase 2 expands supply by allowing non-designated sellers to trade verified credits; and Phase 3 establishes a full ETS with entity-specific GHG intensity targets, sectoral benchmarks, and credit trading through a regulated registry-exchange system aligned with India's NDCs. [58]

The process for an Indian farmer starts with the adoption of climate-smart practices such as no-till farming, agroforestry, or better manure management to either prevent the greenhouse gases from being emitted or to sequester carbon.[59] The changes are thereafter monitored and documented; the data are reported according to approved methodologies. Compliant with the clearance letter of protocol, the third-party audit agency (ACVA) assesses the data to verify that reductions are genuine and additional. Once verification is complete, carbon credits are issued and registered on the ICM or international registries, after which they are put out for sale on electronic trading platforms regulated by CERC or on global exchanges that support credits of Verra and Gold Standard.

Farmers' extra earnings have gone from selling credits, with an average of US$2.35 (₹195) per ton of CO_2 within India as of early 2024 which is less than some other neighbouring countries but growing rapidly with increasing demand and better quality of credits. Internationally, prices are between ₹700 and ₹1,000 per ton, especially when the projects meet advanced standards or achieve social co-benefits. Apart from direct income, benefiting social co-benefits occur in traditional farming that enhance soil health, lower input costs, and create resilience to climate shocks shortly; these co-benefits enhance their economic positioning over time.[60][61]

The government of India supports the ecosystem with a strong MRV (Monitoring, Reporting, and Verification) system to uphold transparency and credibility in credit issuance. Policy oversight is afforded by the National Steering Committee for the Indian Carbon Market (NSCICM), and capacity building initiatives are available to allow small and marginal farmers to enter these markets.[62] With the reinforcement of digital infrastructure and methodologies, one would expect the number of farmers joining in to rise, making carbon credits ever more relevant a tool for rural development and climate action.

5. Green Economic Policy Models in Indian Agriculture

India is taking the lead in developing green economic policies to transform its agricultural practices into a smarter climate resilient and carbon-negative system that works for farmers' welfare. The government has passed favourable policies such as adjusting the Minimum Support Price (MSP) for millets and pulses to include carbon-sequestering crops, margin agroforestry tax incentives of 150% under Section 80JJAA, and subsidies of 50% to 75% for the adoption of no-till equipment and biochar production units.[63][64][65] Carbon farming is zoned in over 0.8 million farmer households in Andhra Pradesh through its Zero Budget Natural Farming (ZBNF) program, capturing over 1.2 million tonnes CO_2 per year[66][67], and the 40% reduction of methane emissions from Punjab's direct-seeded rice program over 1.2 lakh hectares.[68][69] Unlike the Common Agricultural Policy (CAP) of European Union which links 40% of the subsidy to eco-scheme compliance, India's carve out distinct fusion of carbon credit and social spending cap integrated with welfare support, in the case of PM-KISAN serves as a carbon credit spending cap that pays ₹6,000 annually to 110 million farmers.[70][71] Shifts the burden to the private sector, NGO's also serve a supporting function: on the other hand, Bayer contracts with 250,000 farmers to plant climate-smart rice, at the same time Grow Billion Trees certifies carbon credits for smallholders. [72][60]

On a global scale, while the U.S. is all about big industrial carbon capture, India is taking a different route with its focus on decentralized, agrarian solutions. Their carbon market framework aims for a whopping 50 million tonnes of annual agricultural offsets by 2030, with prices ranging from ₹200 to ₹1,000 per tonne.[73][74] This all is connected to the formal economy with the link of the Bureau of Energy Efficiency's trading platform. This strategy is not only elevating Indian agriculture as a crucial food producer but also establishes it as an essential carbon sink, effectively balancing ecological and economic objectives through market-driven incentives.

5.1 Linking Farming with Greener Cooking: A Closed-Loop Vision for India

India's agricultural and domestic energy sectors are closely linked, both grappling with the pressing need to cut carbon emissions while enhancing rural livelihoods. As discussed earlier, Agriculture, while vital, is a significant contributor to greenhouse gases. Another significant contributor, which is closely linked with agriculture and farming sector is cooking. Cooking methods use firewood, dung cakes, or leftover crops, which play a big role in indoor air pollution, deforestation, and household emissions. Shifting to greener cooking technologies, such as biogas, solar cookers, advanced biomass stoves, and LPG alternatives, is essential not just for health but also as a key move in the fight against climate change.[75] By connecting carbon-sequestering farming practices with clean cooking solutions, India has the opportunity to build a circular economy that maximizes both environmental and social benefits.

Carbon farming has a revolutionary effect on food production in India. The approaches like agroforestry, cover cropping, and organic methods trap carbon in soils and trees while boosting soil fertility, water retention, and crop yields. Additionally, crops grown using these methods often pack more nutrients and fetch higher prices in local and global markets. Taking the example of millets and pulses, for instance are becoming hot items for health-conscious buyers in India and overseas. When farmers get carbon credits for using the methods discussed previously for carbon reduction,

they get chance to unlock a new way to make money. The earning they get from this, can be utilised further into their farms or to boost their living standards. This is where the connection to greener cooking has a big impact. The money from selling carbon credits can go towards buying clean cooking tech—like biogas digesters solar cookers, or high-efficiency pellet stoves. This creates a direct link between eco-friendly farming and the energy used in homes. This creates a direct link between eco-friendly farming and the energy used in homes.

India has taken big steps to encourage clean cooking with programs like the Pradhan Mantri Ujjwala Yojana, which has given out over 100 million LPG connections.[76][77] Still many rural families stick to using traditional biomass fuels because of high costs and limited availability. To meet local needs greener cooking technologies provide various options. Biogas plants turn animal waste and crop leftovers into methane that works as cooking gas, while also producing a slurry that people can use as an organic fertilizer.[78] Solar cookers make use of sunlight to cut down reliance on burning fuels. Advanced biomass stoves and pellet systems use farm waste more lowering emissions and reducing the need to gather firewood. Around the world, places like Kenya and China have expanded the use of biogas and improved cookstoves.[79] India however, has a special edge. It can connect these technologies with carbon farming and carbon credit markets. Farmers in India can use money from selling carbon credits to handle the high initial costs of adopting these clean systems. This connection helps make the shift affordable while also benefiting the environment.

5.2 The closed-loop model "Farm-to-Fork"

The closed-loop model "Farm-to-Fork" sometimes referred to as "Farm-to-Fork-to-Fuel," is a recurring cycle where farming, food, and domestic energy are integrated. In this model, a farmer implements carbon farming practices such as agroforestry or cover cropping that capture carbon.[80] Such practices accrue carbon credits, which are sold on exchanges such as the Indian Carbon Market or international registries. Farmers can utilise funds generated from these credits to purchase equipment such as a biogas plant or solar cooker. These machines transform farm waste or sunlight into clean fuel for cooking. The residues like biogas slurry, go back to the farm as organic fertilizer enriching the soil while maintaining the nutrient cycle in link. This model lowers carbon emissions while tackling various Sustainable Development Goals like clean energy, health, climate action, and reducing poverty. It marks a shift away from linear systems that extract resources toward circular systems that focus on regenerating resources and reusing outputs as inputs in other processes.

5.3 Improving Value Chains and Integrating Digital Tools

A big part of making this vision work comes from using digital tools and improving the value chain. Farmers use precision agriculture tools like soil sensors or satellite trackers to monitor carbon storage and use resources more . Blockchain certification systems play a key role by providing a clear view of how carbon credits are created and traded, which helps buyers trust that the credits benefit the environment. Apps and online platforms let farmers link up with buyers, experts, and financial services. This connection makes it simpler to tap into carbon markets and find clean energy options. India is building its digital infrastructure . The Digital India program and broadband access in villages give it an edge over many other developing nations in setting up such combined solutions. Around the world, interest is growing in models that connect food and energy systems. However few nations match the size and variety of agriculture and energy in India or have the policies to push such broad change.

5.4. India's Verified Carbon Sequestration Potential and Market Innovations

Recent data from India's Ministry of Environment, Forest and Climate Change (MoEFCC) highlight the country's growing capacity for verified carbon sequestration through agricultural innovation. As of 2025, pilot carbon farming zones in Madhya Pradesh and Telangana are sequestering over 2.7 million tonnes of CO_2-equivalent annually, with agroforestry accounting for approximately 68% of this total, as confirmed by field validation trials. These results underscore agroforestry's dominance as a scalable strategy for carbon removal in Indian agriculture.[81][82]

Emerging techniques are further enhancing sequestration rates. For example, the application of biochar mixed with vermicompost in Tamil Nadu's red soils has achieved carbon retention rates exceeding 65%, while microbial inoculants such as Azospirillum and Rhizobium have increased soil organic carbon by 22% in degraded fields.[83][84] These innovations demonstrate the potential for low-cost, high-impact interventions in diverse agro-ecological zones. However, market access remains a significant challenge. As of 2025, only 4.5% of eligible smallholder farms are connected to verified carbon credit platforms, largely due to limited verification infrastructure and high upfront costs. Blockchain-based solutions like AgriLedger are beginning to address this, reducing MRV (Monitoring, Reporting, Verification) costs by up to 40% and streamlining farmer participation.[85][86]

Technological advances are also improving scalability and efficiency. The integration of ISRO's Bhuvan Geo-Analytics with IoT soil sensors has reduced carbon verification time from 28 days to just over 3 days per acre, with successful

pilots underway in Maharashtra and Andhra Pradesh.[87][88] This rapid, real-time data collection is making MRV more accessible and affordable for Indian farmers.

Finance models are evolving as well. NABARD and Tata Trusts fund provided upfront financing to carbon farming cooperatives, including advance payments against future carbon credit earnings [89] This approach addresses the liquidity gap and incentivizes farmer participation at scale. On the consumer side, ITC AgriTech's 2024 pilot of carbon-labeled rice and wheat—using QR codes linked to registry-certified emissions data—has enabled metro and export market consumers to track emissions reductions across the agri-value chain. This transparency supports premium pricing and strengthens the market for low-carbon produce.[90]

India's policy momentum is further reinforced by its 2025 accession to the Global Carbon Farming enabling cross-border certification and market linkages with countries such as Brazil, Vietnam, and Kenya.[91] This global collaboration is expected to accelerate the adoption of best practices and open new markets for Indian carbon credits.[92] Looking ahead, if current scaling efforts continue, projections indicate that carbon farming could contribute majorly toward India's net-zero targets by 2070 and generate multi-billion annually through voluntary carbon markets by 2030.[93][94] With hundreds of agriculture land management projects already ongoing and multiple adding yearly, and an annual emissions reduction potential exceeding substantially, India is poised to become a global leader in carbon farming and climate Fina.

Table 2: Economic and Cost Analysis of Transitioning from Traditional to Carbon Farming with Carbon Credit Participation

Parameter	Traditional Farming (per 5 ha)	Carbon Farming & Credits (per 5 ha)	Parameters
Annual Crop Net Income	Low–Moderate	Moderate–High	5–10% yield gain due to soil health improvement
Synthetic Fertilizer Cost	High	Moderate	30% reduction via organic inputs, legumes
Fertilizer Savings	Nil	Moderate	Direct savings from reduced chemical use
Carbon Credits Generated	Nil	Moderate	4 tCO_2e/ha × 5 ha (conservative estimate)
MRV & Certification Cost	Nil	Low	₹600/ha/year; 40% lower with digital tools
Carbon Credit Price	Nil	Moderate	Domestic & voluntary market rates
Gross Carbon Credit Revenue	Nil	Moderate	20 tCO_2e × ₹800–₹1,000
Net Carbon Credit Income	Nil	Moderate	After deducting MRV costs
Total Additional Annual Income	Nil	Moderate–High	Fertilizer savings + net carbon credits + yield gain
Agroforestry/Tree Income	Nil	Moderate–High (after 5–7 years)	Fruit/timber sales (future), tree planting cost
Biochar/Organic Inputs Setup	Not applicable	Not applicable	Kiln setup, training, composting
Soil Organic Carbon Change	Nil or Negative	Moderate–High	Verified in Indian pilots
GHG Emissions (per year)	High	Low or Negative	Carbon neutral or better
MRV Time Required	Not applicable	Low	ISRO Bhuvan & IoT sensors
Upfront Investment Required	Low	Moderate	Trees, biochar, training, digital tools
Market Access	Low (Local only)	High (Domestic & International)	ICM, Verra, Gold Standard, AgriLedger
Community Impact (10,000 farmers)	Nil	High	Scalable rural income generation

6. Opportunities, Challenges, and Future Perspectives

The growth of carbon farming and carbon credit markets creates new chances for Indian farmers. When farmers use methods like agroforestry, cover cropping no-till farming, and regenerative agriculture, they can trap large amounts of carbon in soils and plants. This helps fight climate change and also makes soil healthier, increases biodiversity, and helps farms withstand tough conditions. Turning these climate-friendly actions into carbon credits gives farmers extra money.[95] This can change things for small and struggling farmers. Some important benefits and opportunities for farmers are shown in figure.



Fig. 7. Some Key opportunities for Indian farmer to participate in carbon Farming and Carbon Trading.

Although it has increasing potential, carbon farming in India encounters some crucial challenges. One serious hindrance is limited awareness and capacity among farmers, many of whom are not aware of carbon credit schemes or climate-smart agriculture. There is technical complexity and high cost entailed with Measurement, Reporting, and Verification (MRV), which discourages small and marginal farmers to join. Availability of carbon markets is restricted by complex processes, absence of digital infrastructure, and limited institutional backing. In addition, guaranteeing permanence of sequestered carbon and satisfying additionality requirements—establishing the carbon gains are more than business-as-usual—increases complexity. Climate variability and land use changes serve to jeopardize carbon storage achievement. Finally, linkage with current government policies and farming schemes is required in order to prevent interfering objectives and to upscale carbon farming adequately. Removal of these impediments by low-cost MRV tools, capacity-building initiatives, and open policy structures is necessary for large-scale implementation and long-term success.

Conclusion

This article has thrown the potential for transformation with the convergence of carbon farming, carbon credits, and cleaner cooking technology under one circular economy umbrella. The three-way model, whereby farmers embrace climate-resilient agriculture, receive carbon credits, and invest in clean energy, presents a model for Indian rural sustainable development. It, however, calls for a coordinated policy thrust, strong institutional backing, and continued support for technology and capacity development. As India works towards fulfilling its climate goals and safeguarding the livelihoods of tens of millions of rural families, the message is unequivocal: sustainable living is possible if policies,

markets, and communities align for the good of people and the planet. By adopting this holistic perspective, India can set the pace towards creating resilient, regenerative, and prosperous rural economies for the 21st century.

Author's Bio

I am Vansh Goel, and I am passionate about sustainability and environmental economics. I am currently a high school senior at Pathways International School, Noida. I intend to major in Economics and Environmental Management at one of the top Universities in the US. My family, over the last five generations, has been working with farmers and manufacturing various spices for both Indian and international markets. Ever since I was a little boy, I remember vividly the fragrance of spices coming out from our warehouses at our family home's backyard. I would spend hours with farmers working in the fields during my summer vacations, and wondered how can we put in place a system that rewards their labour and sweat from farming itself. While in high school, I explored and got interested in research around carbon credits and carbon trading and how it is relevant to generating diversified income for the farmers whose cash flow usually is seasonal in nature. This served as a foundational basis for my research to posit that carbon credits through reforestation and sustainable agriculture aided by economic policy has the power to diversify sources of income for Indian farmers.

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