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Generating carbon credits: Transforming agriculture into a carbon sink

Ram Swaroop Meena*

Institute of Agricultural Science, Banaras Hindu University, Varanasi, Uttar Pradesh 221 005

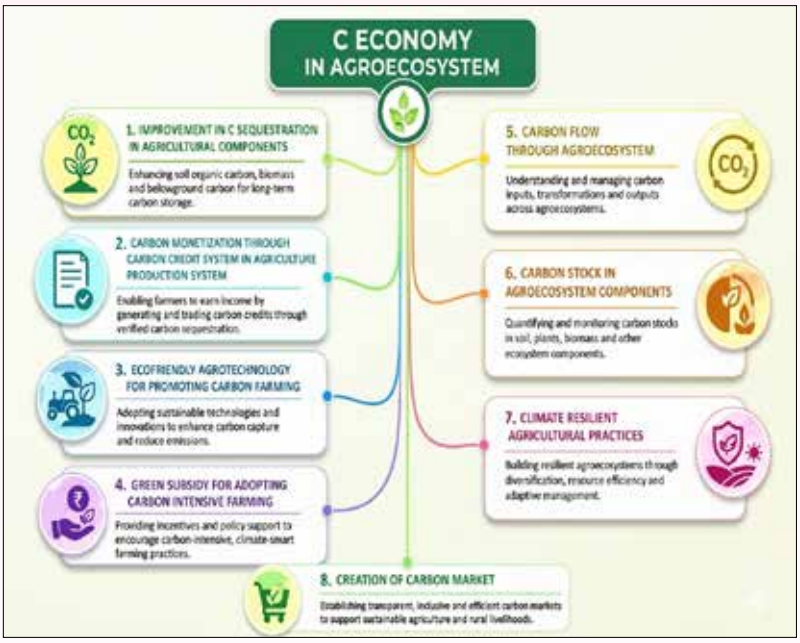
By 2050 the world population will reach about 10 billion and food security for that population is among the most serious concerns before the United Nations. Soil supplies about 98% of our food. In Punjab, Haryana, Uttar Pradesh, Madhya Pradesh, West Bengal and Tamil Nadu, soil organic carbon (SOC) has fallen by roughly 0.2–0.6% over the past 60 years. Carbon farming is one of the approaches to mitigate the impact of conventional agricultural methods in CO_2 emissions. By generating carbon credits in the farm fields, farmers can earn carbon credits, adding extra money in their income.

Keywords: Carbon monetisation, Carbon sequestration, Green credits, Soil organic carbon

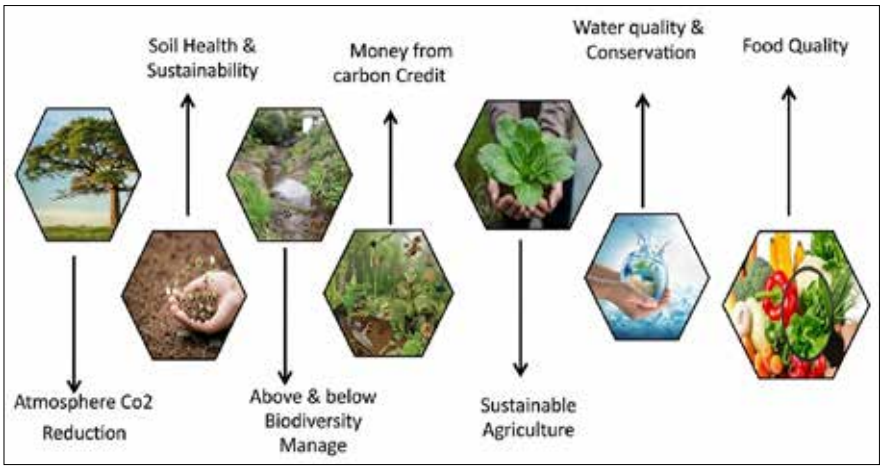
INDIA'S diverse agroecosystems have significant potential both to store and to emit carbon, and poor management accelerates the release of greenhouse gases (GHG). With a cumulative soil organic carbon (SOC) loss of 133 Pg C since the onset of agriculture, most agricultural soils worldwide have lost 25–75% of their original stock. The global technical potential of sequestration is about 2.55–4.96 Pg C under best management practices of which cropland accounts for 0.4–1.2 Pg C. Restoring the SOC pool is therefore a priority for India's food, nutrition, economic and environmental security.

Several agronomic strategies can lower carbon dioxide emissions and move agriculture towards net-negative emissions: no-till or reduced-till farming with crop diversification; cover cropping, green manuring and application of farmyard manure, compost, vermicompost and biochar; optimised fertiliser use through data analytics, residue recycling and precision farming; organic or bio-based fertiliser substitutes; and agroforestry, which captures atmospheric CO_2 while improving input and energy efficiency. Central and state governments have aligned existing natural, regenerative and organic farming schemes to encourage farmer participation in carbon credit programmes. Demand for credits is projected to increase 20 times by 2035, at current prices of US$ 40–80/t.

This article sets out viable plans for transforming agriculture from a problem into part of the solution through net carbon-negative practices, with particular attention to monetising carbon credits for Indian farmers. The Ministry of Power and the Ministry of Environment, Forest and Climate Change adopted the Green Credit Programme in June 2023, covering afforestation, efficient water management, natural and regenerative agriculture, restoration of degraded land, soil health and nutrition. Carbon and green credits remain distinct entities, and conversion between them is



Carbon economy in the agroecosystem and its components



Benefits of carbon credit in agriculture

yet to be worked out; given market uncertainty, farmers need a minimum assured price. In the long term, the programme would strengthen India's defences against climate change, support its net-zero commitment and help ICAR drive the *Viksit Bharat* 2047 mission through climate-resilient agriculture, sustainable intensification and competitive agri-food systems.

Agroecosystem and carbon dynamics

Extensive fossil fuel use, land-use change and consumptive lifestyles have raised gas GHG emissions and driven the climate crisis, making carbon neutrality by 2050 the major task ahead. Emissions from agricultural sources are estimated to have risen by 30% over the last two decades through intensified crop and animal production. Alternative systems are needed to reframe the agroecosystem not as an emitter but as a carbon sink i.e. shifting diets towards plant-based foods, optimising fertiliser and water use, and composting and vermicomposting to cut carbon and nitrogen losses.

Carbon flow, flux and stock regulate the distribution and storage of carbon across the agroecosystem and this carbon economy is central to effective monetisation. Monetisation also requires a market with genuine demand for credits, alongside eco-friendly technologies that strengthen the agricultural carbon sink.

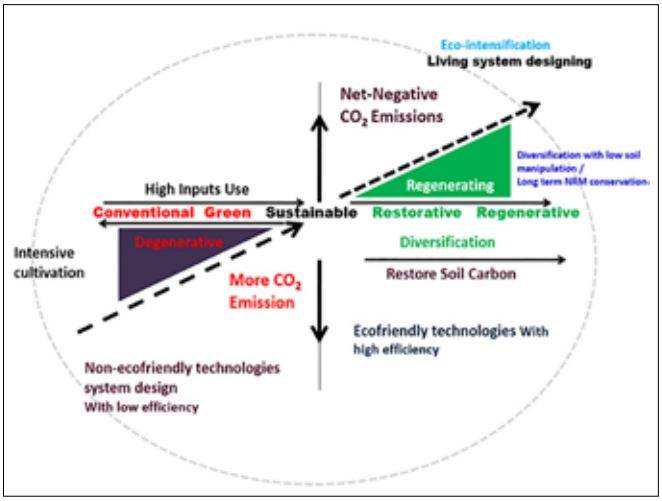
Carbon capture through agricultural practices

Diversifying agricultural practices for carbon capture is essential to the effective implementation of carbon monetisation. Such approaches offer socio-economic upliftment for India's farming community, supporting higher incomes through carbon trading, sequestration and emission reduction. Incentivising credits requires a properly developed market linking buyers and sellers, which would also strengthen global carbon offset programmes.

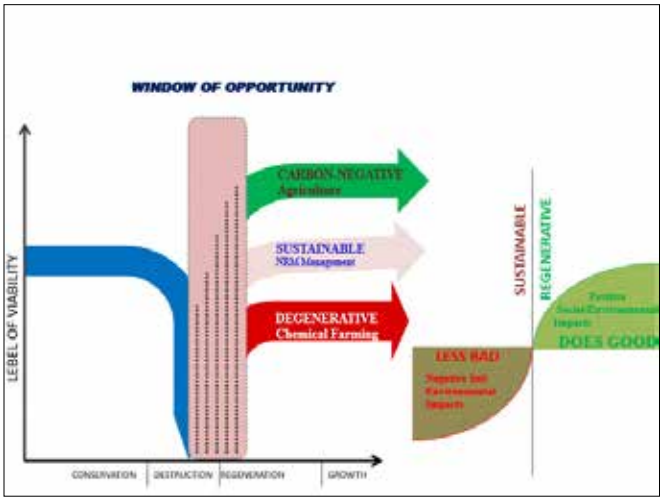
Maintaining soil biota supports carbon and nutrient cycling and hence soil health, reducing fertiliser, water and GHG intensity. Crop rotation with polyculture maintains soil biodiversity and, by promoting microbial biomass and root development, improves SOC sequestration. Perennial grasses build intensive root systems that improve soil structure and strengthen the soil as a carbon sink with fewer agrochemical inputs. Tree belts prevent erosion and moderate soil temperature, while plantations add carbon during vegetative growth.

Implementing carbon credits requires incentivising farmers to move from conventional practice to climate-smart management through voluntary credits and an offset mechanism. The core of the system is screening activities that promote sequestration and monetising them as credits, encouraging participation in climate-resilient practices that would otherwise be financially unattractive. The main difficulty is accurately assessing sequestration achieved on farm, since the quantity determines both the credits generated and the benefit reaching farmers.

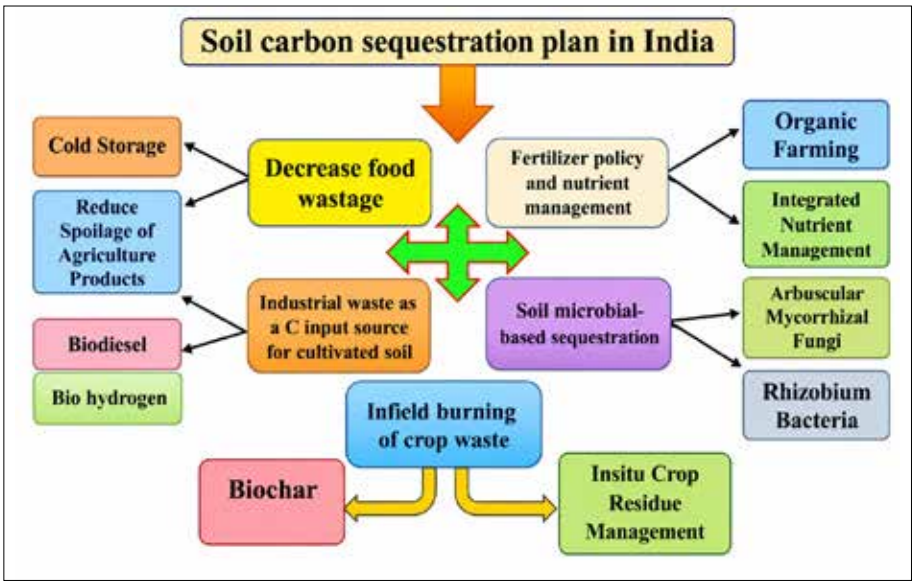
Accurate estimation and verification depend on standardised protocols such as the Soil Enrichment Protocol and the Climate Action Reserve Protocol that screen activities delivering a GHG surplus and establish



Greenhouse gas emissions reduction through regenerative approaches



Regenerating soil through net carbon-negative approaches



Soil carbon sequestration plans for net carbon-negative emissions in India

eligibility. Communities already using climate-resilient practices should be identified, and those yet to adopt them brought within the incentive mechanism.

Net carbon-negative emissions through agronomic interventions

Retaining and, where feasible, raising SOC in low-carbon soils is central to this transition. Reduced or no tillage with crop diversification, cover crops and green manuring, organic amendments including biochar, precision nutrient management and agroforestry together convert an emitting agroecosystem into a net carbon sink, and these measurable changes in soil and biomass carbon underpin any credible carbon credit.

Monetising carbon credits in India

Carbon credits were introduced under the Kyoto Protocol in 1997, and demand is now expanding rapidly worldwide. Their value varies with the market, the type of project activity and the geography of the site, so effective implementation requires participation by farmers and involvement of government. Credits are central to a green economy built on net-zero emissions and carbon monetization within the agroecosystem.

Table 1. Carbon sequestration rate in different cropping systems in India

Crops/ cropping system	Carbon sequestration (Mg C/ha/yr)
Poplar-based agroforestry system	1.96–9.24
Maize-based system	0.21–0.51
Maize–wheat–cowpea	2.09–2.22
Maize–wheat–maize–chickpea	7.48
Maize–wheat–mungbean	8.11
Pigeonpea–wheat	7.67
Soybean–corn	0.68
Soybean–sunflower	0.57
Soybean–sun hemp	0.79

Soil carbon sequestration plans for net carbon-negative emissions

Through extension infrastructure such as Krishi Vigyan Kendras, biochar has gained wide recognition among paddy farmers in Punjab. Its porous, carbon-rich, fine-grained nature and extensive surface area make it an optimal material for enhancing SOC sequestration and reducing carbon footprints, and its role in recalcitrant carbon storage may help regenerate soils.

Carbon credit estimation in croplands

Cropland encompasses arable and ploughable land, rice paddies and agroforestry systems below defined vegetation-structure thresholds, including annual and perennial crops and temporarily fallow land. Carbon stored in cropland varies with crop type, management and local soil and climatic conditions, and stock changes are influenced by rotation, tillage, drainage, residue handling and organic amendments.

Estimating carbon change in cropped areas involves calculating annual variation in carbon stocks across all pools and sources and the yearly emissions of non-CO_2 gases from them, with stock change within a stratum obtained by summing changes across all pools:

$$\Delta C_{LUi} = \Delta C_{AB} + \Delta C_{BB} + \Delta C_{DW} + \Delta C_{LI} + \Delta C_{SO} + \Delta C_{HWP}$$

Where ΔC_{LUi} = C stock changes for a stratum of a land-use category; AB = Above-ground biomass; BB = Below-ground biomass; DW = Deadwood; LI = Litter; SO = Soils; HWP = Harvested wood products.

Strategic decision-making for the economic benefit of farming communities

The Government of India launched the National Action Plan on Climate Change in 2008, comprising eight missions, including the National Mission for Enhanced Energy Efficiency, whose Perform, Achieve and Trade mechanism targets substantial CO_2 reductions. The Paris Agreement provides a further system to aid GHG mitigation and encourage sustainable development under Articles 6.4–7.7. The most significant elements of India's contributions to the UNFCCC are:

- Promoting a healthly and environmentally conscious way of life rooted in local customs and principles
- Promoting fertiliser-saving and SOC-building approaches such as organic, natural and regenerative agriculture
- Choosing an environmentally conscious pathway for economic development
- Reducing emissions by 33–35% against 2020 levels by 2030
- Creating afforestation as a new carbon store capable

of removing 2.5–3 Pg of CO_2 equivalent
- Propagating climate-smart techniques in agriculture and water resources
- Obtaining contributions from advanced countries towards minimising carbon emissions
- Running collaborative research programmes to spread climate-smart technology through India's villages

Future research towards monetising carbon credits

The European Union has a framework for agri-environmental and climate resilience under which certification schemes promote soil carbon sequestration. Farmers may engage commercial certificate providers to assess credits and raise SOC over a specified period, then sell certified credits under carbon-neutral or offset policies. Comparable mechanisms already operate in forestry under the Clean Development Mechanism and REDD+. Agriculture has always been judged by yield, productivity and net financial gain; monetising emission reduction is an emerging complement requiring nature-based, climate-smart and eco-friendly technology. Future research should focus on valuation methodology across practices and agroecosystems, repeated across regions to capture spatial and temporal variation, and should evaluate total GHG emissions alongside sequestration including transport, fertiliser use and mechanization so that the actual monetary benefit can be established.

Table 2. Carbon monetisation policies in India

Policy	Programme
Energy Conservation (Amendment) Act, 2022	Carbon markets in agriculture
Nature-based solutions in agriculture	Combating climate change
National Action Plan on Climate Change (NAPCC)	Climate-resilient agroecosystems
National Policy on Agriculture (NPA)	GHG emission reduction
Intended Nationally Determined Contributions (INDC)	Promotion of C credits
Paramparagat Krishi Vikas Yojana (PKVY)	Organic farming and soil carbon sequestration
Soil Health Card Scheme	Balanced fertiliser use and soil health
Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)	Irrigation and water-use management
National Mission on Oilseeds and Oil Palm (NMOOP) and National Food Security Mission (NFSM)	Soil carbon sequestration through cultivation
National Mission on Sustainable Agriculture (NMSA)	Climate-smart agriculture
Compensatory Afforestation Fund Management and Planning Authority (CAMPA)	Biodiversity conservation and carbon capture through afforestation

Policy framework for carbon monetization

Framing policy for carbon incentives is the biggest challenge in implementing carbon monetization, and different countries have framed such policies at different times. However, every policy carries limitations. Reliable measurement of carbon stock in agricultural systems is the first requirement. As benefits reach farming communities, cost viability improves and a sustainable carbon economy becomes possible; a competitive market and sound pricing are essential to this. Technological integration in pricing would support evaluation and benefit sharing, while reform of policy and legal frameworks would make the process practically functional. Sustained commitment depends on education and awareness, and socio-cultural context and landholding size remain decisive.

SUMMARY

Carbon monetisation is emerging as a practical route to agricultural sustainability, climate resilience and smart farming. India's soils have lost 0.2–0.6% SOC over six decades, yet adoption of best management practices by most small and marginal farmers could raise sequestration by 70–130 Tg CO_2-eq annually while lifting foodgrain production beyond 400 mt by 2050. Reduced tillage with crop diversification, cover crops and green manuring, organic amendments and biochar, precision nutrient management, residue recycling and agroforestry together move the agroecosystem from emitter to carbon sink. Within the TEEBAgriFood framework, these practices are investments in natural capital whose climate-regulation, soil and nutrient-cycling service flows can be measured and, through carbon and green credits, captured economically for the farmer. Realising that value requires standardised measurement protocols, a competitive credit market with an assured minimum price, supportive policy frameworks and sustained awareness building.

*Corresponding author email: meenars@bhu.ac.in

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Editor
INDIAN FARMING
Directorate of Knowledge Management in Agriculture
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Krishi Anusandhan Bhavan I,
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