Policy Paper 01/2025

Voluntary Carbon Market in Indian Agriculture: Status, Challenges and Way Forward

Indian Council of Agricultural Research
Central Research Institute for Dryland Agriculture
Hyderabad, Telangana

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National Innovations in Climate Resilient Agriculture
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Foreword

India is the largest producer of milk, pulses and jute and second largest producer of rice, wheat, cotton, fruits and vegetables, and is home to one of the largest agricultural sectors in the world. However, Indian agriculture continues to face several daunting challenges of increasing productivity, profitability and resilience in the backdrop of increasing population, depleting natural resource base, aggravating climate change and reducing farm income. The impacts of climate change are global, but countries like India are highly vulnerable as large population depends on agriculture. India, being a signatory and prominent member of the United Nations, has several international commitments such as Panchamrit, carbon and land degradation neutrality, biodiversity conservation, and Sustainable Development Goals (SDGs). Agriculture sector in the country accounts for about 14% of GHGs emission. However, agriculture sector can also be a significant carbon sink through adoption of sustainable land management practices, such as agroforestry, conservation agriculture and improved livestock management.

The agriculture sector plays a significant role in carbon trading because it has the potential to both emit and sequester carbon. Therefore, opportunities for carbon trading in the agriculture sector, a major contributor to the Indian economy, are significant. Carbon farming projects not only provide incentives to the farmers to adopt sustainable land-use practices, but can help to conserve natural resources and reduce GHG emissions. Carbon trading by tapping global Voluntary Carbon Market (VCM) is gaining momentum in India. Multiple local initiatives are already being implemented to generate value by selling carbon credits. Farmers can reap both direct and indirect benefits by participating in carbon markets through sequestering carbon and by reducing the GHG emissions from their lands.

The Framework for Voluntary Carbon Market in Agriculture Sector and Accreditation Protocol of Agroforestry Nurseries was launched and it would support in development of a market-based mechanism to incentivize and finance sustainable agricultural practices. Standardized methodologies are essential to quantifying real and accurate GHG benefits of a project and to generate Verified Carbon Units (VCUs). Accurate measurement and verification of carbon credits from agricultural and forestry activities are typically difficult and costly. The ICAR and the National Agricultural Research and Education System (NARES) at large can play a vital role in facilitating the implementation of VCM in agriculture. The NARES can further strengthen research to develop Tier-2 and Tier-3 emission factors for agricultural practices, develop methodologies for MRV of carbon credits generated from major agricultural practices, provide technical backstopping and demonstrate the potential of sustainable agricultural practices in generating carbon credits. I hope that this document will serve as a good reference material for different stakeholders.

Dated the 4th December, 2024
New Delhi

(Himanshu Pathak)

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Message

Carbon (C) trading in the agricultural sector refers to the buying and selling of carbon credits that are generated by practices that reduce GHG emissions or increase C sequestration on agricultural land. The concept of C trading in the agricultural sector is seen as a way to provide financial incentives for farmers to adopt environmentally friendly practices, which can help to mitigate the effects of climate change. Encouraging activities like zero-till agriculture, agro-forestry, improved water management, crop diversification and reduced use of chemical fertilizers can improve soil health and its capacity to store carbon. Adopting such carbon abatement practices can help to sequester carbon, which can contribute to the reduction of GHG emissions and help to mitigate the effects of climate change.

Carbon trading in agriculture sector has been in practice in USA, Australia, New Zealand and Canada through voluntary C markets (VCM). The Chicago Climate Exchange (CCX) was the largest C trading scheme that included agriculture and specifically no-till farming for C trading. In the absence of a global environmental policy framework to standardize the monitoring, reporting and verification (MRV) of soil carbon stock changes and/or reductions in soil-derived greenhouse gas emissions, private sector and civil society organizations have played a key role in governing the production and trade, and/or direct sale of carbon credits.

Global market for carbon trading systems has grown rapidly in the past 20 years with the largest and most liquid markets in Europe and California. Similarly, C trading by tapping global VCM markets is gaining momentum in India. Multiple local initiatives are already being implemented to generate value by selling carbon credits. By participating in VCM, farmers and landowners can earn revenue from the sale of carbon credits generated in their farm through adoption of sustainable agriculture practices.

The publication of this document titled "Voluntary Carbon Market in Indian Agriculture: Status, Challenges and Way Forward" has been brought out timely contributing to mitigate climate change by promoting and adoption of sustainable farm practices. I appreciate the authors for publishing this document and hope that this document will be useful for different stakeholders involved in VCM in Indian agriculture.

Dated the 4th December, 2024
New Delhi

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Contents

1. Background

India is home to one of the largest agricultural sectors in the world. The country is the largest producer of milk, pulses and second largest producer of rice, wheat, cotton, groundnut, sugarcane, tea, jute, eggs, fruits and vegetables in the world. India is also one of the leading producers of spices, fish, poultry, livestock, and plantation crops. However, Indian agriculture continues to face several daunting challenges of increasing productivity, profitability and resilience in the backdrop of increasing population, depleting natural resource base, aggravating climate change and falling farm income. We are now reimagining the Indian agriculture and prioritized for enhancing farmers income (200%), reducing fertilizer and water use (20%), increasing use of renewable energy (50%), reducing greenhouse gas emission intensity (45%) and rehabilitating degraded land of 26 million ha (Mha) by 2030 (Mohapatra *et al*., 2022). India, being a signatory and prominent member of the United Nations, has several international commitments such as *Panchamrit* and carbon and land degradation neutrality, biodiversity conservation, regional agricultural development and Sustainable Development Goals (SDGs).

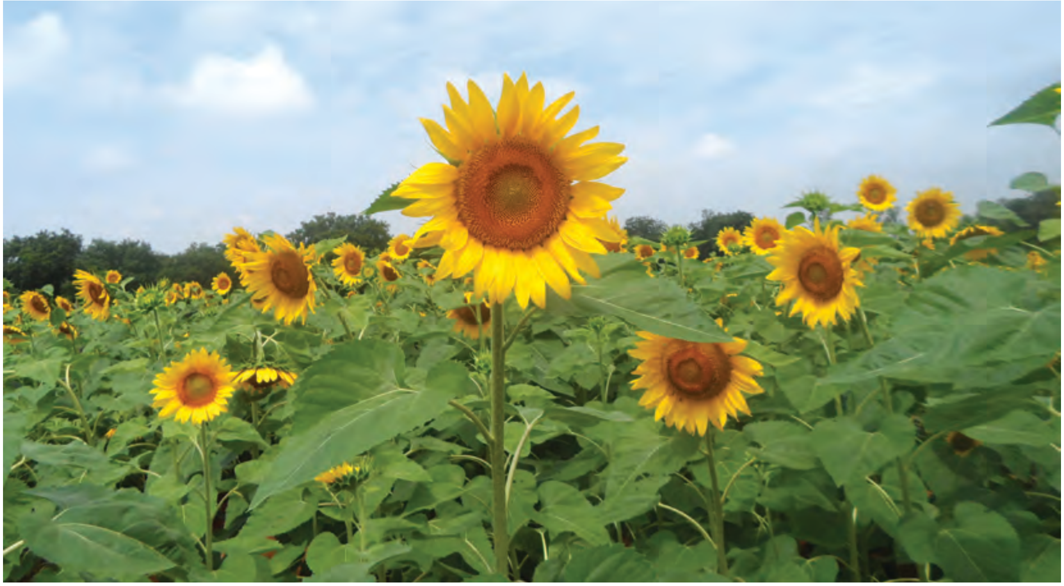
The impacts of climate change are global, but countries like India are highly vulnerable as large population depends on agriculture. As per Sixth Assessment Report of the United Nations Inter-Governmental Panel on Climate Change (IPCC), the Global surface temperature will continue to increase until at least the mid-century under all emissions scenario. The global warming of 1.5^{o}C and 2^{o}C will be exceeded during the 21st century, unless the reduction in the carbon dioxide and other greenhouse gases (GHGs) emissions occur in the coming years. As per the Food and Agriculture Organization (FAO), agriculture and related land use activities contribute more than 18% of global CO_2 emissions. In India, Agriculture sector accounts for about 14% of GHGs emission, of which the major share is due to enteric fermentation (53.0%), followed by rice cultivation (17.4%), fertilizer applied to agricultural soils (21.0%), manure management (6.5%) and field burning of agricultural residues (2.0%). However, agriculture sector can also be a significant carbon sink through the use of sustainable land management practices, such as agroforestry, conservation agriculture, improved water management and innovative livestock management.

Several private companies have started investing in carbon projects to offset their emissions since the 80s. The Kyoto protocol, introduced in 1997 and ratified in 2005, was the first of its kind aimed at addressing climate change. It introduced compliance mechanisms such as the Clean Development Mechanism (CDM) and Joint Implementation (JI), which allowed developed countries to invest in emissions reduction projects in developing nations to offset their own emissions (Ojamae, 2023). The CDM was developed to help nations meet Kyoto targets, but it also served to shift a lot of capital from the developed world to the developing world. While imperfect, CDM projects laid the groundwork for the modern Voluntary Carbon Market (VCM).

In 2015 during COP21, 196 countries signed the Paris Agreement. This replaced the Kyoto Protocol with new emission reduction targets for countries and the countries agreed to a goal of limiting the global temperature increase to 1.5^{0}C. The agreement also included an Article 6 which is the section of the agreement that aims to increase climate ambition by allowing countries to voluntarily cooperate with each other to achieve their emission reduction targets. Discussions and negotiations are ongoing since 2015 and more specifically regarding Article 6.4

which recognizes the ability for companies or individuals to engage in mitigations of greenhouse gas emissions as well and how this will be reconciled with each country's targets (known as nationally determined contributions or NDCs) (Ojamae, 2023).

The agriculture sector plays a significant role in carbon trading because it has the potential to both emit and sequester carbon. Therefore, opportunities for carbon credits in the agriculture sector, a major contributor to the Indian economy, are significant. C (carbon) trading in the agricultural sector refers to the buying and selling of carbon credits that are generated by practices that reduce GHG emissions or increase C sequestration on agricultural land. The concept of C trading in the agricultural sector is seen as a way to provide financial incentives for farmers to adopt environmentally friendly practices, which can help to mitigate the effects of climate change. Encouraging activities like zero-till agriculture, agro-forestry, improved water management, crop diversification, reduced use of chemical fertilizers, improved livestock management etc. can improve soil health and its capacity to store carbon, and reduce GHG emissions. Adopting such practices can help to sequester carbon, which can contribute to the reduction of GHG emissions and help to mitigate the effects of climate change. It is estimated that soil carbon sequestration is a cost-effective measure to mitigate climate change and can sequester around 2.6 gigaton emissions per year (Vibha and Pabreja, 2023). Carbon offset projects besides providing incentives to the farmers to adopt sustainable land-use practices, can help to conserve natural resources and reduce environmental impacts. They can also promote rural development, by creating jobs and income-generating opportunities in rural areas, and by supporting the development of small and medium-sized enterprises in the sector.



2. Global scenario of VCM

Carbon trading in agriculture sector has been in practice in USA, Australia, New Zealand and Canada through voluntary C markets (NAAS, 2014). The Chicago Climate Exchange (CCX) was the largest C trading scheme that included agriculture and specifically no-till farming for C trading. Globally, there are calls for concerted action to bring soils to the forefront of the carbon agenda for climate change mitigation and adaptation, and for scaling up of improved management of agricultural soils through carbon schemes that reward farmers for their adoption of soil health practices which promote soil carbon sequestration (SCS) (Phelan *et al*., 2024). Policymakers and practitioners alike are increasingly recognizing that it is necessary to transform agricultural SCS from an aspirational to a widely implemented, mainstream climate mitigation strategy. SCS schemes –are regarded as key to securing the provision and regulation of ecosystem services associated with the carbon cycle (e.g., GHG and climate regulation) (Lal *et al.,* 2021). Moreover, these schemes provide a framework for driving the global economy towards net zero and for taking climate action in line with the UNFCC Paris Agreement and the global '4 per 1000 Initiative: Soils for Food Security and Climate'.

In the absence of a global environmental policy framework to standardize the monitoring, reporting and verification of soil carbon stock changes and/or reductions in soil-derived greenhouse gas emissions, private sector and civil society organizations have played a key role in governing the production and trade, and/or direct sale of carbon credits (Phelan *et al*., 2024).

Global market for carbon trading systems has grown rapidly in the past 20 years with the largest and most liquid markets in Europe and California. In recent years, China has also introduced a cap-and-trade program in 2020 that will be double the size of emission reduction by Europe Emissions Trading System (ETS). As a result of EU ETS, total EU emissions have reduced by 350 million tCO_2eq (Khan, 2022). Effective environmental policies strengthening climate adaptation and mitigation across economies will further drive demand for carbon credits in agriculture.

Carbon offsets have become a business imperative for companies that realize the emerging opportunities in low carbon markets. In 2019, 1,600 companies worldwide disclosed that they currently use internal carbon pricing or that they anticipate doing so within two years. With unpredictable yields caused by climate change, farmers welcome the additional income stream as a result of the carbon market (Khan, 2022). Growing demand of the carbon market has led to new agricultural programs and pledges by agribusiness and food retailers resulting in opportunities for farmers to participate. It is, however, crucial for a program to price the carbon higher than implementation costs to ensure farmer interest.

It is predicted that like other commodities, as demand for carbon credit grows, so will the price which will eventually normalize or slow down the demand in carbon markets. Demand may also reduce as companies try to offset carbon emissions internally through new technology and may not need to buy carbon credits to reduce CO_2e from “business as usual”. The latter observation is evidenced by increasing number of carbon pledges to reduce Scope 1 and Scope 2 carbon emissions (i.e. internal direct and indirect carbon emissions) (Khan, 2022).

If carbon price continues to be lower than transaction costs and marketed to farmers as an additional incentive to co-benefits (e.g. higher crop productivity), then supply may shrink as farmers exit the carbon market. This case would only be true if the market remains voluntary and is not regulated. In US, the Growing Climate Solution Act will put forward bipartisan policies wherein participation is voluntary. Other large emitting countries like China have systems (e.g. Emissions Trading Scheme) in place but implementation remains largely uncertain in agricultural sector.

3. Initiatives in India

Carbon trading by tapping global VCM markets has started gaining momentum in India. Multiple local initiatives are already being implemented to generate value by selling carbon credits. Further initiatives could generate carbon credits worth a total of $480 billion (₹3,94,405 lakh crores) from 2030 to 2070, making it a net-positive opportunity if integrated well into domestic carbon markets. Several factors make the development of a Voluntary Carbon Market (VCM) in the Indian agricultural sector feasible.

Soil organic carbon (SOC) is a crucial component of healthy soils and sustainable agriculture. Increased organic matter in soil, improves soil aggregation which in turn improves soil aeration, soil water storage, reduces soil erosion, improves infiltration, and generally improves surface and groundwater quality. However, the soil organic carbon which is the seat of major soil processes and functions, is only <5 g/kg in rainfed soils, while the desired level is 11 g/kg. Maintaining or improving soil organic matter is a prerequisite to ensuring soil quality, productivity, and sustainability. India's voluntary commitment under the Paris Agreement includes a target to sequester 2.5 to 3 billion tonnes of CO_2e through additional forest and tree cover by 2030. A voluntary carbon market for the agriculture sector can support this target by incentivizing the adoption of agroforestry and other sustainable practices that increase tree cover and sequester carbon. By creating a demand for carbon credits generated from SOC sequestration, the voluntary carbon market can provide financial incentives for farmers to adopt climate-resilient agricultural practices that improve soil health and mitigate climate change.

The emissions from agriculture sector are dominated by the emissions from enteric fermentation from livestock. CH_4 production in ruminants depends upon quality, quantity of feed, type of animal and digestibility of pasture and feeds. Ruminants are capable of subsisting on relatively low-quality forages and crop residues. Low intake clubbed with low digestibility of these feed resources contributes substantially to limit their productivity with emission of sizable quantity of CH_4 (Sejian *et al*., 2011). Methane mitigation strategies can be broadly divided into preventive and 'end of pipe' options. Preventive measures reduce C / nitrogen inputs into the animal husbandry, generally through dietary manipulation and, although a reduction in the volume of CH_4 emitted per animal may result, this is often secondary to the primary objective of improved production efficiency. Alternatively, 'end of pipe' options reduces – or inhibit - the production of CH_4 (methanogenesis) within the animal husbandry. Any reduction strategy must be confined to the following general framework viz., development priority, product demand, infrastructure, livestock resource and local resources. The attractive emission mitigation projects must balance the needs in all of these areas, that no element creates a constraint on continued improvement in production efficiency, and the resulting CH_4 emissions reductions (NAAS, 2014).

The rice fields are a major source of emission of CH_4 and N_2O. Researchers have attempted to model and estimate GHG emissions from rice fields under various growing conditions. However, there are uncertainties in the estimation of GHGs from Indian rice fields because of diverse soil and climatic conditions and crop management practices. Adoption of appropriate rice production technologies including direct seeded rice, alternate wetting and drying provide an opportunity to reduce GHG emissions and earn carbon credits.

Indian agriculture produces about 500-550 million tons (Mt) of crop residues annually. However, a large portion of this, about 90-140 Mt annually is burnt on-farm primarily to clear the field for sowing of the succeeding crop (NAAS, 2012). In some parts of India, post-harvest agricultural wastes are burnt in the field to prepare the field for the next crop. Emissions of CO_2 during the burning of crop residues are considered neutral, as it is re-absorbed during the next growing season. However, biomass burning is one of the significant sources of atmospheric aerosols and trace gas emissions, that has a major impact on human health. In addition to aerosol particles, biomass burning owing to forest fires and crop residue burning are considered as a major source of CO_2, CO, CH_4, volatile organic compounds (VOC), nitrogen oxides and halogen compounds. Avoidance of residues burning through efficient residue recycling would also be an opportunity to earn carbon credits while reducing GHG emissions and environmental pollution.

Voluntary carbon markets also provide an opportunity for companies and individuals to take responsibility for their carbon emissions and invest in projects that have a positive impact on the environment and local communities. By purchasing carbon credits from agriculture projects in India, buyers can contribute to sustainable development goals, support rural livelihoods, and promote climate resilience. Farmers can reap both direct and indirect benefits by participating in carbon markets through sequestering carbon and by reducing the GHG emissions from their lands. However, it is necessary to implement pilot programs in selected crops/ agro-climatic regions to test the feasibility of carbon trading in agriculture before recommending large scale adoption/upscaling.

Presently most of the VCM projects in the country are registered in global registry such as verra, Gold Standard etc. which are well known among stakeholders. India has recently come up with the Energy Conservation (Amendment) Bill which paves the way for a compliance carbon market for the country. The Bill notes that the ambit of such a market could include agriculture as it contributes to significant emissions. Thus, it is envisaged that carbon credits from agriculture will also be part of this compliance market, specifically with respect to energy use in the agriculture sector. It remains to be seen which methodology will allow for that, as the current article 6.4 methodologies are still being drafted. This will provide an opportunity for the agriculture sector in India to be supported by domestic markets.

Carbon Credit Trading Scheme (CCTS)

For the compliance market, the Government on 28th June, 2023 notified Carbon Credit Trading Scheme (CCTS) as part of its process to establish a carbon credit market in India. The Energy Conservation (Amendment) Bill, 2022, which was passed by the Indian Parliament, empowers the Central Government to specify a Carbon Trading Scheme in consultation with the Bureau of Energy Efficiency (BEE). The scheme outlines that an 'Accredited Carbon Verifier' is an agency accredited by the BEE to carry out validation or verification activities in relation to the CCTS. Under the scheme the Carbon Credit Certificate is issued to the registered entity by the central government, or any authorized agency, in the CCTS. Each certificate issued represents the reduction or removal of one tonne of CO_2 equivalent (tCO_2e). Further, the Indian Carbon Market Governing Board (ICMGB) has been created to oversee the Indian Carbon Market (ICM), comprising members from various relevant central ministries and agencies. CCTS will cater to the country's carbon market for the compliance side though the notification mentions VCM will also be on boarded on CCTS platform.

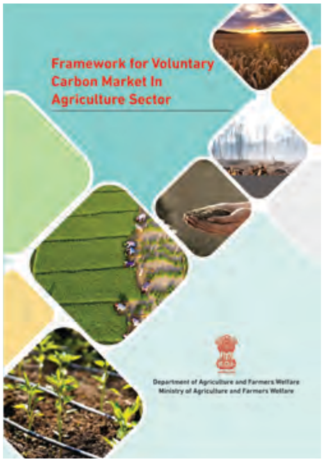
Green Credit Program (GCP)

Green Credit Initiative was launched by Hon'ble Prime Minister on the sidelines of COP 28. It is an initiative within the government's Lifestyle for Environment or LIFE movement. The Green Credit Rules, 2023, has been notified on 12th October 2023 under the Environment Protection Act 1986. Green Credits (GCs) are a form of environmental rewards that represent the positive environmental actions awarded to entities who participate in tree plantation initiatives under the Green Credit Program. The rules put in place a mechanism to encourage voluntary environmental positive actions resulting in issuance of green credits. In its initial phase, voluntary tree plantation is envisaged on degraded lands, waste lands, watershed areas etc. under the control and management of Forest departments. The generation of Green Credit under Green Credit Rules, 2023 is independent of the carbon credit under Carbon Credit Trading Scheme 2023. Governance structure of GCP includes the steering committee members from concerned ministries/departments, experts and institutions. Indian Council of Forestry Research and Education (ICFRE) is designated as GCP administrator and is responsible for implementation and management of GCP. Digital process of GCP includes dedicated web platform and

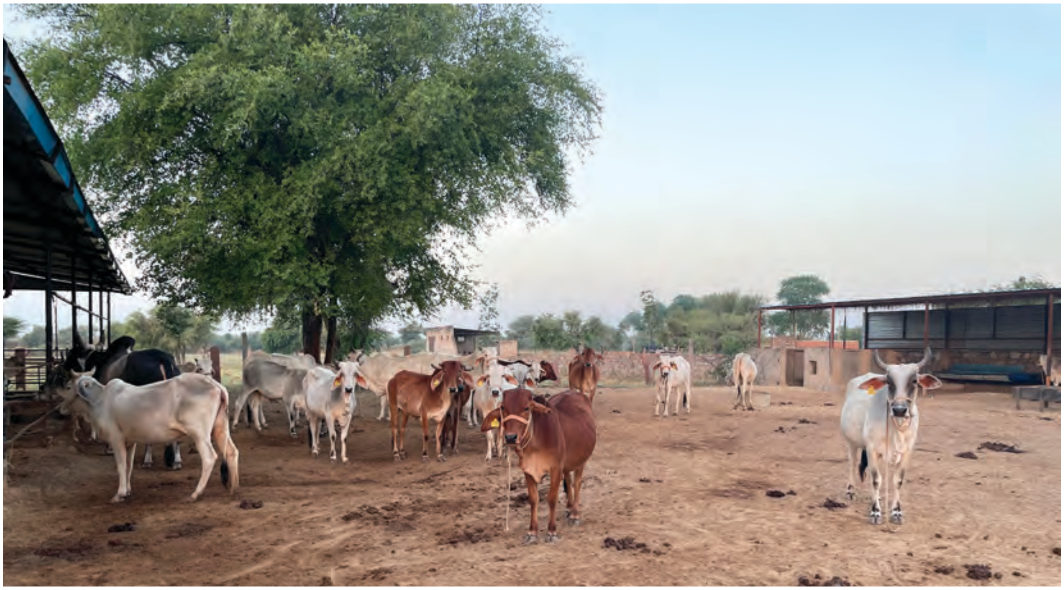
GC registry for streamlining the operations. In addition to these methodologies and guidelines, including registration, accounting and GC issuance monitoring ensures the transparency and accountability of GCP.

Activities under Green Credit Program includes tree plantation, water management, sustainable agriculture, waste management, air pollution reduction, mangrove conservation and restoration, ecomark label development and sustainable building and infrastructure.

Framework for VCM in agriculture sector



The Framework for Voluntary Carbon Market in Agriculture Sector and Accreditation Protocol of Agroforestry Nurseries was launched by Shri Arjun Munda, Union Minister of Agriculture & Farmers' Welfare and Tribal Affairs, on 16th January 2024. This document provides a framework for promoting a VCM in India for the agricultural sector bringing out the potential of sustainable agriculture practices for VCM, available methodologies, precedence in other counties and other challenges in VCM. The Framework would support in development of a market-based mechanism to incentivize and finance sustainable agricultural practices. The major objective of VCM framework is to create awareness and capacity building of the stakeholders, motivating farmers to adopt sustainable agricultural practices. By participating in voluntary carbon markets, farmers and landowners can earn revenue from the sale of carbon credits generated in their farm through adoption of sustainable agriculture practices. This revenue can be used to invest in the scaling up of sustainable practices, leading to a virtuous cycle of increasing carbon sequestration and promoting sustainable agriculture. In the long run this would contribute to sustainable development goals, support rural livelihoods, and promote resilience in agriculture.



4. Carbon Farming Projects

There are several initiatives on carbon farming in India mostly by private entities. More than 140 agriculture land management projects are listed in the Verra registry with an annual estimated emissions reduction of more than 27 million tons CO_2e. This reduction is equivalent to getting 6 million gasoline-powered passenger vehicles off the road for a year. This converts to 27 million carbon credits, the value of which might be around INR 2200 crores (@US$ 10 per carbon credit). Assuming 60% of this reaches farmers, it amounts to around INR 1300 crores (Cariappa, 2023). A few carbon farming projects at various stages of registration listed in Verra registry are given below.

The farmers are likely to be rewarded with carbon credits to continue with the environmentally sustainable methods in the long-run. Carbon credits from farmers can be purchased by those industries particularly aviation, mining or fertilizer, who are not in a position to reduce their carbon footprints because of the very nature of their business. The carbon credits conceptually seem encouraging for climate change and agriculture. However, as per the Berkely Carbon Trading Project, agricultural activities globally accounted for only 1 per cent of all carbon credits issued for emissions reduction projects in 2021.

Project name	Project proponent (s)	Location	Interventions	Regis-tration status	Annual estimated emissions reduction (tCO2e)	Duration of the project
Agricultural land management	Godrej Properties Ltd	Beed District of Maharashtra	Tree plantations, differ-ential cropping patterns, vermicomposting, etc	Regis-tered	33764	2017-2037
Horticulture plantation in Central India	AadharStambh Consultancy Services Private Limited	Madhya Pradesh	Planting, nurturing, and management of horticultural fruit bearing species including guava, orange, lemon, etc.	Under validation	115000	2021-2041
Promoting regenerative agriculture and growth through income generation	Grow Indigo Pvt Ltd.	Andhra Pradesh, Chhattisgarh, Karnataka, Odisha, and Telangana	Improved fertilizer management, cover cropping, crop rotation, reduced tillage, improved water management, crop residue management, agroforestry, etc.	Under develop-ment	5326066	2020-2040
Aaraku Valley livelihood project	Livelihoods Fund SICAV SIF France	Andhra Pradesh	Planting of trees, horticultural crops, shrubs, coffee, bamboo etc.	Regis-tered	80660	2010-2030
Incentivizing smallholder farmers to transition to low-emissions agriculture and agroforestry	Climeverse Private Limited	Central Plateau, Southern Plateau, and East Coast Plains region of India	Dry-Direct Seeded Rice (DSR), Wet-DSR, and Alternate Wetting and Drying (AWD) for paddy, zero tillage, cover cropping, crop residue management, improved fertiliser practices, green manuring, and agroforestry	Under develop-ment	463650	2022-2032
Afforestation, Refor-estation and Reveg-etation (ARR)	Crop Zone Agro Forestry Limited (CZAFL)	Andhra Pradesh, Telangana, Karnataka and Maharashtra	Planting of fruit bearing trees and commercial species.	Regis-tered	10673	2017-2036
Community based reforestation	Indian Farm Forestry Co-operative Limited	Uttar Pradesh	Promote plantation on wastelands and marginally productive lands	Regis-tered	5651	2008-2038
Mahogany Planation in India	MahoganiVish-wa Agro Pvt Ltd	Maharash-tra, Madhya Pradesh, Karna-taka, Gujarat and Telangana	Planting of Mahogany	Regis-tered	8446	2019-2049
Improved agricultur-al practices for rice cultivationin India	Kosher Climate IndiaPvt. Ltd.	Assam and WestBengal	AlternateWetting andDrying(AWD)	Registra-tion re-quested	217728	2023-2043

Project name	Project proponent (s)	Location	Interventions	Regis-tration status	Annual estimated emissions reduction (tCO2e)	Duration of the project
Enhancing livelihoods of farmers in Gujarat through agroforestry	Shri Hari BhujalVikash Mandal (SHBVM)	Gujarat	Planting of agroforestry species	Under validation	6465	2020-2050
GHG emission reduction through intermittent floodingin ricefields	Landmark Agri-Exports Private Limited	Madhya Pradesh	AWD	Under validation	58722	2020-2027
Maharashtra and Gujarat initiative for regenerative agri-culture andincome creation	GrowIndigo PrivateLtd	Maharashtra and Gujarat	Fertilizer and water man-agement, cover crops, zero- or reduced-till-age,crop rotation,agro-forestry	Under develop-ment	4861245	2020-2040
Transformational Regenerative Inte-grated Biodiverse Agriculture for Liveli-hoods (TRIBAL)	Archipel India Foundation	Telangana	Agroforestry utilizing both fruit and multi-purpose tree species, shade coffee systems, intercropping of pulses and millets, green manuring, mulching and organic composting	Under validation	219473	2023-2043

Accelerating the carbon farming/decarbonization has the potential to bring significant benefits, not only to India but also to the global community. India can strategically use this shift towards a low-emission trajectory to reshape its economy, with a strong emphasis on fostering growth in advanced industrial sectors. This strategy can be effectively leveraged, taking advantage of the availability of cost-effective clean energy export markets, particularly as the region anticipates a rapid surge in energy demand in the coming years. Carbon markets can play a very critical role in India's journey to achieve its net zero and decarbonization goals as well as in catalysing certain key sectors such as transportation, agriculture, forestry, waste management etc. While India is aggressively reducing emission intensity of many sectors, it would still rely heavily on the carbon market for offsetting residual emissions to achieve net zero. This resulting carbon market is estimated to be at least worth $50 billion. This estimate only factors seven hard-to-abate sectors comprising cement, steel, aluminum, electricity utilities, aviation, automobile (passenger cars), oil and gas (refining and extraction). Additionally, India can achieve a carbon market potential of $30 to $50 billion by 2050 (at a conservative price of $15 per carbon credit) from agriculture, land restoration activities, and reducing emissions from deforestation and forest degradation (REDD+) (Singh, 2022).

5. Methodologies for monitoring, reporting and verification of agricultural carbon crediting projects

A carbon market methodology defines a standard set of parameters, criteria, and operations required for the calculation of emission reductions or removals from a carbon project during its lifetime.

Baselines, additionality, and leakage are key concepts in carbon market methodologies:

- The **baseline scenario** represents the level of emissions or removals of greenhouse gases without the project.
- **Additionality** is the reduction in emissions or increase in removals caused by the mitigation activity or activities promoted by the project, which are additional to the baseline scenario.
- **Leakage** is defined by the emissions that occur outside project boundaries as a consequence of the implementation of the project activities, which need to be accounted for.

Standardized methodologies are essential to quantifying real and accurate GHG benefits of a project and to generate Verified Carbon Units (VCUs). In addition to the major organizations such as Verra, Plan Vivo and Gold Standard with standards and methodologies developed for voluntary carbon offset programs in agriculture, countries such as USA and Australia have also established standards for quantifying and verifying emission reductions/carbon removals from agriculture sector.

Some of the relevant methodologies currently being used in agriculture sector globally are briefly presented here.

i. The agricultural land management (ALM) methodology (Verra VM0042)

Provides procedures to estimate the GHG emission reductions and removals (CO_2, CH_4 and N_2O) resulting from the adoption of improved ALM practices. The methodology is compatible with regenerative agriculture and has a particular focus on increasing soil organic carbon (SOC) storage.

The crediting baseline and additionali-ty are determined via a project method. The baseline scenario assumes the continuation of pre-project ALM practices. Practices in the baseline scenario are determined by applying a minimum three-year historical look-back period to produce an annual schedule of activities (i.e., tillage, planting, harvest and fertilization events) for each sample unit within the project area (e.g., for each field), to be repeated over the baseline period. Baseline emissions/stock changes are then modeled. Alternatively, baseline SOC stock change may be directly measured in "baseline control sites" managed according to pre-project practices as set out in the schedule of activities. The baseline scenario is re-evaluated as required by the latest version of the VCS Standard, and revised, where necessary, to reflect current agricultural production in the region.

Additionality is demonstrated by a barrier analysis and showing that the practice change implemented under the project activity is not common practice in the project spatial boundary. A practice change constitutes any of the following:

- Adoption of a new practice
- Cessation of a pre-existing practice (e.g., stop tillage or uncontrolled irrigation);
- Adjustment to a pre-existing practice
- Some combinations of the above.

Any quantitative adjustment (e.g., decrease in fertilizer application rate) must exceed five percent of the pre-existing value to qualify as a practice change.

The methodology provides three approaches for quantifying emission reductions and removals resulting from the adoption of improved ALM practices.

Measure and model - a biogeochemical, process-based model is used to estimate GHG fluxes related to SOC stock changes, soil methanogenesis and use of nitrogen fertilizers and nitrogen fixing species. Edaphic characteristics and actual agricultural practices implemented, measured initial SOC stocks and climatic conditions in sample fields are used as model inputs. Periodic measurements of SOC stocks are required every five years at minimum.

Measure and re-measure - direct measurement is used to quantify changes in SOC stocks. This approach is relevant where models are unavailable or have not yet been validated or parameterized for a particular region, crop or practice, or where project proponents prefer to use a direct measurement approach for SOC stock change. In this approach SOC stock changes are directly measured in the baseline scenario in linked baseline control sites.

Default factors - CO_2 flux from fossil fuel combustion and N_2O and CH_4 fluxes, excluding CH_4 flux from methanogenesis, are calculated using default emission factors. GHG flux is calculated following the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories using equations contained in this methodology.

There is a considerable uncertainty in the estimates under Indian conditions, concerning both C flux rates and soil C storage capacity. Since soils have a finite capacity to store additional C, the total amount of C sequestered and the estimates there of depend on the time horizon considered. Further, rice is cultivated under different ecologies such as upland, lowland, and midland with various management practices in India. Hence, it would be difficult to accurately quantify GHG emissions either through modelling or by use of default factors under Indian conditions. It is necessary to improve the models with India-specific data parameters and also develop Tier-2 and Tier-3 emission factors.

ii. Methodology for biochar utilization in soil and non-soil applications (Verra VM0044)

This methodology quantifies the carbon dioxide removals resulting from the conversion of waste biomass into biochar at new biochar production facilities. Eligible soil and non-soil applications include crop- and grasslands and emerging products such as biochar-amended concrete and building materials. This methodology is applicable globally.

The project activity must install and operate a new (greenfield) biochar production facility(ies) where GHG benefits are credited only for the biochar that is utilized in the eligible soil and non-soil applications. The start date of the project is defined as the first instance of biochar production. The baseline scenario is the continuation of pre-project waste handling and disposal (WHD) where the waste biomass would either be left to decay or be combusted for purposes other than energy. This methodology applies the most conservative and operational approach by not considering emission reductions from changing the WHD practices at the sourcing stage. Thereby, the default net GHG emissions in the baseline scenario at the sourcing stage are considered zero (the most conservative assumption).

This methodology uses a standardized approach for the demonstration of additionality, following an activity method with the processing of waste biomass to biochar as the basis for a positive list. This approach stipulates that the total mass of waste biomass converted to biochar amounts to five percent or less of the total mass of waste biomass available worldwide. The methodology employs a comprehensive monitoring and accounting framework that captures the GHG impacts in the three important stages of a biochar value chain: sourcing, production, and application (i.e., the use of biochar in soil or non-soil applications). The methodology also includes a section to address permanence of biochar, including decay rate and reversal risk from natural and non-natural risks. Monitoring must be conducted for both the baseline and project scenarios. For emissions associated with the production stage, calculations are based on one or more monitored biochar production variables according to the parameters described (e.g., production temperature and biochar material properties), or use default values detailed in the methodology, according to the type of production technology. Eligible projects must document and prove the final application of biochar.

In Indian conditions, there is an immense scope for converting millions of tonnes of crop residues which are not used as fodder into biochar and use the same for enriching soil carbon. Many ICAR institutes and SAUs have reported work on biochar production from different bio-residues and its use as a soil amendment. The outcomes reveal that biochar application helps in improving soil health and crop productivity. Several methods have been standardized for biochar production from bio-residues such as heap method, drum method, biochar stove etc. The efficiency of each of these methods in terms of biochar recovery, GHG mitigation potential etc. vary and difficult to capture from the available methodologies.

iii. The Small-Holder Agriculture Mitigation Benefits Assessment (SHAMBA) tool (Plan Vivo)

The methodology allows deriving carbon credits from soil carbon and other agricultural sources. This increases the volume of carbon credits for which smallholder farmers are eligible and enhances their access to other climate finance. SHAMBA is user-friendly, designed specifically for smallholders in sub-Saharan Africa to calculate carbon capture. Users with little technical expertise can use SHAMBA to estimate how changes in smallholder agricultural practices will generate climate benefits in line with greenhouse gas accounting requirements. SHAMBA calculates the expected climate benefits of tree planting, agroforestry, agricultural practices that increase organic inputs to soils and reducing burning crop residues.

iv. Soil organic carbon activity module (Gold Standard)

This Soil Organic Carbon (SOC) Activity Module prescribes requirements and guidance to quantify and monitor greenhouse gas (GHG) emissions and soil organic carbon (SOC) changes resulting from change in soil management practices within agricultural systems through application of biostimulants for soil revitalisation. The eligible activities are intended to achieve net carbon sequestration in the soil carbon pool. This Activity Module is applicable for a wide area of technological levels, from low tech land use to industrialized land management, using eligible biostimulants for soil revitalisation. The mode of action of biostimulants for soil revitalisation is to act on microorganisms, for example to activate and stimulate the fungal flora. As microorganisms play a role in soil carbon sequestration, biostimulants for soil revitalisation can lead to soil carbon sequestration. This activity module shall be applied in conjunction with the Soil Organic Carbon (SOC) Framework Methodology.

The SOC methodology provides three approaches for the quantification of SOC improvements for baseline and project scenario. This accommodates the reality that not all relevant measurements and parameters may be available to all projects and SOC activities.

- Take on-site measurements to directly document baseline and project SOC stock levels
- Use peer-reviewed publications to quantify baseline and project SOC stock levels
- Apply default factors to quantify SOC changes, relating to the general methodology described in the IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2019) using tier 2 level approach whenever possible.

India's diverse soil types can be grouped into eight orders. Taxonomically, soils of India fall under Entisols (80.1 M ha), Inceptisols (95.8 M ha), Vertisols (26.3 M ha), Aridisols (14.6 M ha), Mollisols (8.0 M ha), Ultisols (0.8 M ha), Alfisols (79.7 M ha), Oxisols (0.3 M ha) and miscellaneous types (23.1 M ha) (Srininasarao *et al.*, 2015). Soil depth plays an important role in estimating SOC sequestration. Selecting appropriate sampling design, depth of soil, use of proper analytical methods and baseline selection are prerequisites for estimating accurately the soil carbon stocks. Traditional methods of wet digestion and dry combustion (DC) are extensively used for routine laboratory analysis; the latter is considered to be the "gold standard" and superior to the former for routine laboratory analysis. Recent spectroscopic techniques can measure SOC stocks in laboratory and in-situ even up to a deeper depth. Aerial spectroscopy using multispectral and/or hyperspectral sensors located on aircraft, unmanned aerial vehicles (UAVs) or satellite platforms can measure surface soil organic carbon. Although these techniques' current precision is low, the next generation hyperspectral sensor with improved signal noise ratio will further improve the accuracy of prediction. At the ecosystem level, carbon balance can be estimated directly using the eddy-covariance approach and indirectly by employing agricultural life cycle analysis (LCA). However, Estimation of SOC using current remote sensing techniques with aerial and satellite platforms is linked to problems of low accuracy and higher uncertainties. Imaging spectroscopy needs refinement with development of location-specific calibration and validation. At the landscape level, determination of SOC stock change using eddy covariance techniques require long-term studies and reduction of uncertainties associated with flux estimation and biomass sampling. Accounting soil carbon change using agricultural LCA method needs reliable SOC data in agricultural ecosystems, which can be achieved by using suitable modelling or measurement techniques. Continuous research that encourages investment in refining and developing SOC estimation techniques for furthering soil carbon and climate change science is recommended (Nayak et al., 2019).

v. Water and erosion impact assessment of sustainable agricultural land management projects (Gold Standard)

This methodology links the impacts of adopting sustainable agricultural land management (SALM) practices including agricultural biodiversity on soils and water and uses soil erosion as a proxy to quantify water benefits. The methodology compares the impact of current land use and farming practices (baseline) and the adoption of sustainable land management practices (project) on soil erosion which is then used to identify benefits of a project in terms of soil erosion reduction, increased water storage, and reduced water runoff.

Methodologically, the Universal Soil Loss Equation (USLE) and the Revised Universal Soil Loss Equation (RUSLE) is applied, which has been established over 50 years ago and became globally one of the most widely applied empirical soil erosion models. The USLE model incorporates the main components of soil loss from sheet and gully erosion, which once parameterized can predict changes in soil erosion. The USLE and RUSLE are empirical model-based approaches used to assess long-term average soil erosion risk, quantified in tonnes per hectare per. year. The model is designed to estimate long-term annual erosion rates on agricultural fields because of the considerable variation of the input parameters to varying weather conditions.

One of the most common approaches to modelling soil erosion worldwide has been the implementation of the original USLE and its revised version, the RUSLE. However, despite its widespread use, often there are discrepancies in the methods used to compute it and, in the values elicited for the five individual factors that comprise this function. Such pitfalls subsequently skew the final results obtained and often many studies also fail to adequately examine the accuracy of the enumerated soil loss amounts. Majhi et al (2021) examined these aspects with respect to the raft of USLE-based studies undertaken in India over the last few decades, reviewing a total of 100 investigations in this regard. Results reveal that almost all studies had either over- or underestimated at least one of the five factors, thereby possibly misrepresenting the actual soil loss occurring from their examined areas. Even more worryingly, most studies had failed to document their methods succinctly or in sufficient detail to ascertain their efficacies or provide viable templates for replication elsewhere. Presently, with the considerable amount of open-source data available to apply the USLE at the sub-continental, continental or global scales, many studies have been undertaken in this regard. However, USLE applications in field-settings or catchments cannot benefit much from these data due to their coarse resolution and the associated uncertainty. It is necessary to develop location-specific data on rainfall erosivity factor (R), soil erodability factor (K), slope length and steepness factor (LS), cover management factor (C) and conservation practice (P) factor.

vi. Methane emission reduction by adjusted water management practice in rice cultivation (AMS-III AU)

The methodology comprises technology/measures that result in reduced anaerobic decomposition of organic matter in rice cropping soils and thus reduced generation of CH_4. The methodology includes projects such as:

- Rice farms that change the water regime during the cultivation period from continuously to intermittent flooded conditions and/or a shortened period of flooded conditions;
- Alternate wetting and drying method and aerobic rice cultivation methods;
- Rice farms that change their rice cultivation practice from transplanted to direct seeded rice.

  This methodology is applicable under the following conditions:

- Rice cultivation in the project area is predominantly characterized by irrigated, flooded fields for an extended period of time during the growing season, i.e. farms whose water regimes can be classified as upland or rainfed and deep water are not eligible to apply this methodology. This shall be shown from a representative survey conducted in the geographical region of the proposed project or by using national data. This project area characterization shall also include information on pre-season water regime and applied organic amendments, so that all dynamic parameters are covered by the baseline study;

- The project rice fields are equipped with controlled irrigation and drainage facilities such that both during dry and wet season, appropriate dry/flooded conditions can be established on the fields; (c) The project activity does not lead to a decrease in rice yield. Likewise, it does not require the farm to switch to a cultivar that has not been grown before;
- Training and technical support during the cropping season that delivers appropriate knowledge in field preparation, irrigation, drainage and use of fertilizer to the farmer is part of the project activity and is to be documented in a verifiable manner (e.g. protocol of trainings, documentation of on-site visits). In particular the project proponent is able to ensure that the farmer by himself or through experienced assistance is able to determine the crop's supplemental N fertilization need. The applied method shall assess the fertiliser needs using for example a leaf colour chart or photo sensor or testing stripes. Alternatively, a procedure to ensure efficient fertilization considering the specific cultivation conditions in the project area backed by scientific literature or official recommendations shall be used;
- Project proponents shall assure that the introduced cultivation practice, including the specific cultivation elements, technologies and use of crop protection products, is not subject to any local regulatory restrictions;
- Except the case where the default value approach "Emission reductions using IPCC tier 1 approach or default values" is chosen for emission reductions calculations, project proponents have access to infrastructure to measure CH_4 emissions from reference fields using closed chamber method and laboratory analysis;
- Aggregated annual emission reductions of all fields included under one project activity shall be less than or equal to 60 kt CO_2 equivalent.

In India, rice is grown under highly diverse conditions with area stretching from 79° to 90°E longitude and 16° to 28° N latitude under varying agro-ecological zones. It is cultivated mostly in wet season with unpredictable rainfall distribution. It is also grown in areas, where water depth reaches 2-3 m or more. Rice culture in Kuttanad district of Kerala is grown below the sea level, while in Jammu and Kashmir, it is grown up to an altitude of 2000 m above sea level; with temperature range of 15-40°C and average annual rainfall range from 30 mm in Rajasthan to more than 2800 mm in Assam. A wide range of rainfall distribution pattern (drought, submergence, deep water) and distinct differences in soils (coastal and inland salinity, alkalinity, acidity), agro-climatic situations (high humidity) and seasons has resulted in the cultivation of thousands of varieties and therefore, one can see a standing rice crop at some parts of the country or the other in any time of the year. Rice is primarily grown under four major ecosystems broadly classified as (i) irrigated, (ii) rainfed lowland, (iii) rainfed upland and (iv) flood-prone (Pathak et al., 2020). The major factors that affect GHG emissions from rice cultivation are water management, soil organic C content, soil temperature, and fertilizer application rates. Hence, it is necessary to develop location-specific (Tier-3) emission factors for accurate measurements of GHG emissions from different rice ecosystems.

vii. Methodology for the reduction of enteric methane emissions from ruminants through the use of feed ingredients (Verra VM0041)

This methodology provides procedures to estimate enteric methane (CH_4) emission reductions generated from the suppression or inhibition of methanogenesis, achieved by the introduction of a feed ingredient into ruminant diets. This methodology considers emission reductions only from enteric fermentation. Feed ingredients applicable under this methodology reduce CH_4 emissions by directly acting on the population of methanogenic archaea in the rumen, or by suppressing CH_4 production through modification of the rumen environment, thus limiting methanogenesis.

Depending on the location in which a project is implemented and the availability of data, this methodology provides three approaches to the quantification of baseline emissions and two approaches to the quantification of project emissions. Specifically, the quantification of baseline emissions may be performed using data from either on-site direct measurements, or by applying one of two different IPCC-recommended methods to model emissions using country-specific or peer-reviewed biometric data. The quantification of project emissions may be performed using data from either on-site direct measurements, or by applying a published emission reduction factor derived by meta-analysis.

As per the 20th Livestock Census 2019, India has a total livestock population of 535.78 million showing an increase of 4.6%, over the livestock census of 2012, and is a home of about 11.5% of the total livestock population in the world. India is a mega-biodiversity in the world and maintains more than its proportionate share of livestock breeds. Approximately 6% of the total domestic animal biodiversity exists in India. As per the Food and Agricultural Organization (FAO), there are 61 cattle breeds, 19 buffalo breeds, 59 sheep breeds, 29 goat breeds, 3 pig breeds, 3 ass breeds, 6 horse breeds, 8 camel breeds and 18 poultry breeds in India (Kushwaha, 2017). Further, the composition of livestock feed varies depending on the availability of crop residues and byproducts, socioeconomic conditions of farmers and availability of common grazing land. All these factors make it more difficult for accurate measurement of GHG emission from livestock sector by relying on a single methodology or Tier-1 emission factors. This necessitates the development of appropriate methodologies suiting to Indian livestock sector.

viii. Methodology for reducing food loss and waste (Verra VM0046)

The methodology applies to project activities which reduce the amount of food discarded, and therefore increases food available for human consumption. Project activities may prevent food loss or waste at different stages of the food chain (e.g., farm level, food processing facility, retailer, food service/hospitality, residential). The methodology provides procedures to quantify the net greenhouse gas (GHG) emission reductions from keeping food (edible and/or inedible parts) in the human food chain. The methodology includes downstream emission reductions from diverting food from a food loss and waste (FLW) destination, including destinations without valorization (e.g., landfill without biogas capture) and with valorization (e.g., soil amendment production, energy recovery).

ix. Afforestation/Reforestation (A/R) GHG emissions reduction & sequestration methodology (Gold Satandard)

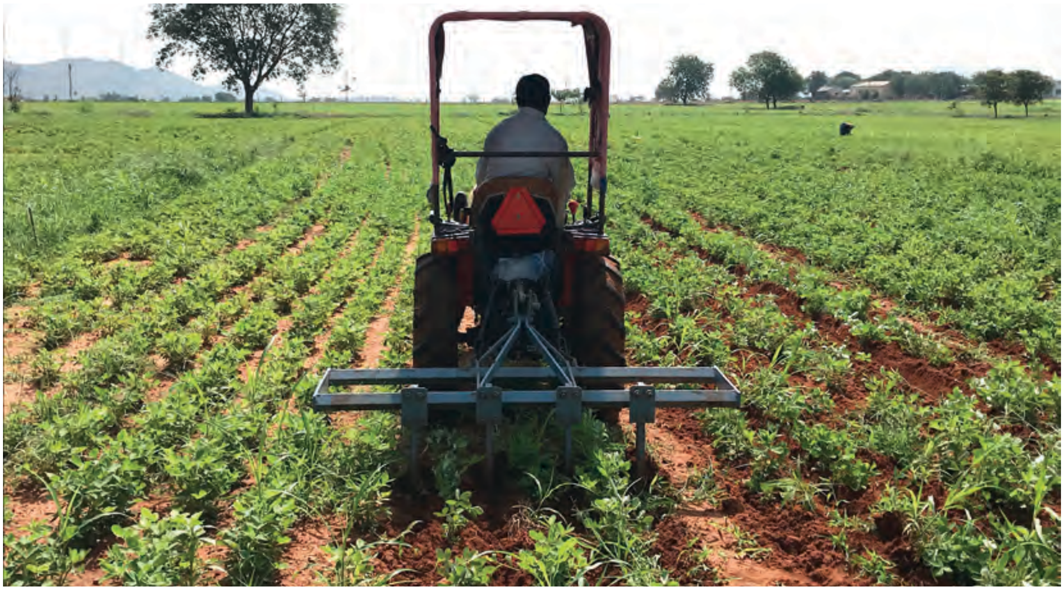
Projects that include the planting of trees on land that does not meet the definition of a forest are eligible to apply this methodology. The project area shall meet all of the requirements below for this methodology to be applicable for the calculation of CO_2-certificates from the project.

Projects can apply all silvicultural systems:

- Conservation forests (no use of timber)
- Forests with selective /limited harvesting
- Rotation forestry
- All projects can include agriculture (agroforestry) or pasture (silvopasture activities.

Project areas shall not be on wetlands. Project areas with organic soils shall not be drained or irrigated (except for irrigation for planting). Soil disturbance (through ploughing, digging of pits, stump removals, infrastructure, etc.) on organic soils shall be in less than 10% of the area that is submitted to certification (not 10% of the entire project area). The most likely scenario without the project (baseline scenario) shall be defined for the project area. This scenario shall not show any significant increase of the Baseline biomass ('tree' and 'non-tree').

The change in soil carbon stocks and sequestration potential of the agroforestry systems is determined by the type of agroforestry system implemented, land use before implementation, soil type, tree age, management practices, and rainfall. Each of the perennial tree components requires independent allometric equations for estimation of tree biomass. Under NICRA project, allometric equations have been developed for mango and guava by IIHR, Bengaluru. Similar work should be undertaken to develop allometric equations for other predominant fruit/tree species and develop appropriate methodologies for accurate assessment of carbon sequestration potential of perennial tree based systems.



6. Challenges in implementation of VCM in agriculture

Despite the recent interest of several countries in VCM and the growth in carbon trading in agriculture sector, VCMs face several challenges that need to be addressed. Major challenges in implementation of VCM in Indian agriculture are:

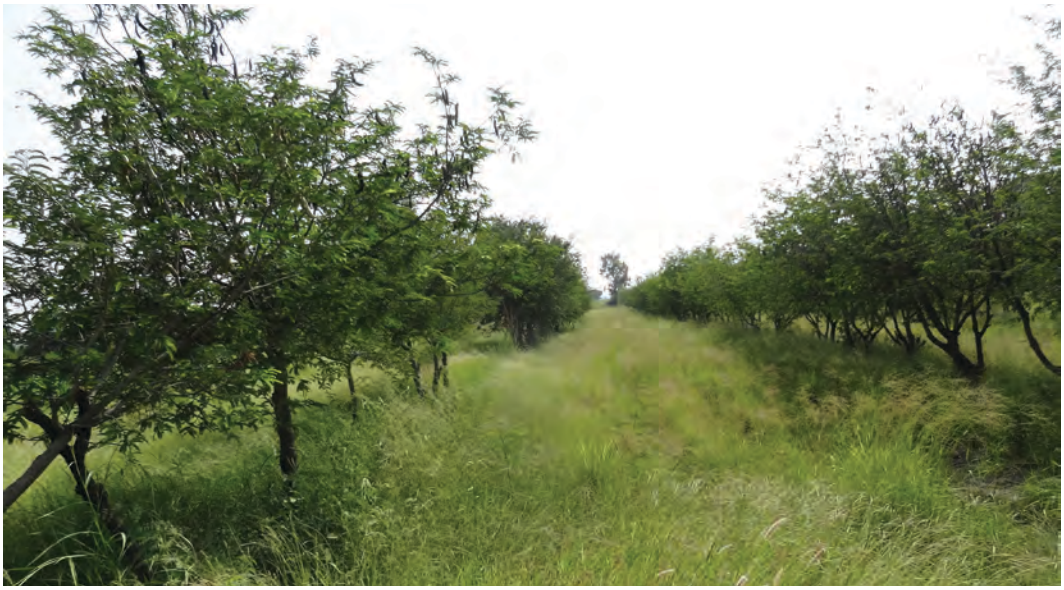
- The credibility of agricultural carbon credits will play a critical role in the determination of payments received by farmers through VCMs. Hence, the success of VCMs in agriculture sector thus far has been modest. For example, Chicago Climate Exchange was closed in 2010 after 7 years of activity due to lack of trading volume and very low carbon prices. The Kyoto Protocol was plagued with uncertainties on how to avoid double counting of emissions reductions and on how participating nations could generate and use certified emission reductions (CERs) to meet the Kyoto target. Nevertheless, voluntary carbon markets have received a strong boost from the leaders of almost 200 nations in December 2021 through the Glasgow Climate Pact.

- The upfront costs of soil sampling and project registration, the opportunity cost of changing practices, potential near-term reduction in yields and the market price of nature-based carbon credits.
- Carbon accounting issues: Difficulties associated with ensuring the additionality and permanence of carbon sequestered, avoiding leakage, and reversals of carbon stored in soils.
- Fragmentation of land holdings is one of the most persistent challenges, posing significant impediments to the resource use efficiency, productivity, and sustainability of agriculture in the country. As per the latest information available from Agriculture Census, the average size of operational holdings has decreased from 2.28 hectares in 1970-71 to 1.84 hectares in 1980-81, to 1.41 hectares in 1995-96 and to 1.08 hectares in 2015-16. These small holdings pose challenges in aggregation of land for implementation of carbon farming projects on a large scale/landscape mode.
- Accurate measurement and verification of carbon credits from agricultural and forestry activities are typically difficult and costly. Collecting soil samples and measuring soil organic carbon is currently the most accurate way to gauge the amount of carbon stored in the soil, but it is too costly and time-consuming to be widely used. Data collection from satellite mapping and remote technologies may provide an accurate calculation of soil carbon at a lower cost. However, this method is still lacking in terms of roughness, soil moisture, and vegetation cover, which would lead to less robust estimation although advances to the systems are being developed.
- Non-additionality is one of the major risks making conservation programs cost-ineffective. Agricultural conservation practices are considered to yield additional environmental gains only if they would not have been adopted without payment. Evaluating whether GHG reductions are additional can be deceptively difficult.
- Permanence is a major driver of carbon credit quality. Carbon credits generated from Land Use, Land-Use Change, and Forestry (LULUCF) face natural risks such as fire, disease, pest outbreaks, and other natural disasters. Carbon reversal from dis-adoption of conservation practices can occur when a participant of a carbon program stops using the contracted practice when the contract

expires. Further, there is a maximum amount of carbon that ecosystems can hold. Therefore, carbon sequestration only removes carbon until that maximum capacity is reached. Changes in management practices can reverse the gains in carbon sequestration (N_2O and CH_4 emission reductions are non-saturating).

- Related to the credence attribute of carbon credits, farmers may be reluctant to change production practices in order to generate carbon credits of unknown value. Similarly, in the face of an uncertain market, lending institutions may be reticent to fund producers who possibly need specific assets for the production methods applied in the generation of carbon credits (Wongpiyabovorn *et al*., 2022).
- Non-receipt of promised payment for carbon credits, and lack of awareness about the contract terms by the farmers.
- A further barrier to participation in carbon programs is the lack of transparency in the price mechanism for participating farmers. Farmers interested in carbon programs are currently being offered anywhere between \$10 and \$40 per acre to implement practices that will generate carbon credits, but prices will be subject to market fluctuations beyond pilot programs (Plastina and Wongpiyabovorn, 2021). Similarly, the cost involved in development and implementation of projects is too high which may discourage farmers to participate in such projects. For example, the administration expenses may range from 3.5 – 4.0 lakhs, auditor fee 15.0 – 20.0 lakhs and issuance fee of 0.2-0.3 USD per carbon credit.

The ICAR and the National Agricultural Research and Education System (NARES) at large can play a vital role in facilitating the implementation of VCM in agriculture. The NARES can further strengthen research to develop Tier-2 and Tier-3 emission factors for major agricultural practices, develop methodologies for measurement, reporting and verification (MRV) of carbon credits generated from major agricultural practices, provide technical backstopping and demonstrate the potential of sustainable agricultural practices in generating carbon credits. The ICAR Institutes, SAUs and KVKs may be involved in capacity building of various stakeholders particularly the farming community so that more farmers can be covered under carbon projects.



7. Implementation of VCM in agriculture – Role of ICAR

The Indian Council of Agricultural Research (ICAR) is an apex research organization of the country and has been spearheading agricultural research, education and extension activities for productivity enhancement and diversification of Indian agriculture. The ICAR and the National Agricultural Research and Education System (NARES) at large, are determined to harness the advances of science for the welfare of society. The Council is committed to transform itself into an organization engaged fully with the farmers, industry, entrepreneurs and consumers at large. As we are reimagining Indian agriculture, several long-term priorities are also set. These include increasing use of renewable energy to 50%, reducing GHG emission intensity by 45% and rehabilitating 26 million ha degraded land. India has several international commitments such as Panchamrit and carbon neutrality, land degradation neutrality, biodiversity conservation, regional agricultural development and SDGs. With 114 ICAR institutes, 74 agricultural universities and 731 KVKs spread across the country, ICAR can play a major role in facilitating the implementation of VCM in Indian agriculture. Under ICAR's National

Innovations in Climate Resilient Agriculture (NICRA) project, during the last 12 years, emphasis has been placed on the development of technologies, which can reduce the GHG emissions without compromising on yield. The potential of various technologies including alternate methods of rice cultivation, agroforestry systems etc. in reducing GHG emissions and C sequestration has been documented.

Quantification of emission reductions

Various ICAR institutes such as Indian Agricultural Research Institute (IARI), New Delhi, Indian Institute of Farming Systems Research (IIFSR), Modipuram, Indian Institute Soil Science (IISS), Bhopal, Central Arid Zone Research Institute (CAZRI), Jodhpur, ICAR Research Complex for NEH Region (ICAR-NEH), Umiam, Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad are working on various themes related to the GHG emissions. Facilities like, Eddy Covariance towers are established at IARI, New Delhi and National Rice Research Institute (NRRI), Cuttack for continuously monitoring the GHG emissions from the crop fields during growing season so as to quantify precisely the extent of GHG emissions from rice based cropping systems. Research Facilities like Rainout shelter, Carbon dioxide Temperature Gradient Chamber (CTGC), Free Air Carbon Dioxide Enrichment (FACE), Free Air Temperature Enrichment (FATE) etc. have been established to understand the impact of elevated carbon dioxide (eCO_2) and temperature and develop resilient practices that can withstand these stresses. Practices which can further reduce the GHG emissions such as improved systems of paddy cultivation, fertilizer management, improved fertilizer materials, crop diversification, etc. are explored for further reducing the GHG emissions from the paddy-based systems.

ICAR-IARI, New Delhi is conducting experiments on quantification of GHG emissions in rice-wheat and rice-rice system in different agroecological zones of the Indo-Gangetic Plains, assessing potential of microbial interventions for GHG mitigation at farmer’s fields and yield penalty for abatement of GHG emissions from crop fields. ICAR-CSSRI, Karnal is studying GHG emissions from different tillage with residue management systems under rice-wheat, rice-rice and rice-cotton cropping systems in coastal ecologies. ICAR-IIFSR, Modipuram is working on GHG emissions from different components of IFS models and from different crop establishment methods and management practices under different soil organic strata of rice-wheat cropping systems in irrigated conditions. ICAR-NRRI, Cuttack analyzed four rice production systems *viz.,* aerobic rice (AR), shallow lowland rice (SLR), deep water rice (DWR) and zero tilled rice (ZTR) using life cycle assessment of GHGs emissions and estimate carbon footprint. ICAR-RCNEH, Umiam is assessing greenhouse gas emissions from lowland rice of Meghalaya.

Animal chamber facilitates for collection of gases both in exhaled breath and appearing in the form of flatulence from the animal and help measure total methane concentration. Open circuit respiration chamber is regarded as the standard method for estimation of methane emission from ruminants, because the environment can be controlled and the reliability and stability of instruments can be measured. However, an artificial environment created by air conditioning may affect animal behavior and voluntary feed intake e.g. dry matter intake (DMI). At ICAR-NDRI, Karnal, animal chamber system is in use. Recently a prototype based on open circuit calorimetry has been built and tested. Fabrication of polycarbonate chambers are in process for energy metabolism studies and to facilitate precise monitoring of GHG emission from livestock production system. The effects of level of feeding, effect of feeds and feeding stuff, effect of chemical and physical composition, restricted versus ad libitum feeding, different feeding schedules, different additives etc. on enteric fermentation are being investigated and evaluated.

The method based on SF6 tracer is relatively a new technique and recent development on methane measurement. The SF6 method is in use at NDRI and National Dairy Development Board (NDDB) in India. The basic principle of the method is that methane emission is proportional to the emission rate of SF6 tracer gas from the rumen. For this purpose, SF6 a non-toxic, physiologically inert, stable gas is used and the gas mixes with rumen air in the same way as methane.

There are no methodologies available for the direct estimation of GHGs from the aquaculture ponds and this has stimulated the research to develop, standardize and estimate the emission of GHGs from the aquaculture ponds. A cylindrical acrylic chamber with a float can be used to trap the GHGs emanating from the surface of aquaculture pond water. The chamber is allowed to float freely in the pond and the samples are to be collected at different time intervals in tedlar bags. The GHGs fluxes collected at different time intervals in different tedlar bags are to be transported to the laboratory in ice cool box for analysis by GC system with Headspace within 72 hours. The GHGs are quantified based on the standard GHGs response in the chromatogram.

Some of the major constraints and gaps related to the agricultural sector's mitigation efforts or quantification of mitigation co-benefits (MoEFCC, 2021) include: a) There is a need to focus efforts on obtaining information about the coverage of various climate resilient practices (horticulture, micro-irrigation systems, agroforestry, direct seeded rice etc) and develop country-specific/location-specific emission factors (tier 2 and tier 3) for future reporting. These emission factors would also be used in methodologies for quantification of emissions reduction/avoidance. Developing country-specific emission factors and sequestration rates is an important activity since it allows for more accurate measurement of mitigation activities and scientifically sound estimates.

Carbon footprint analysis of major rice production systems

ICAR-NRRI, Cuttack evaluated the three contrasting rice production systems, i.e. aerobic rice (AR), shallow lowland (SLR) and zero-tilled rice (ZTR) production systems for carbon foot print (CF) analysis through life cycle assessment (LCA). The total LCA of GHGs emissions deriving from three main components, such as, cradle (from factory and transportation of input; i.e., pre-farm) to farm, on-farm and farm-gate to consumption. The emission factors were used for conversion of inventories to CO_2 equivalent / carbon-equivalent emissions. Zero tillage rice system saved 34.0 and 48.6% of net life cycle GHG-emission over AR and SLR system, respectively. On the other hand, soil organic C sequestration in rice production systems over initial ranged from 0.41- 1.9 t/ha. The highest C-sequestration was recorded under ZTR and lowest in AR System.

Emission at pre-farm (input production to farm) segment ranged from 0.26, 0.23, 0.24 t C-eq/t for AR, SLR, and ZTR, respectively. Irrespective of the rice production systems, pre-farm emission was 9.9 and 1.3% higher in AR and ZTR over SLR, respectively. The transportation of inputs and farm machinery contributed maximum percentage i.e. 37.2% in AR, 27.2% in SLR and 28.9% in ZTR in pre-farm activities. In on-farm segment, emissions were much lower than pre-farm and post-farm segments. The LCA of GHG emission from post-harvest processing was 0.57, 0.70 and 0.67 t C-eq/t for AR, ZTR and SLR system, respectively.

For the production of one ton of rice, after accounting for soil C-sequestered, carbon foot print (net LCA of GHG emissions) followed the sequence of SLR> AR>ZTR. For production of one ton of rice, the production system emitted 0.73, 0.76, and 0.87 t C-eq/t in ZTR, AR, and SLR, respectively. The total life cycle GHGs for production of one ton of rice were 0.94, 1.18 and 1.04 t C-eq/t in AR, SLR, and ZTR, respectively. The AR emitted the lowest total GHG-C-eq/t of rice production, followed by ZTR and SLR, respectively. The post-harvesting segments contributed maximum to total LCA followed by transportation of inputs and farm-machinery, then on-farm soil emissions.

Carbon sequestration potential of agroforestry systems

ICAR-CAFRI, Jhansi contributed to assessment of carbon sequestration potential of agroforestry systems existing on farmer's fields in different agroclimatic regions through simulation model (CO_2Fix model), mapping of agroforestry area using GIS and remote sensing technique. The assessment of carbon sequestration potential (CSP) has been completed in 57 districts covering 17 states (U.P., Gujarat, Bihar, West Bengal, Rajasthan, Punjab, Haryana, Himachal Pradesh, Maharashtra, Tamil Nadu, Andhra Pradesh, Karnataka, Madhya Pradesh, Orissa, Jharkhand, Chhattisgarh and Telangana). The tree species existing on farmers' fields varied from district to district in the same state. The number of trees on farmers' fields varied from 4.02 to 111.82 trees per hectare in these states.

The net carbon sequestered in agroforestry systems existing on farmer's field under different states is about 11.25 t C/ha from baseline over simulated period of 30-year. The carbon sequestration potential (CSP) of agroforestry systems in these states is 0.35 t C/ha/yr. The carbon sequestration potential was extrapolated based on data available for different districts of a particular state. The total CSP in different states varied from 0.032 to 1.849 million tons carbon and total CSP of agroforestry existing in farmer's fields in17 states is 8.13 million tons carbon. The soil organic carbon (SOC) in agroforestry systems existing on farmer's field in different states (Rajasthan, Madhya Pradesh, Maharashtra, Andhra Pradesh, Karnataka and Telangana) was higher than pure crop. The SOC in agroforestry systems under these states varied from 53.47 to 100.13 t C/ha in 0-90 cm soil depth.

Under preliminary estimate based on tree cover (10% tree cover as minimum threshold), the total area under agroforestry in the country is worked out to be 14.45 million ha (M ha), excluding fallow land. Andhra Pradesh & Telangana, Uttar Pradesh, Maharashtra, Rajasthan, Gujarat and Karnataka states have >1 M ha area under agroforestry. Land use and land cover analysis (LULC) for the selected districts in 12 agro-climatic zones was done using remote sensing (LISS-3) data. Total area under agroforestry in these regions was estimated to be 23.25 million ha of total geographical area (267.66 million ha) of these regions.

The ICAR along with SAUs and KVKs can further work in this direction to facilitate the implementation of VCM in Indian agriculture sector:

a) Technical backstopping

ICAR has been undertaking research programs on carbon farming, and quantification of GHG emissions and carbon sequestration potential of various technologies. Hence, ICAR may be involved to look into various technical aspects and if required develop technical standards/ methodologies for the implementation of VCM in the country. On 3rd January 2024, MoA&FW through an office memorandum suggested that ICAR should come out/ develop standards regarding quantification of carbon credits that can be generated from adoption of various sustainable agricultural practices. Further, it was suggested that KVKs, ICAR institutes/SAUs may demonstrate the potential of sustainable agricultural practices in generating carbon credits on their research fields and develop standards which can be adopted in VCM projects. ICAR Institutes such as CRIDA, Hyderabad; IIFSR, Modipuram; IARI, Delhi; CAFRI, Jhansi; NDRI, Karnal; IISS, Bhopal; NBSSLUP, Nagpur can serve as the centres for extending all technical support for implementing VCM in Indian agriculture and capacity building of various stakeholders. ICAR including KVKs and SAUs through their ongoing/new research programs may further quantify carbon sequestration/emission reduction potential for improved agricultural practices across different agro-climatic zones. Such standards/quantified information can serve as the point of reference for designing VCM projects and for developing project modalities which will be useful for project developers. Programs under NMSA may provide budgetary support for NARES to develop the standards for VCM projects in Agriculture.

b) Implementation of pilot projects

It is necessary to implement few pilot projects in diverse agroclimatic zones of the country to understand various dimensions of carbon farming and also to quantify the extent of carbon credits that could be earned by adopting improved agricultural practices. Few KVKs with technical backstopping from ICAR institutes may implement pilot projects in selected crops/agro-climatic regions to test the feasibility of carbon trading in agriculture. Seven ICAR institutes and few SAUs (listed below) have started implementation of pilot projects to demonstrate the benefits of adoption of climate resilient technologies with mitigation co-benefits, capacity building of stakeholders, and to generate carbon credits as a source of additional income to the farmers.

Institute	Project title	Proposed Interventions (Sustainable agricultural practices)
ICAR-Indian Institute of Soil Science, Bhopal	Soil carbon sequestration and greenhouse gas reduction through sustainable agricultural practices for central India	• Integrated nutrient management • Conservation agriculture • Balanced fertilization
ICAR – National Rice Research Institute, Cuttack	Harnessing the benefits of carbon farming through sustainable agriculture practices in paddy cultivation in Odisha	• Enhancing water use efficiency in rice-based cropping systems • Enhancing N use efficiency in rice-based cropping system
ICAR-Indian Institute of Farming Systems Research, Modipuram	Sustainable agriculture approaches for reducing carbon footprints in the upper Indo-Gangetic Plains	• Promotion of organic farming/IFS • Crop diversification with the inclusion of pulses • Conservation tillage, crop rotation, agroforestry, efficient irrigation, and integrated pest management.
ICAR-Central Research Institute for Dryland Agriculture, Hyderabad	Promotion of dryland horticulture for higher carbon credits and income generation	• Promotion of dryland fruit-based agroforestry systems
ICAR - Central Coastal Agricultural Research Institute, Goa	Potential of plantation-based systems in generating carbon credit through biochar production in the west coast region of India	• The conversion of waste biomass into biochar at new biochar production facilities
ICAR-Indian Institute of Water Management, Bhubaneswar	Reducing GHG emissions in irrigated crops through micro-irrigation in different agroecological regions of India	• Water and fertilizer savings under micro-irrigation in different agroecological regions of India.

Institute	Project title	Proposed Interventions (Sustainable agricultural practices)
Tamil Nadu Agricultural University, Coimbatore	Transformative solutions towards significant reduction of GHG emission under the rice ecosystem	• Adopting CSA practices- a) Direct seeded rice, and/or b) Alternate wetting and drying irrigation practices.
ICAR-Central Institute for Cotton Research, Nagpur	Reducing GHG emissions from cotton cultivation	• Minimize soil tillage on cotton cropland • Minimize the use of synthetic fertilizers in general and nitrogen fertilizers in particular because these are an important source of N2O emissions • Minimize the burning of cotton crop residues where still applied and recycle these for soil fertility management
Assam Agriculture University, Jorhat	Participatory sustainable, regenerative agriculture and agroforestry system for voluntary carbon market	• To enhance carbon dioxide sequestration through sustainable, regenerative agriculture and agroforestry in homesteads and small tea gardens
Punjab Agricultural University, Ludhiana	Carbon crediting in the rice-wheat system through crop residue management: a farmer participatory approach	• To provide straw management strategies (in-situ or ex-situ) other than burning and develop a model farm for measuring the GHG emissions reduction (ER) and net carbon storage • To maximize improvement in soil quality and crop productivity under the rice-wheat system • To establish consistent, transparent, and robust criteria for generating carbon credits by combining direct measurement of C build-up and model estimates
Gujarat Natural Farming Science University, Anand	Evaluation of soil organic carbon sequestration under natural farming condition: Enhancing soil quality and capitalizing on carbon markets	• Implement natural farming practices to study the effect of farming practices on soil organic carbon sequestration • To study various effects of natural farming practices on soil health • To study the effect of natural farming practices on soil microbial biodiversity

C) Methodologies of measurement

A carbon market methodology defines a standard set of parameters, criteria, and operations required for the calculation of emission reductions or removals from a carbon project during its lifetime. Methodologies are essential to quantifying real and accurate GHG benefits of a project and to generate Verified Carbon Units

(VCUs). In addition to the major organizations such as Verra, Plan Vivo and Gold Standard with standards and methodologies developed for voluntary carbon offset programs in agriculture, countries such as USA and Australia have also established standards for quantifying and verifying emission reductions/carbon removals from agriculture sector.

In India, the average size of operational holdings has decreased from 2.28 hectares in 1970-71 to 1.08 hectares in 2015-16. These small holdings pose challenges in aggregation of land for implementation of carbon farming projects on a large scale/landscape mode. Unlike in developed countries, in India with few exceptions, farmers generally grow several crops (as mixed or intercropping systems) in small patches within each village making it difficult for implementation of activities related to carbon farming on a contiguous land. Similarly, Indian farmers generally practice mixed farming in which crop and animal production constitute about 70-90% of the agricultural enterprises. These factors make it difficult to demonstrate and justify as to how the project activity(s) meets the applicability conditions of the methodologies available with international registries. Similarly, most of the methodologies use default emission factors (Tier 1 methods) as one of the approaches for quantification of emission reductions and removals. Further, appropriate methodologies are not available for quantification of estimated GHG emission reductions and removals from some of the systems/activities such as integrated farming systems, backyard poultry, small ruminants, aquaculture etc.

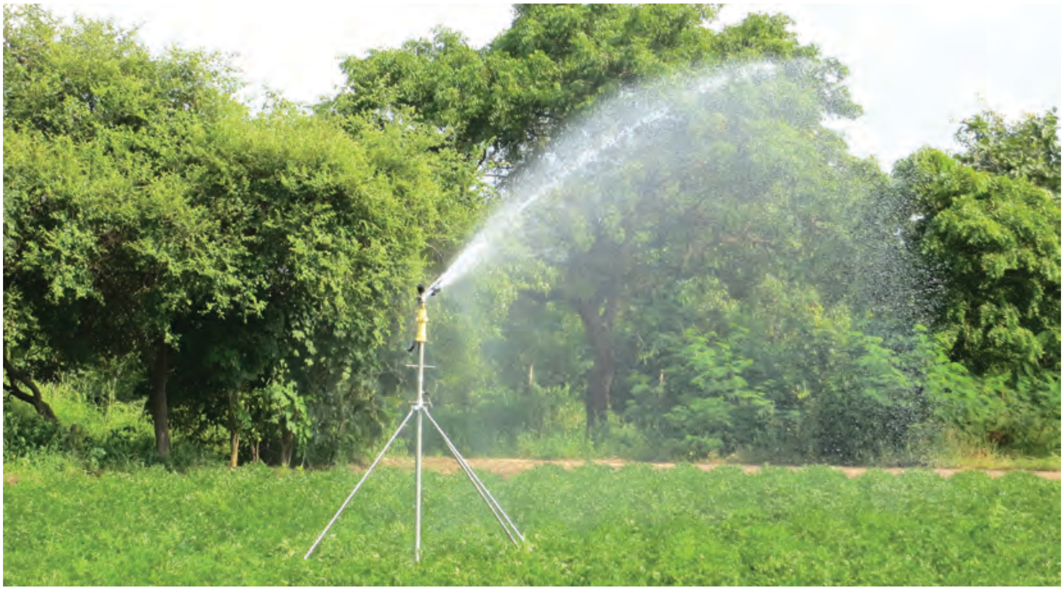
Hence, it is necessary to develop appropriate methodologies suiting to Indian conditions for quantifying and verifying emission reductions/carbon removals from agriculture sector. While developing the methodologies, emphasis should be to make them simpler, less cumbersome, use location-specific quantification approaches using Tier 2 and Tier 3 factors, where available. It is essential to develop Tier 2 and Tier 3 factors particularly for rice based cropping systems, livestock and agroforestry systems. Further, the methodologies for quantification of GHG emission reductions and removals should be robust but simple and cost effective. The following ICAR institutes and other organizations are developing VCM methodologies for important agricultural management practices/systems.

Institute	Methodology/tool to be developed
ICAR-Indian Institute of Soil Science, Bhopal	Tool for assessing changes in soil organic carbon
ICAR – National Rice Research Institute, Cuttack	Methodology for sustainable intensification of rice fallow for reducing GHG emission, enhancing N fixation and C sequestration
ICAR-Indian Institute of Farming Systems Research, Modipuram	GHG emission reduction through integrated farming systems (IFS)
ICAR-Central Research Institute for Dryland Agriculture, Hyderabad	Methodology for quantification of carbon removals/sequestration from agroforestry systems
ICAR-Indian Institute of Water Management, Bhubaneswar	Methodology for micro-irrigation and/or fertigation
ICAR-Central Institute for Cotton Research, Nagpur	Methodology for reduced GHG emission from cotton cultivation
Tamil Nadu Agricultural University, Coimbatore	Tool for paddy watch-digital measurement, reporting and verification (MRV) systems for water efficiency in rice field
International Rice Research Institute (IRRI) South Asia Regional Centre, Varanasi	Contextualization rice methodology and developing digital MRV for Indian rice systems
International Crops Research Institute for Semi-Arid Tropics (ICRISAT), Hyderabad	Digital platform for MRV of verified carbon standards to incentivize regenerative agriculture practices in rice system
Gujarat Natural Farming Science University, Anand	Natural farming

Although these methodologies are aimed to cater to the needs of domestic carbon market, efforts may be made to register some of the methodologies with international organizations.

d) Capacity building of stakeholders

One of the mandates of ICAR is technology assessment, demonstration and capacity development through a network of 11 Agricultural Technology Application Research Institutes (ATARIs) and 731 Krishi Vigyan Kendras (KVKs). To upgrade the knowledge and skill of farmers, farm-women and rural youth, the KVKs organized 60672 various types of training programmes benefiting 16.82 lakh farmers including farm women and rural youth. Similarly, knowledge and skill of 1.16 lakh extension personnel were upgraded through 3948 training programmes. Enhancing awareness and understanding of carbon markets among agricultural stakeholders is important to promote carbon market. Specific training programs or knowledge-sharing platforms can facilitate this process. The ICAR Institutes, SAUs and KVKs have a greater role to play in capacity building of various stakeholders particularly the farming community so that more farmers can be covered under carbon farming projects.



8. Summary

India is home to one of the largest agricultural sectors in the world. The impacts of climate change are global, but countries like India are highly vulnerable as large population depends on agriculture. The agriculture sector plays a significant role in carbon trading because it has the potential to both emit and sequester carbon. Therefore, opportunities for carbon credits in the agriculture sector, a major contributor to the Indian economy, are significant. The carbon economy in Indian agriculture can be improved by reducing the total GHG emissions and by increasing the carbon sink. There are several technological options to reduce emission of GHGs from Indian agriculture. Carbon offset projects besides providing incentives to the farmers to adopt sustainable land-use practices, can help to conserve natural resources and reduce environmental impacts. The Framework for the VCM in the agriculture sector in India would support in development of a market-based mechanism to incentivize and finance sustainable agricultural practices. Despite the recent interest of several countries in VCM and the growth carbon trading in agriculture sector, VCMs face several challenges that need to be addressed. The ICAR and the National Agricultural Research and Education System (NARES) at large can play a vital role in facilitating the implementation of

VCM in agriculture. The NARES can further strengthen research to develop Tier-2 and Tier-3 emission factors for major agricultural practices, develop methodologies for measurement, reporting and verification (MRV) of carbon credits generated from major agricultural practices, provide technical backstopping and demonstrate the potential of sustainable agricultural practices in generating carbon credits. The NARES has a greater role to play in capacity building of various stakeholders particularly the farming community so that more farmers can be covered under carbon projects.

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Abbreviations

AR	: Aerobic Rice
ARR	: Afforestation, Reforestation, and Revegetation
A/R	: Afforestation/Reforestation
AWD	: Alternate Wetting and Drying
CCTS	: Carbon Credit Trading Scheme
CO_2	: Carbon Dioxide
CTGC	: Carbon dioxide Temperature Gradient Chamber
CF	: Carbon Footprint
CH_4	: Methane
CICR	: Central Institute for Cotton Research
CRIDA	: Central Research Institute for Dryland Agriculture
CSSRI	: Central Soil Salinity Research Institute
CDM	: Clean Development Mechanism
CSA	: Climate Smart Agriculture
DWR	: Deep Water Rice
ETS	: Emissions Trading System
FAO	: Food and Agriculture Organization
FACE	: Free Air Carbon Dioxide Enrichment
FATE	: Free Air Temperature Enrichment
GCP	: Green Credit Program
GHG	: Greenhouse Gas
IARI	: Indian Agricultural Research Institute
ICM	: Indian Carbon Market
ICAR	: Indian Council of Agricultural Research
ICFRE	: Indian Council of Forestry Research and Education
IIFSR	: Indian Institute of Farming Systems Research
IIHR	: Indian Institute of Horticultural Research
IISS	: Indian Institute of Soil Science
IIWM	: Indian Institute of Water Management
IPCC	: Intergovernmental Panel on Climate Change
ICRISAT	: International Crops Research Institute for the Semi-Arid Tropics
IRRI	: International Rice Research Institute
KVK	: Krishi Vigyan Kendra

LULC	: Land Use and Land Cover
LCA	: Life Cycle Assessment
MRV	: Measurement, Reporting and Verification
M ha	: Million Hectares
MT	: Million Tonnes
MoEFCC	: Ministry of Environment, Forest and Climate Change
NARES	: National Agricultural Research and Education System
NBSSLUP	: National Bureau of Soil Survey and Land Use Planning
NDDB	: National Dairy Development Board
NDRI	: National Dairy Research Institute
NICRA	: National Innovations in Climate Resilient Agriculture
NMSA	: National Mission for Sustainable Agriculture
NRRI	: National Rice Research Institute
NDC	: Nationally Determined Contributions
N_2O	: Nitrous Oxide
PAU	: Punjab Agricultural University
REDD+	: Reducing Emissions from Deforestation and Forest Degradation
RCNEH	: Research Complex for North Eastern Hill Region
RUSLE	: Revised Universal Soil Loss Equation
SLR	: Shallow Lowland Rice
SHAMBA	: Small-Holder Agriculture Mitigation Benefits Assessment
SCS	: Soil Carbon Sequestration
SOC	: Soil Organic Carbon
SAU	: State Agricultural Universities
SALM	: Sustainable Agricultural Land Management
SDGs	: Sustainable Development Goals
TNAU	: Tamil Nadu Agricultural University
UNFCC	: United Nations Framework Convention on Climate Change
USLE	: Universal Soil Loss Equation
VCU	: Verified Carbon Unit
VOC	: Volatile Organic Compounds
VCM	: Voluntary Carbon Market
ZTR	: Zero-Till Rice

NOTES

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ICAR - Central Research Institute for Dryland Agriculture
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