Examining the Burgeoning Voluntary Agricultural Carbon Credit Market in India: Incentives, Challenges, and Efficacy for Smallholder Farmers

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Abstract

This study examines the implications of the developing Voluntary agricultural Carbon credit Market (VCM) on smallholder farmers in India and on carbon farming efforts globally. Agricultural carbon crediting, also known as carbon farming, is a key piece of carbon pricing theory. Carbon farming creates monetary incentives for farmers to introduce sustainable management practices that increase Soil Organic Carbon (SOC) — such as improved residue management. VCMs allow farmers to supplement their revenue while credit buyers can offset their unabated emissions.

However, there are many challenges to the implementation of carbon farming systems. The largest challenge is that evaluating SOC content in a field is very time consuming and expensive. The high starting cost of soil testing handicaps smallholder farmers in India, with very small plots. Some other challenges include lack of transparency of credit prices, inadequate regulations, all of which lead to leakages in the market, with the amount of carbon sequestration falling short of the social optimum (Aldy 2011).

Through a cost-benefit analysis, this study will attempt to determine the potential economic outcomes for an exemplar smallholder farmer entering the carbon farming market. The study utilizes soil samples and crop yield data from intervention plots in Odisha, India in addition to current data on carbon credit prices offered to farmers, in order to calculate change over time in farm income. This study will also consider a positive economic analysis of an increase in carbon credit exports from India due to massive enrollment in voluntary credit markets for agriculture.

Because the carbon farming market in India is booming, and because India is the world's second largest agricultural producer with the largest number of traditional carbon credits exported in the last few years (Sahil Ali 2022), it is incredibly important to understand how carbon farming will affect both farm businesses and the national economy. There is also very little literature on carbon farming specific to small plots in India, which makes this a critical area of research for the future.

2. Background

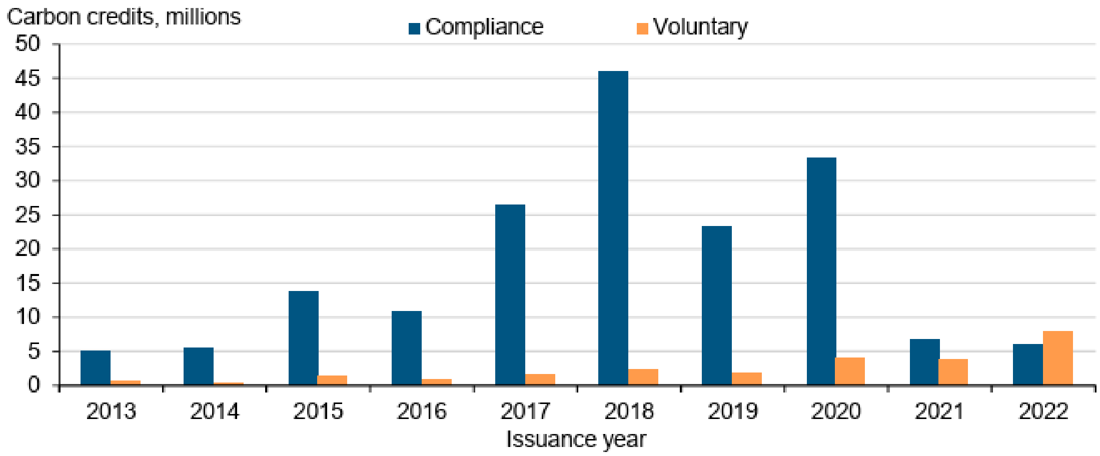
2.1 Voluntary Carbon Markets (VCM)

Global participation in carbon markets began with the 1997 Kyoto protocol. By that time, the idea of crediting had already been explored in the U.S. with emissions offsetting and SO2 credits for the Clean Air Act, and the Montreal Protocol's tradable permits for CFCs (Chandrasekhar 2023). It was through the Kyoto Protocol, however, that three international market-based methods were introduced. These were the Clean Development Mechanism (CDM)— through which countries with emissions commitments could buy credits from approved emissions reduction projects in developing countries, Joint Implementation (JI) — through which committed countries could buy from other committed countries, and finally, Emission Trading (ETS)— which allowed all countries to sell emission reductions as a commodity. After 2012, with the official end of the Kyoto Protocol, there are a couple market-based compliance methods still in place, such as the European Union ETS, the California Cap and Trade program, and the Chinese national ETS. In addition, the international CDM projects created through Kyoto are sustained through the Paris Agreement. However all of these compliance methods have been joined by a burgeoning and much more unregulated voluntary carbon market.

Voluntary Carbon Markets (VCMs) complement compliance markets, allowing more buy-in from different sectors not typically covered by government regulations, and allowing smaller projects— like smallholder farmers to effectively enter into carbon credit contracts. Advertising carbon neutrality increases businesses' profit margin by attracting environmentally conscious consumers and investors and/or justifying higher pricing of goods and services. This incentivizes businesses to trade in VCMs.

Though compliance markets still regulate a majority of international carbon credits, The VCM side has been growing rapidly since 2020, with some countries like the U.S. circulating more credits from VCMs than from compliance markets in the last two years (USDA).

Agriculture, forestry, and land use carbon credits by issuance year: Compliance and voluntary markets in the United States, 2013–2022



Source: So, Haya, & Elias, 2023.

2.2 Carbon Farming

Along with the boom in VCM, carbon farming and agricultural carbon markets have been on the rise as well. In the last ten years, there has been a steady increase in the number of carbon farming-focused firms and markets available for farmers to buy into (Chandrasekhar 2023). This is largely because Agriculture is a net source of carbon and contributes to reducing the carbon stock in soil in addition to being a very large potential carbon sink. Nature-based Carbon Dioxide Removal is often more efficient and easier to implement than technical removal methods, so 'carbon sequestration' efforts are largely pushed towards farmers and agroforestry projects. In purchasing a carbon credit, the business pays cash to an appropriately regulated exchange for a certificate. The certificate guarantees that an appropriately regulated monitoring agency will contract with a farmer to sequester carbon. The monitoring agency and the farmer share the cash to cover the costs of running the exchange, monitoring and sequestering, and generate profits for the monitoring agency and the farmer.

The way that voluntary carbon farming has been advertised to farmers around the world is that it is an easy way to supplement farm income, and allows farmers to invest more time and money into implementing more sustainable management practices on their land (Popkin 2023). The practices that are recommended to these farmers to sequester carbon— such as improved residue management and cover cropping— also hold many co-benefits for the productivity and longevity of the farm. In fact, studies focused on staple crops such as wheat and rice show that increasing soil carbon by one ton can double yield in kg/ha (Arelleno Vazquez 2024).

2.3 India and Carbon Farming

India’s involvement in the global carbon credit market began with ratification of the Kyoto Protocol in 2002. Currently, India holds the second highest number of existing CDM projects in the world, most of which come from the renewable energy sector (Kaul 2023). Because India is the second largest agricultural economy in the world, it is extremely important for the future of the global voluntary agricultural carbon credit market to understand how India’s farmers would be affected by an influx of agricultural carbon credits.

Currently, there are no set targets for the agricultural market in India’s compliance market, meaning that Indian farmers who are interested in entering into carbon farming contracts have a few voluntary markets to choose from. In January of 2024, India’s Ministry of Agriculture and Farmers Welfare launched a VCM framework for the country’s agriculture sector. One of the key players in the carbon farming market in India is Grow Indigo, which is a joint venture with U.S. based Indigo Ag and Indian Mahyco Grow (Reuters 2023).

Grow Indigo has also rolled out a specific carbon credit program that allows multiple farmers to enter into a contract together, or even a Gram Panchayat (village council). This is especially valuable because, with the small size of most farmers’ landholdings, many private crediting markets do not find it feasible to enter into a contract. Grow Indigo also supplies farmers with technical information on sustainable practices and technology through the contract.

Figure 1: Mini rotavators for rental or sale around 3 ft in width (left), Farmers manually transplant rice patty (right)

This study will focus only on residue management as a sustainable method, which essentially means re-incorporating harvested rice straw back into the soil using a rotavator, to recapture lost organic matter. A rotavator is essentially a tilling machine that breaks up soil while also mixing in organic matter. The disc arm can vary in width from three to nine feet, depending on the size of the field. In the case of smallholder farmers in India, the largest size would be a three foot arm, and many farmers would use a mini rotavator for smaller plots.

2.4 Concerns of Efficacy and Equity in Carbon Farming

In the last approximately thirty years since the Kyoto Protocol, there has been a wide variety of carbon crediting systems on the market. But—especially with the recent boom in VCMs —many argue that these have fallen short of the original promise: to internalize the externality of carbon emissions. Discourse around carbon credits as a whole in the last couple of years holds that the credits are ineffectual, with many pitfalls and leakages due to unreliable certification and/or carbon sequestration (Trouwloon, 2023).

With VCMs, there exist many different certification approaches which often lead to a lack of transparency and increased potential for greenwashing (Gunther, 2024). In order to standardize eligibility of a VCM project as 'carbon removal', the European Commission's 2022 proposal for carbon removal attempted to allow all carbon pool related projects to be registered, promoting the Land Use related activities, while still ensuring long-term sequestration. However, this regulation still only covers a small portion of carbon farming credits that will likely enter the market in the near future.

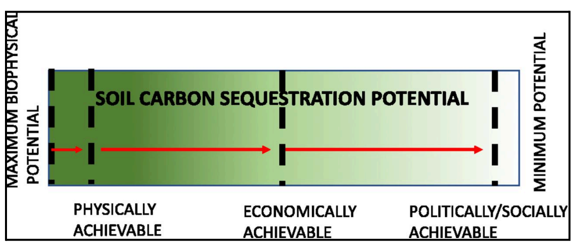


Figure 2: The amount of sequestration that is achievable is dependent on many factors (Tuomas, 2024)

The act of determining carbon sequestration is also very complicated, where many projects fail to take into account soil sequestration potential when beginning carbon farming projects. Different soils have different carbon saturation limits that are often overestimated in an attempt to promote carbon sequestration methods. There is also a gap in many farm soils between carbon sequestration potential and actual sequestration achieved in practice— due to microbial processing of carbon limited by poor soil structure and moisture stress, as well as carbon stabilization limited by waterlogging and sulfur deficiency (Tuomas, 2024).

Other concerns of carbon farming projects include the disadoption of sustainable practices by farmers due to a lack of economic benefits and lack of information. When a farmer disadopts, they may quickly erase accumulated benefits from years of regenerative practices. One tillage pass can release back to the atmosphere all the carbon sequestered over multiple years of no-till practices (Wade, 2017).

In terms of equitable access to the credit market, there are serious barriers for smallholder farmers to enter the carbon farming market. The difficulty and high starting cost of soil testing to verify the amount of Soil Organic Carbon sequestered mean that smallholder farmers may not be able to afford entering into a carbon credit contract from the beginning. There is also potential for farmers, especially in the global south, to have asymmetric information about the market price of credits (Reddy 2024).

A study of farmers in Haryana and Madhya Pradesh has determined that there is also exclusion of marginalized communities (Scheduled Castes and Scheduled Tribes) in carbon credit systems, in addition to poor communication and training from project developers (Cariappa, 2024). It is essential that any carbon credit company consider these information equity issues in order to establish a just payment for ecosystem services plan.

2.5 Objectives and Motivations

This study aims to examine the implications of the developing voluntary agricultural carbon credit market in India on smallholder farmers. The research will include details of carbon credit pricing and the costs and income sources of smallholder farmers in Odisha, India. In addition to this economic analysis, I will discuss the social factors affecting smallholder farmers, and the geo-political implications of India's participation in global carbon farming markets.

3. Methodology

3.1 Data Collection

The data for this research comes from a pilot randomized control study (RCT) conducted by Aprajit Mahajan's Lab, where group meetings with farmers from multiple villages were set up and interested farmers volunteered to participate. Initially, 100 farmers volunteered from the Jajpur district in Odisha, from sixteen different villages, however due to the difficulty and cost of conducting soil carbon tests on so many fields, 30 farmers were chosen, of which 15 were randomly selected as the treatment group.

The farmers in the treatment group were given instructions on the sustainable management practice, crop residue management, specifically the method of incorporating crop residues such as straw back into the soil. This practice has been shown to increase soil health and soil organic carbon levels, in addition to other co-benefits such as water infiltration.

Soil testing was conducted on each of the thirty fields once before the first growing season in April 2022, and once after the second growing season, in fall of 2023. Soil Samples were taken from five places in each field at both 0-15 cm and 15-30 cm. Soil samples were processed over multiple days and reduced to 500g each for SOC evaluation. SOC evaluation was conducted through the Walkley-Black method, utilizing ferrous Ammonium Sulfate and diphenylamine indicators.

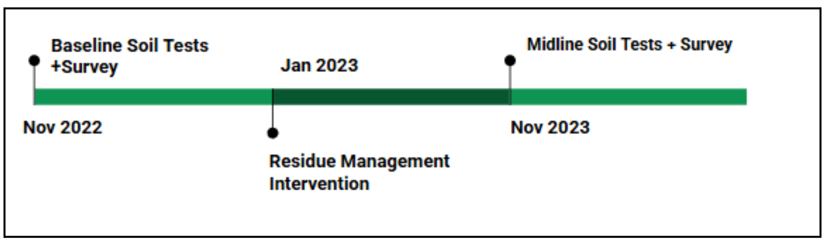


Figure 2: Timeline of pilot RCT and Data Collection

There are two different groups of farmers in Jaipur district, some manually harvest and some harvest mechanically. It is estimated that around 60% harvest manually, and 40% mechanically. It is important to note that the farmers that harvest manually are usually able to sell the rice straw residue from the harvesting process, whereas the farmers harvesting mechanically do not produce intact straw and thus are not able to sell the residue.

In this study, the cost of rotavators was covered by the study group. Rotavator renting is a key starting cost that would likely hinder the adoption of residue management by farmers in the area, so it is an important consideration in this study design.

3.2 Difference- in-Differences

In order to determine with confidence that a difference in yield or in SOC content is significant, we must utilize a difference in differences (DiD) method. The basic process of a DiD method is to first define the treatment and control groups that exist in the 2022 and 2023 data, then take the average difference between the value of the treatment data between 2022 and 2023, as well as the average difference between the 2022 and 2023 control data. Then taking the difference of these two averages will result in the true effect of the treatment. This study uses a DiD regression, with the model in formula 1.

$$\text{Outcome} = \beta_0 + \beta_1 * \text{Treatment} + \beta_2 * \text{Post} + \beta_3 * \text{Treatment} * \text{Post} + \varepsilon \quad (1)$$

The coefficients signify the different weights attributed to variability in values between control and treatment groups (β_1), between 2022 and 2023 years (β_2), and the 'difference in differences' coefficient, which represents average variability between both variables in the dataset (β_3).
A one-tailed significance test with a p-value of 0.05 must then be conducted using the DiD outcome. This allows us to determine whether we can reject the null hypothesis — that the diff Treatment > diff Control.

3.3 Cost Benefit Analysis

Using the carbon stock difference determined through the DiD method, we can construct a five-year cost-benefit analysis. In an average carbon farming contract, there are two costs: the cost of soil testing, and the cost of renting a rotavator. The average cost of soil testing is 40 USD, and the average cost of renting a rotavator for 8 hours is around 1000 Rs or 12 USD (UBKV, 2024). In the 60% of cases where farmers harvest manually, there is the added cost of losing income from incorporating rice residue instead of selling. The average price per hectare given for rice straw in Odisha is around 3000 Rs, or 35.15 USD (Duncan, 2020). The benefits of entering into a carbon farming contract are calculated by taking the difference in carbon stock in t/ha, multiplying by the size of the field, and scaling by the current market price of carbon. In our preliminary case, we will assume that the current market price of carbon matches the Social Cost of Carbon (SCC), which is currently 190 USD based on EPA assessments. Overtime there is also the added co-benefit of yield increase due to carbon sequestration, which increases the farmer's overall income. In addition, in the preliminary cost-benefit analysis, as rotavator costs are paid for by the research group, rotavator costs will not be factored into the final net benefit.

	Item	Value
Costs	Residue Sale Loss	- 35.15 USD
	Rotavator Rental	-12 USD
	Soil Test	- 40 USD
Benefits	Soil Carbon payment	Stock increase in tons x 190 USD
	Yield Co-Benefits	Yield increase in tons x price per ton of rice

Table 1: Itemized Cost and Benefits including values of all items

4. Results

4.1 Difference in Differences

After calculating the average difference in differences for all three variables—yield, SOC stock in t/ha from 0-15 cm and SOC from 15-30cm— I found that only the difference in SOC stock from 15-30 cm was significant with the one-tailed t-test. This failure to determine significance could be due to a number of different factors, from human error in yield reporting to changes in tillage practices that affected SOC from 0-15 cm. The difference calculated at 15-30 cm was 0.26 t/ha between 2022 and 2023, which is quite low compared to the lowest 1 t/ha that most crediting markets will go. Without a significant difference in yield we are also unable to determine yield changes overtime, therefore the benefits for the farmer can only be calculated through the SOC variable.

SOC 15-30 cm	Baseline (2022)	Midline (2023)
Control	8.549 t/ha	8.534 t/ha
Treatment	9.133 t/ha	9.378 t/ha

Table 2: Inputs into the Difference-in-Differences model.

In order to certify that there are parallel trends prior to the intervention and that the 0.26 t/ha value for SOC stock is accurate, we must show that most aspects of these farmers' fields were the same across control and treatment groups. Because we do not have SOC stock data from before 2022, we can use yield trends from 2020 to 2023 and certify that the groups are derived from the same population characteristics before and during the treatment time period. Figure 3 visualizes this overlap.

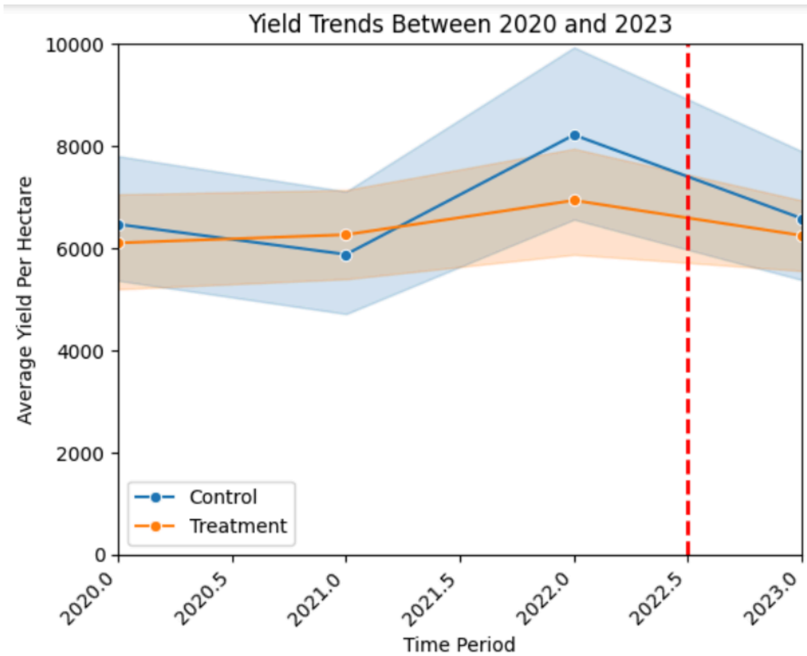


Figure 3: Visualizing parallel trends using the yield variable

4.2 Preliminary Cost Benefit Analysis

Using only the variables that were found to be statistically significant and the specific guidelines of the pilot RCT, we can construct a very preliminary cost benefit analysis that acts as a toy example of a manually harvesting small farmer. Still, there are a couple of assumptions that need to be made to make a more realistic model based on available data. The first is that even though the soil was tested once per year in the pilot RCT, we will assume a more realistic scenario for a five-year contract where soil is tested only in the first and fifth year. This will reduce the burden of soil testing costs on the farmer, and create a more realistic net benefit. Over these five years, we assume a 5% discount rate each year applied to the return to reflect the present value of net benefits. Finally, we assume that the size of the farmers' field is one hectare, allowing us to scale the 0.26 t/ha value by 190 USD Social Cost of Carbon, and calculate a 49.4 USD benefit from SOC stock payments each year.

Year		1	2	3	4	5
Benefits	SOC stock payments (USD)	49.4	49.4	49.4	49.4	49.4
	Yield	0	0	0	0	0
Costs	Residual	35.15	35.15	35.15	35.15	35.15
	Rotavator	0	0	0	0	0
	Soil Test	40	0	0	0	40
Return		-25.75	14.25	14.25	14.25	-25.75
Discounted Return		-24.52	12.93	12.31	11.72	-20.18

Table 3: Cost Benefit Analysis assuming that the size of the farmer's field is 1 ha

Given these data constraints and assumptions, we find that in the five year time span, an average smallholder farmer incurs a negative net benefit from entering into a carbon credit contract. The sum of five years of returns is -7.74 USD, and this is barring fixed costs for rotavator rental which were not included in this preliminary analysis.

5. Conclusions

Through a cost-benefit analysis, this study determined potential economic outcomes for smallholder farmers Odisha, India. The study used soil samples and crop yield data from intervention plots in addition to current data on carbon credit prices offered to farmers. The outcome for the average smallholder was negative due to the high costs of soil tests and losing residue payments. The study also analyzed the economic impact of an increase in carbon credit exports from India due to massive enrollment in voluntary credit markets for agriculture.

5.1 Limitations

Due to data constraints and a number of uncertainties in this study, it is difficult to determine exact returns for a smallholder farmer entering into a carbon credit contract.

More years of data, more soil tests, and a larger sample size would give a better representation of SOC stock and yield changes due to the residue management intervention. The biggest uncertainty that could not be captured in the preliminary analysis was carbon pricing changes. This study used the Social Cost of Carbon to price carbon stock changes, in order to capture the economic damage prevented by one ton of sequestered carbon. However, many carbon credit marketplaces have much lower carbon prices, since voluntary markets are not required to hit strict compliance targets. Grow Indigo, the India-focused credit market, currently pays farmers a maximum of 80 USD per ton of carbon sequestered, and even this is dependent on market changes. Given all of these different variables and uncertainties, it is difficult to recommend carbon credit contracts to an individual farmer in this study. However, due to the emerging carbon crediting market in India— and the number of smallholder farmers that may want to enter the market— it is vital that a comprehensive understanding of benefits to farmers be made available.

5.2 Further Research

The first point of future research would be to understand the economies of scale that would mitigate soil testing and other starting costs if an entire Gram Panchayat of similar farmers were to enter into a carbon contract, similar to the program offered by Grow Indigo. In this case, consider an average sized Panchayat— around 1000 farmers - where each farmer has an average farm size of 1 hectare, with 60% of farmers harvesting manually. It follows that 600 of those farmers lose rice straw payments. We can safely assume that the group will buy a rotavator, with the cost of purchasing a rotavator around 13,300 Rs or 156 USD (Modi, 2020). Using Grow Indigo's current maximum payment of 80 USD per ton of carbon sequestered and scaling the total benefits and soil tests by each of the 1000 farmers' fields in the group, we see a positive net benefit over five years. In Table 3 we see that the final net benefit per farmer is around 11 USD. There are a couple of other aspects to examine in this example scenario, including how the Panchayat might ensure that all of its farmers voluntarily participate in the sustainable farming treatment, and how edge effects might come into play. Another aspect to take into account is how the SOC stock benefit might change with market changes. Grow Indigo does ensure a minimum payment of 20 USD per ton to farmers, so that even if market demand is low, the farmer has some incentive to continue the contract. Therefore, it would be valuable to calculate a farmers' benefits given this variability.

Year		1	2	3	4	5
Benefits	SOC	20800	20800	20800	20800	20800
	Yield	0	0	0	0	0
Costs	Residual	2109	2109	2109	2109	2109
	Rotavator	120	0	0	0	0
	Soil Test	40000	0	0	0	40000
Return		-21429	18691	18691	18691	-21309
Discounted Return		-20408.57	16953.29	16145.99	15377.13	-16696.16
Total Net Benefit		11371.68				

Table 4: Total Net Value is positive, even with SOC stock payments at half of the preliminary analysis (80 USD)

In addition to looking into future contract scenarios, it is valuable to look into potential decreased costs of soil tests and increased benefits from yield increases. In this preliminary analysis, yield differences due to increase in SOC stock were left out of the benefits due to a lack of significant differences over time. However, studies have shown that farm yields are expected to increase along with SOC. Therefore this increase in yield would likely affect the final net value for farmers. It is also possible that soil testing could become much less expensive in the near future as much research is being conducted into using satellite data to predict SOC stock. This would greatly reduce the barrier to entry into carbon credit contracts for individual farmers, especially those with small landholdings.

6. Acknowledgements

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