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ENHANCING SOIL ORGANIC CARBON SEQUESTRATION BY ORGANIC FARMING PRACTICES: A CASE STUDY, ISSUES AND BENEFITS

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Abstract

Organic farming provides many benefits: it can improve soil quality, food quality and soil carbon sequestration. This study was designed to compare soil carbon sequestration levels between conventional and organic potato farming fields in Bhikanpur, Agra. The results from soil analysis indicate that organic farming leads to soil with significantly higher soil carbon storage capacity than conventional farming. Therefore, research should be conducted to develop a fairer organic farming system that can enhance both local and global sustainability. Soil carbon sequestration is enhanced through agricultural management practices viz., increased application of organic manures, use of intercrops and green manures, higher shares of perennial grasslands and trees or hedges, etc., which promote greater soil organic matter (and thus soil organic carbon) content and improve soil structure. Studies of carbon and nitrogen dynamics in ecosystems are leading to an understanding of the factors and mechanisms that affect the inputs to and outputs from soils and how these might be manipulated to enhance Carbon sequestration. Both the quantity and the quality of soil Carbon inputs influence Carbon storage and the potential for Carbon sequestration. Changes in tillage intensity and crop rotations can also affect Carbon sequestration by changing the soil physical and biological conditions and by changing the amounts and types of organic inputs to the soil.

INTRODUCTION

Organic agriculture offers a unique combination of environmentally-sound practices with low external inputs while contributing to food availability (Zundel et al., 2007). In developed countries, there is a steadily growing market for organic products, driven by the rising consumer awareness for health and environment (Willer et al., 2009), which offers farmers a chance to produce for premium price markets and hence, an opportunity to increase their farm profitability and livelihoods. Recent studies have highlighted the substantial contribution of organic agriculture to climate change mitigation and adaptation (Niggli et al., 2009; Scialabba and Muller-Lindenlauf, 2010, in print). The potential of organic agriculture to mitigate climate change is mostly claimed on the basis of assumptions concerning the soil carbon sequestration potential of organic management.

The benefits of organic farming regarding climate change can be summarized as follows:

- Organic agriculture has considerable potential for reducing emissions of greenhouse gases.
- Organic agriculture in general requires less fossil fuel per hectare and kg of produce due to the avoidance of synthetic fertilizers. Organic agriculture aims at improving soil fertility and nitrogen supply by using leguminous crops, crop residues and cover crops.
- The enhanced soil fertility leads to stabilization of soil organic matter and in many cases to a sequestration of carbon dioxide into the soils.
- This in turn increases the soil's water retention capacity, thus contributing to better adaptation of organic agriculture under unpredictable climatic conditions with higher temperatures and uncertain precipitation levels. Organic production methods emphasizing soil carbon retention are most likely to withstand climatic challenges particularly in those countries most vulnerable to increased climate change. Soil erosion, an important source of CO_2 losses, is effectively reduced by organic agriculture.

- Organic agriculture can contribute substantially to agro forestry production systems.
- Organic systems are highly adaptive to climate change due to the application of traditional skills and farmers' knowledge, soil fertility-building techniques and a high degree of diversity.

Weaknesses of organic farming

This paper recognizes that organic agriculture also has weaknesses, mainly related to productivity and yield losses in some crops and production areas. Such issues highlight the need for research. In order to improve organic agriculture's performance and to allow more assistance to be provided to organic agriculture projects in low-input or developing countries, where CO_2 mitigation would be most beneficial, more research is needed in the following areas:

- Soil fertility management, crop growth and health.
- Better exploitation of leguminous plants in improved crop sequences.
- Habitat management with improved manipulation and exploitation of diversity at all levels.
- Crop breeding programmes focusing on the adaptability of plants to low-input situations in soils, on weed competition, and on pest and disease tolerance.
- Improved plant protection techniques and compounds from natural sources.
- Breeding strategies and programmes for adaptability to management and environmental stress situations in organic livestock production.
- Reduced tillage organic systems.

In spite of these weaknesses, organic agriculture is so far the most promising approach for mitigation and adaptation to climate change. Organic agriculture represents a positive example of how farmers can help mitigate climate change and adapt to its predictable and unpredictable impacts. It can serve as a benchmark for allocating development resources to climate change adaptation, or to measure progress in implementing climate-related multilateral environmental agreements.

The aim of this document is to describe the potential of organic agriculture to sequester carbon and to meet the requirements of carbon accounting systems. Furthermore, the document discusses the suitability of measurement and verification methodologies to agriculture systems, including an analysis of existing carbon accounting systems in terms of their usability for organic agricultural management practices.

A literature review of studies comparing carbon sequestration in soil under organic and conventional management. All these studies showed a higher soil carbon content in organic plots, as compared to conventional management practices. In one comparative field trial, the baseline carbon content of the organic plots was higher, and so was the total carbon decrease over time (Stalenga et al., 2008). In one study, the higher carbon sequestration was only significant for organic farming combined with no tillage, but not for a deep tillage organic system (Tizio et al., 2008). In one other study, only the biodynamic system with high livestock density showed a significant advantage (Fliessbach et al., 2007). One study showed slightly higher sequestration for an optimized conventional system including some "organic" strategies such as cover crops, crop rotation and mulches without abstaining from mineral fertilizers use (Wells et al., 2000); however, the difference of the optimized "conventional" system to the "organic" system including the same conservation practices was not significant.

MATERIAL AND METHODS

Field Area

The study area was Bhikanpur Agra. It is a major vegetable production area. Soil type is sandy loamy. Organic and conventional potato farmer groups for the study were selected. Additional analyses are being conducted to provide estimates for regional sequestration potentials and to determine quantitative relationships among sequestration rates, climate, soil attributes, land cover, and land management.

The difference between conventional and organic potato production systems Comparison of farm management systems between conventional and organic potato production (Table1)

How much carbon can be stored in soils?

There are a whole range of SOC levels in different soils. For instance, for the surface soils, SOC ranges from about 10% in the alpine soils to less than 0.5% in the desert soils. The amount of SOC stored in the soil profile can be considerable. For example, if there is 1% SOC over 30 cm soil depth, the amount of SOC stored over 1 hectare of land can weigh about 42 tonnes. Usually, the surface layer has the highest level of SOC which decreases with depth down the soil profile. The actual amount of SOC present in a soil is dependent on a number of factors.

Measuring soil carbon

- SOC is usually measured in the laboratory on soil samples collected from the field. There are two kinds of test for SOC determination, namely one which is based on acid digestion and the other based on combustion principle. The latter measures all the carbon presents in a sample of soil whereas the former measures only part of the organic carbon.
- SOC results are usually expressed as % C by weight (i.e. g C per 100 g of soil). SOC results can be converted to soil organic matter (SOM) level by multiplying SOC value by a conversion factor of 1.72. This assumes that SOM present in soil, on average, is made up of 58 % carbon.
- Very often it is more practical to express SOC on per ha basis, namely as tonnes C per ha. To perform such calculation, knowledge of the bulk density of the soil to the sampling depth and the sampling depth is needed. As an example, if SOC = 1.0 % and bulk density of the soil = 1.4 Mg/m^3 to 30 cm depth (1 Mg = 1000 kg = 1 tonne), the amount of SOC present in the soil to 30 cm depth of 1 hectare of land can be worked out as follows.

Tonnes carbon per ha = SOC (%) X Soil density (Mg/m3) X Sampling Depth (cm)

1X 1.4X30= 42 tonnes per hectare

RESULTS

The soil in the organic farming system showed higher soil carbon content than conventional soils after four years of continuous organic farming, however, there were no significant differences in soil bulk density between the two farming systems (Table 1). Soil carbon storage in organic farming was significantly increased compared with conventional farming. These differences were also obvious in soil carbon content profile, which was significantly higher in the organic field than the conventional field, especially in the top 10 cm soil layer. However, soil carbon contents are somewhat lower. This difference suggests that there was diversification of soil carbon content depending on the site specific location, however, organic fields showed higher carbon content than the conventional fields.

These soil samples were also analyzed for organic carbon content by the above mentioned methods. Potato yields were estimated by air dried subsamples taken using a 1 m row section after manually harvesting whole fields.

Benefit by using Soil Testing Kit in Cultivation of Potato is 2306-1485= Rs. 821/acre

Production of Vermicompost = 1200 kg

Cost in production of Vermicompost = Rs. 2800

Cost of Vermicompost per kg = Rs. 2.30

Cost of cultivation of one acre potato with self made Vermicompost- Rs. **4425.00**

Cost of cultivation of one acre potato with purchased Vermicompost- Rs. 7125.00

Cost of cultivation of one acre potato using chemical fertilizers - Rs. 5400.00

Benefit by using self made Vermicompost

A) As compared to purchased Vermicompost: 7125-4425=Rs. **2700.00** per acre.

B) As compared to chemical fertilizers: 5400-4425=Rs. **975.00** per acre.

C) Fertility and nutrient management

Potatoes have high nitrogen and potassium requirements. These can be met by using manures, compost and crop rotations. Soil nutrient levels can assess with a soil test. If nutrient levels are deficient, apply organic amendments. Most organic potato growers consider producing their crop with 120 pounds of nitrogen, 25 pounds of phosphate and about 140 pounds of potash per acre (Sideman and Johnson, 2006). Nutrient requirements vary by potato variety and yield goals. Lowering the soil pH will help prevent common potato scab problems, but not powdery scab. A soil pH of 5.0 to 5.2 is recommended for preventing scab, but this pH level may affect other crops in the rotation, as well as nutrient availability (Charlton, 2008). Sulfur is an organically acceptable way to lower soil pH.

D) Importance of soil organic carbon in agriculture -Soil organic carbon as the basis of soil fertility

Soil organic carbon is important for all three aspects of soil fertility, namely chemical, physical and biological fertility.

Nutrient Availability: Decomposition of soil organic matter releases nitrogen, phosphorus and a range of other nutrients for plant growth.

Soil Structure and Soil Physical Properties: SOC promotes soil structure by holding the soil particles together as stable aggregates improves soil physical properties such as water holding capacity, water infiltration, gaseous exchange, root growth and ease of cultivation.

Biological Soil Health: As a food source for soil fauna and flora, soil organic matter plays an important role in the soil food web by controlling the number and types of soil inhabitants which serve important functions such as nutrient was cycling and availability, assisting root growth and plant nutrient uptake, creating burrows and even suppressing crop diseases.

As a buffer against toxic and harmful substances. Soil organic matter can lessen the effect of harmful substances e.g. toxins, and heavy metals, by acting as buffers, e.g. sorption of toxins and heavy metals, and increasing degradation of harmful pesticides.

Cultivation: Cultivation operations can expose SOC and increase losses by decomposition and erosion. Historically, excessive cultivation using inappropriate implements resulted in soils being 'over-worked', and the consequent loss of SOC has caused many land degradation problems such as erosion and soil structural decline.

Fallowing: In the past, keeping the soil bare was a common cropping practice. Fallowing was maintained by repeated cultivation for weed control. SOC declines rapidly under fallowing because of the increased decomposition of organic matter due to the cultivation operations as well as the higher soil moisture conditions prevailing in the fallowed soils.

E) Management practices that reduce soil organic carbon

Some management practices, such as fallowing, cultivation, stubble burning or removal, and overgrazing can reduce SOC by reducing inputs to the soil, increasing the decomposition of soil organic materials, or both.

F) Management practices that increase soil organic carbon

There are a wide range of management options and farming practices that can increase SOC levels by either increasing inputs or decreasing losses, e.g. stubble retention. Inputs can also be increased by direct additions of organic materials, composts, manure and other recycled organic materials.

G) Practices leading to increased productivity of crops and pastures – In theory, any management practice that can increase production from an area of land should lead to increased SOC storage because of the increase in carbon inputs. Farmers are familiar with practices such as fertilizer application, improved rotations, improved cultivars and irrigation which can lead to large yield increases. Productivity increases can also be achieved by crop intensification practices such as double cropping, opportunity cropping and multiple cropping. However, it should be noted that some of the yield increasing practices involve the use of fertilizers and irrigation water which require large energy consumption and therefore increase carbon dioxide emission.

Conservation farming **–** This is rapidly gaining worldwide acceptance as a farming practice to improve soil and water conservation. In cropping, cultivation is either reduced (reduced tillage) or completely eliminated (no-tillage) and stubble (crop residue) is retained. Reduced tillage reduces carbon losses (from both reduced cultivation and reduced fossil fuel usage) and stubble retention increases carbon inputs to the soil; both of these lead to SOC increases.

Use of organic amendments **–** These are manure, plant debris, composts and biosolids from sewage which are applied to agricultural soils. They are all high in organic carbon and therefore represent additional carbon inputs to the system. Some of these recycled organics also contain a high plant nutrient content and can act as organic fertilizers, reducing the use of inorganic fertilizer. They are important for organic farming systems. (Prime fact 735, Increasing Soil Organic Carbon of Agricultural Land).

CONCLUSION

The use of organic fertilizer has resulted in increased soil organic carbon storage and gross benefits for farming. Therefore, organic farming for potato production may help not only to mitigate global warming by carbon sequestration, but also to establish a sustainable food system. Land owners and farmers can increase their profits by converting conventional farming to organic farming. Organic production practices maximize the use and recycling of on-farm nutrient sources, including animal and green manures. Techniques such as accurate soil analyses and nutrient crediting help producers avoid excess fertilizer applications. Sustainable farming methods also include soil-building and -conserving practices such as adding organic matter and minimum-tillage approaches.

According to the soil analysis, organic farming showed significantly higher SOC storage, which may help not only to mitigate global warming, but also to establish a sustainable food system. Organic potato farmer also has potential to improve soil quality, reduce the cost of chemicals that have recently been increasing with the price of fossils fuels, and increase farmers' incomes due to its higher price. However, organic farming requires intensive labor such as weeding and applying fertilizer to the fields. This suggests that by converting conventional farming to organic farming, land owners and farmers can increase their profits. Thus organic farming has great potential to improve environmental quality; it also creates social justice problems. The improved management options are all proven practices that may be readily incorporated into existing farming systems to improve agronomic performance, conserve water and reduce erosion. They can also result in higher crop yields. Increased SOC results from a greater return of organic matter into the soil in the form of stubble and root matter (stubble retention), and reduced losses from cultivation and runoff. Therefore, the adoption of farming systems that can increase SOC is a win-win situation. In addition to mitigating climate change, systems that increase SOC are also more productive, more profitable and more sustainable.

However, the effectiveness of a particular management practice in increasing soil carbon is site specific and dependent on local factors such as climate, soil types and management skill. In soil carbon sequestration, as we are interested only in the net carbon change, simple low-energy options such as conservation farming, grazing management and better rotation are particularly attractive. (Prime fact 735, Increasing Soil Organic Carbon of Agricultural Land)

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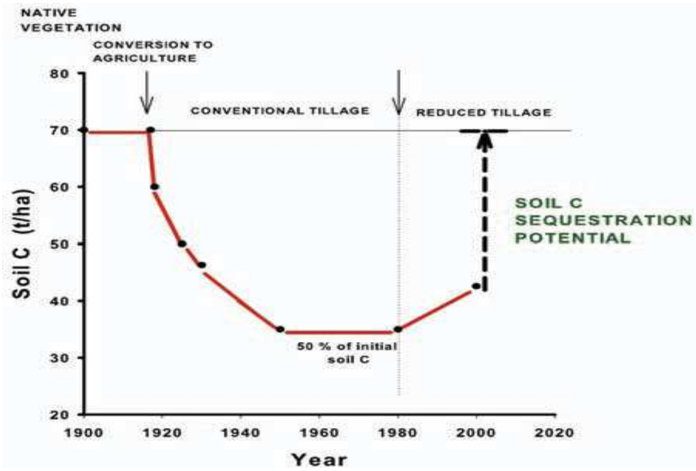

Figure 1 Historical changes in SOC as a result of agricultural development, showing soil carbon sequestration potential

Table 1

	CHEMICAL FERTIIZERS	ORGANIC FARMING
pH	8.9	7.9
Carbon	0.03%	0.2%
Nitrogen	0.2%	0.48%
Microbial population	105×10^3	445×10^4
Productivity	Decreased	Increased

Table 2

Comparison of soil carbon sequestration between organic and conventional potato fields in the top 10 cm soil depth.

	Soil Bulk Density g mL–1	Carbon Content	Soil Carbon Storage Mg ha–1
Organic	0.88	2.89	25.0
Conventional	0.80	2.22	17.6

Table 3

Cost benefit analysis of Potato Cultivation by without and with soil testing (Per Acre)

Items	Input without soil testing	Cost of fertilizers	Input with soil testing	Cost of fertilizers
Level of Elements	Unknown	-	Known	Rs. 35
Nitrogen	70kg N 154 kg Urea	Rs.750	Medium 45 kg N 99 Kg Urea	Rs. 500
Phosphorus	40 Kg	Rs. 1056	Medium 25 kg P 55 Kg DAP	Rs. 660
Potash	60 Kg K 100 Kg MOP	Rs. 500	Medium 35 Kg K 58 Kg MOP	Rs. 290
Total		Rs. 2306		Rs. 1485

Table 4

Cost benefit by production of Vermicompost

S.NO.	Items	Quantity	Estimated Cost (Rs.)	
			Minimum	Maximum
1.	Organic Waste Biomass	One ton	150	300
2.	Cow dung	50 cubic feet	150	200
3.	Earthworm	10 Kg	2000	2500
4.	Overhead		500	800
Total			**2800**	**3800**

Table 5

Cost benefit analysis of Potato Cultivation by using Vermicompost vs chemical fertiliser

Sr. No.	Input with self making vermicompost & Fertilizers	Quantity per acre	Cost Rs. per acre	Input with purchased vermicompost	Quantity per acre	Cost Rs. per acre	Input with chemical fertilizers	Quantity per acre	Cost Rs. per acre
1.	Vermicompost	1000 Kg @ Rs 2.30 /- per kg	2300/-	Vermicompost	1000 Kg @ 5/- per kg	5000/-	-	-	-
2.	DAP	100 Kg @ Rs. 12/- per kg	1200/-	DAP	100 Kg @ Rs. 12/- per kg	1200/-	DAP	3 Quintals = 6 Bags @ Rs. 600/- per bag	3600/-
3.	Urea	50 Kg @ Rs. 5/- per Kg	250/-	Urea	50 Kg @ Rs. 5/- per Kg	250/-	Urea	1.5 Quintals= 3 bags @ Rs. 250/- per Bag	750/-
4.	Potash	25 Kg @ Rs 5/- per kg	125/-	Potash	25 Kg @ Rs 5/- per kg	125/-	Potash	1 Quintal = 2 bags @ Rs 250 /- per bag	500/-
5.	Micronutrients	500 ml	550/-	Micronutrients	500 ml	550/-	Micronutrients	500 ml	550/-
	Total		**4425/-**	**Total**		**7125/-**	**Total**		**5400/-**

Table 6

Management practices that can increase soil organic levels of agricultural soils

Management category	Management practices to increase soil carbon
Crop management	Soil fertility enhancement Better rotation Erosion control
Conservation tillage	Stubble retention Reduced tillage
Pasture management	Fertilizer management Grazing management Earthworm introduction Irrigation Improved grass species Introduction of legumes Sown pasture
Organic amendments	Animal manure Green manure

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