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Soil Carbon Sequestration in any Cropping Pattern and their Interactive Effect on Persistent use of Inorganic fertilizer and organic Manure: Economic Benefits of Soil Carbon Sequestration

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Abstract

This review describes the best carbon management methods that increase the possibility of improving carbon stocks in soils. Carbon dioxide is a heat trapping gas produced both in nature and by human activities. Man-made sources of carbon dioxide come from the burning of fossil fuels such as coal, natural gas and oil for uses in power generation and transportation. Carbon sequestration is the process to stabilize carbon in solid and dissolved forms so that it doesn't cause the atmosphere to warm. The process shows tremendous promise for reducing the human "carbon footprint." The build-up of carbon dioxide and other greenhouse gases in the atmosphere can trap heat and contribute to climate change which cause a tremendous loss in agriculture and allied sectors. Agroecosystems can degrade and deplete the soil organic carbons levels but this carbon deficit opens up the opportunity to store carbon through new land management practices.

Introduction

Soil is the most significant organic carbon (C) pool on earth. The dynamics of soil organic carbon (SOC) can indicate variation in SOC sequestration capacity (an indicator to evaluate the C sequestration ability of soil, which depends on soil type, nutrient reserves, soil depth, etc. The C sequestration capacity may affect soil quality and the mitigation function of climate change and crop productivity. Due to the considerable SOC stock, small fluctuations may cause significant changes in atmospheric CO_2 concentration, ultimately causing global climatic conditions. Carbon sequestration is affected by the cropping system and management practices adopted. Previous studies done by different researchers revealed both its positive and negative impacts on carbon sequestration. The agriculture sector in India in 2007 contributed greenhouse gas (GHG) emissions to the tune of 334.41 mg of CO_2 equivalent with net emissions of 1727.31 mg of CO_2 equivalent and gross emissions of 1904.73 mg of CO_2 equivalent in the country. It ranked 3rd next to energy (58%) and industry (22%) sectors (INCCA, 2010). Agricultural soil has dual nature as it also serves as a potential sink for atmospheric carbon as soil organic carbon (SOC), which contributes to enhancing productivity and quality (Rudrappa *et al*., 2001). Soil scientists regard SOC as the most important indicator of soil quality and agronomic sustainability because of its impact on other physical, chemical, physio-chemical and biological indicators of soil quality (Reeves, 1997).

What is Soil Carbon Sequestration?

oil carbon sequestration transfers carbon dioxide from the atmosphere into the soil through crop residues and organic solids which is not immediately reemitted. This transfer or "sequestering" of carbon helps offset emissions from fossil fuel combustion and other carbon-emitting activities while enhancing soil quality and long-term agronomic productivity. The skilful management of soil carbon sequestration can enhances the biomass of soil carbon that cause minimal soil disturbance, preserve soil and water, boosts soil structure and improves soil fauna activity. Uninterrupted, no-till crop production is a prime example.

Objectives of improving soil carbon stocks:

1. The relationships between management practices and changes in soil carbon stocks which will link with different soil management practices (i.e., alternating crop rotations) to soil organic carbon (i.e., carbon sequestration) and ecosystem services generated that contribute to crop productivity.
2. The SOC is associated with different soil aggregates, with a particular emphasis on quantifying long-term changes in soil organic carbon (SOC), soil microbial biomass carbon (SMBC), soil microbial biomass nitrogen (SMBN) and mineralizable C in cropping sequence.
3. Quantify the economic (monetary) benefits of carbon sinks (or stocks) generated from the soil, translating the carbon stocks into the net revenue of agricultural productions by linking it to crop productivity and crop yield.

Soil Organic Carbon in India:

The data in (Table 1) show that SOC content in most soils is less than 10 g/kg and is basically less than 5 g/kg. Because of the low clay contents, the SOC concentration is especially low in alluvial soils of the Indo-Gangetic Plains, coarse-textured soils of southern

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India, and arid zone soils of north-western India (Dhir *et al.*, 1991). The widespread low levels of SOC concentrations to soil-mining practices of excessive tillage, imbalance in fertilizer use, little or no crop sediments returned to the soil and severe soil degradation. Consequently, even the well-established relationship between climate (temperature and precipitation) (Miller *et al*., 2004) and SOC concentration does not exist.

Table 1.Soil organic carbon (SOC) concentration of some soils in India (Nambiar, 1994)

Location	Soil type	Texture	SOC content (g/kg)
Bangalore, KT	Haplustalf	Sandy loam	5.5
Barrackpore, WB	Eutrochrept	Sandy loam	7.1
Bhubaneswar, OR	Haplaquept	Sandy	2.7
Coimbatore, TN	VerticUstochrept	Clay loam	3.0
Delhi	Ustochrept	Sandy loam	4.4
Hyderabad, AP	Tropaquept	Sandy clay loam	5.1
Jabalpur, MP	Chromustert	Clayey	5.7
Ludhiana, PB	Ustochrept	Loamy sand	2.1
Palampur, HP	Hapludalf	Silty clay loam	7.9
Pantnagar, UP	Hapludoll	Silty clay loam	14.8
Ranchi, BR	Haplustalf	Silty clay	4.5

Carbon Management:

1. Reducing soil disturbance

1.1 Zero or no-tillage

Zero-tillage (ZT; also known as no-tillage) is an increasingly applied conservation practice in soil disturbance. It consists of cultivating crops while adopting agricultural practices that leave the soil undisturbed. The only soil disturbance occurring under zero-tillage is related to the movement of the farming machines generally used for weeding, seeding and harvest. Most authors refer to ZT as a system applied over a period far longer than a specific crop cycle and includes other practices such as crop rotation and cover crops. The drastic reduction of the pressure on soil due to the adoption of the ZT system brings different benefits to the ground soil, especially over long periods, such as:

- Increased fraction and stability of macro-aggregates and improvement of water infiltration.
- Reduction of erosion.
- Greater aeration.
- Improved soil moisture and removal of bulk density in the topsoil.

However, zero tillage can hamper crop emergence and soil workability in wetter and heavier soils. So, it is not suitable for all soils and bioclimatic regions. ZT can protect organic matter from high temperature and thus reduce mineralization and positively affects soil chemical characteristics as depicted in Figure 1. (e.g. cation exchange capacity and organic matter content).

1.2 Reduced tillage

In this work, we refer to reduced tillage (RT) to cover all those practices which, regardless of whether the methods are inversion (e.g. mouldboard plough) or non-inversion tillage-based (e.g. chisel).RT significantly reduces soil disturbance by the shallower depth of tillage; reduced frequency of passes over the soil or by tilling only specific field portions (e.g. strip and ridge tillage). RT practices improve soil structure by favoring soil aggregation and SOC stabilization (Sheehy *et al.*, 2015). Alliaume et al. (2014) note that, when combined with mulching and manure, RT can favour moisture conservation, further reducing runoff and soil erosion because of the greater quantity of water intercepted and stored.

1.3 Direct drilling

By cultivating a narrow band of soil where seeds are placed and then covered by a rear roller or a harrow, direct drilling (DD; also known as no-till seeding) allows the main crop to be swon into the previous crop stubble on an untilled soil (Morris et al., 2010). Because of the significant reduction of soil disturbance and the presence of crop residue, it protects soil particles against water and air0 erosion to a much greater degree than under conventional seeding (inversion-tillage based). When soil is left undisturbed from sowing to harvest, DD is, in all respects, a zero-tillage practice and its effects on grounds are similar to those due to ZT (Arrouays *et al.*, 2002).

Figure 1. Strategies for carbon management. A) No tillage and B) Direct drilling

2. Enhancing C-input

2.1 Cover crops: catch crops and green manure

The cultivation of cover crops (CCs) ensures soil cover in periods in which no crop cultivation is scheduled in an annual cropping system. De Baets et al. (2011) listed several physical and chemical functions associated with cover crops, ranging from nitrogen fixation and carbon sequestration to improved soil aggregation and wind and water erosion prevention. The impact of cover crops on the development of soil microorganisms and fauna and the prevention of contaminant leaching to groundwater is further recognized. Based on the specific soil functions affected by cover crops, Dabney *et al*. (2010) divide cover crops into catch crops and green manure. Catch crops are grown with the specific aim of preventing leaching nitrogen losses (Cicek *et al.*, 2015) by taking up available nitrogen in the soil. Catch crops can be sown after the main crop harvest (usually in conventional systems) or after animal manure application (usually in organic systems). However, timely sowing would

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maximize their root growth and thus their effectiveness at catching leached nutrient. Green manure is instead a cover crop that fulfils both the fertilizing function, by improving the nutrition of the consecutive crop and the soil amendment function, affecting soil physical conditions (Alliaume *et al*., 2014). To this ends, green manure crops can be ploughed into soil or left as a mulch to decay on the soil surface (Varela *et al.*, 2014). Similarly, to catch crops, the effectiveness of this practice is highly affected by the management and the timeliness with which specific cropping operations are carried out (e.g. sowing season and mowing period)

2.2 Crop rotation

Because of the nature of the selected crops (e.g. legumes, cereals, grassland) and/or of the management practices adopted, the succession of different crops in a specified order on the same fields (i.e. Crop rotations, CR) greatly affect physical and chemical soil characteristics (Angus *et al.*, 2015). For instance, groundwater storage is favoured when the rotation is under a no tillage system and when specific crops and techniques are adopted (e.g. corn after cotton better than corn after rice; Dakhlalla *et al*., 2016); thereby, nitrogen leaching can significantly be reduced to low levels through a proper combination of few crops (e.g. barley with Italian ryegrass rather than with pea and grasslands; Eriksen ., 2015) depicted in Figure 2.

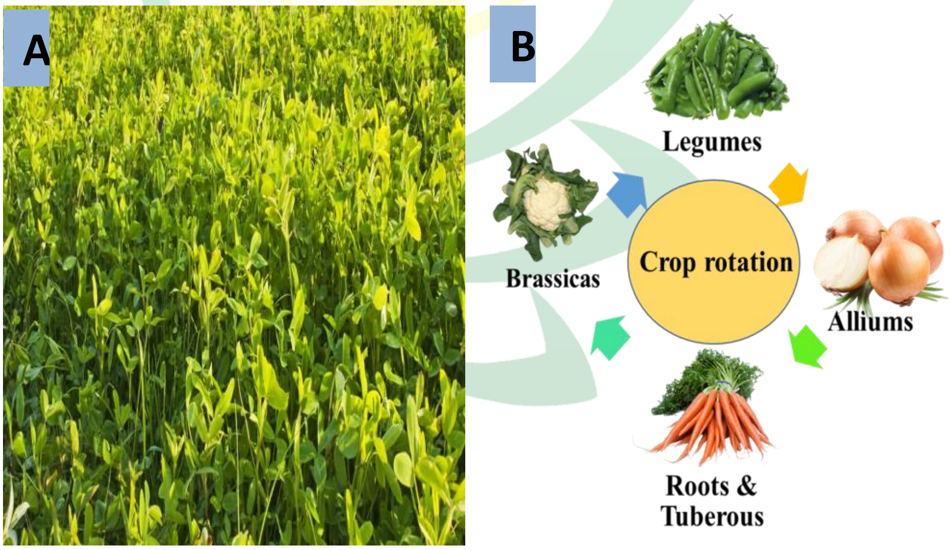

Figure 2. Strategies for enhancing carbon input in soil. A) Green manure crops and B) Crop rotation

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3.Burning of crop residues

Return of residues to the soil rather than residue removal or the application through burning of the crop residues depicted in figure 3, have the potential to quickly increase soil carbon levels. Residue management directly affects the increase and/or the maintenance of soil organic matter, which in turn will affect chemical (e.g. pH, cation exchange capacity, nutrients cycling) and physical soil properties (e.g. soil particle aggregation, soil moisture content and soil temperature. When residues are not incorporated into the soil through tillage, they physically protect soil against water and wind erosion further favouring water retention.

Figure 3. Burning of crop residues

Economically benefit through Soil Organic Carbon

Some of the benefits from a 1% increase in soil organic carbon include:

- Improved farmland water storage capacity by 144,000 litres per hectare;
- Improves soil structure and aeration – prevents soil erosion;
- Increases farm productivity and profitability by up to 30% 1;
- Improves water quality and run-off for rivers and lakes (e.g. Great Barrier Reef & Murray-Darling Basin);
- Increases in bio-diversity;
- Reduces the amount of nitrous oxide emissions;
- Remediation of soil salinity; and
- Improves human and animal health by increasing nutrient density in food.

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Expected Outcomes from further study:

- To study about the influence of applied nutrients under various soil management practices with various soil carbon sequestration regime on yield and yield attributes.
- Estimation of soil carbon and physio-chemical properties of soil.
- Identify needs and determine the technical potential versus achievable potential in soil C sequestration.
- Develop a framework for diverse management scenarios to optimize the net SOC pool.
- Determine multi-functional land-use/soil management systems in which soil C sequestration is an integral component.
- Economic effects on production of yield in comparison with previous year data.