Ecofarming
e-Magazine for Agriculture and Allied Sciences
http://www.rdagriculture.in
e-ISSN: 2583-0791
Ecofarming Vol. 02(04): 178-183, 2022

Soil management practices for increasing soil carbon sequestration

Pankaj Singroha[1], K.K. Bhardwaj[1], Manisha Arya[1], Anu[2]

[1]Department of Soil Science
CCS Haryana Agricultural University, Hisar, Haryana, 125 004, India

[2]Department of Agronomy
CCS Haryana Agricultural University, Hisar, Haryana, 125 004, India

Email: pankajsingroha95@gmail.com

***Received:* August 02, 2022; *Revised:* August 06, 2022 *Accepted:* August 07, 2022**

Abstract

The two biggest issues facing agriculture in the future are mitigating climate change and maintaining food security for a human population that is expanding at an exponential rate. To combat these issues, improved soil management techniques are essential for increasing the productivity of agroecosystems, soil fertility, and carbon sequestration. Soils contain more than twice as much carbon than the air pool, the land plant or biotic pool, or any other secondary terrestrial carbon pool. Reduced tillage, diversified crop rotation, residue retention, mulching, and other management practices have all been heavily advocated for soil organic carbon stock boosting. Agroforestry systems are more effective than monocultures at utilising the site's resources for biomass growth, and the enhanced growth may lead to larger soil carbon inputs. The current synthesis evaluates a variety of contemporary and anticipated future agricultural management techniques that have an impact on the storage and sequestration of soil organic carbon.

Keywords: Carbon sequestration, climate change, soil organic carbon, soil management practices.

Introduction

From the perspective of climate change, the rise in atmospheric carbon dioxide (CO_2) is the most compelling factor. With around 1206 Pg of organic carbon in the upper 1 m of soil, which is more than the atmospheric carbon store of 800 Pg, soils are the primary source and sink of carbon and a crucial part of the global carbon (C) cycle. CO_2 is removed out of atmosphere and stored in the soil carbon pool through a process known as soil carbon sequestration. Plants play a major role in mediating this process through photosynthesis, with carbon being stored as soil organic carbon (SOC). Although the rate of inorganic carbon formation is very low, in arid and semi-arid climates, soil carbon sequestration can also result through the conversion of CO_2 from air found in soil into inorganic forms such secondary carbonates. Either by reducing emissions or by capturing it in aquatic and terrestrial ecosystems, this rising atmospheric CO_2 concentration can be decreased. Soils are the largest carbon storage area in the terrestrial biosphere. Carbon sequestration entails the transfer of CO_2 from the atmosphere into a long-lasting reservoir (e.g., soil, biota). C sequestration can occur through biotic or abiotic processes. Through photosynthesis or other biogenic factors, the biotic process takes place. A positive carbon sequestration relates to an increase in the stock of SOC, whereas a negative carbon sequestration implies a net loss of SOC. Restoring degraded soils, switching to a soil-restorative land use (such as afforestation or natural fallowing), and implementing better soil/crop/vegetation management techniques can enhance the amount of C that is returned to the soil through increased biomass. The principal ecosystems whose soil stores a significant quantity of SOC include natural forests, forest plantations, agroforestry, grasslands, and cultivated fields. Through improved land and soil management in agricultural soils, the 4-per-mille programme, introduced by the French Minister of Agriculture at the UN Climate Change Conference (COP21) in Paris (2015), seeks to rise SOC supplies by 0.4% year. Carbon sequestration has the potential to reduce global warming and stop the negative effects of climate change, but the use of management strategies must be adapted to various ecosystems and not be prohibitively expensive.

Why carbon sequestration is important?

SOC stocks are influenced by changes in the climate as well as the vegetation, soil management techniques, and soil water regime. A higher percentage of the soil's organic matter reserves is transformed or mineralized in general when temperatures are higher and precipitation patterns remain the same. Therefore, more organic matter must be introduced (harvest residues, cover crops, field fodder), or actions that promote mineralization (soil cultivation) must be decreased in order to maintain or enhance the current SOC stock. In order to combat climate change, atmospheric CO_2 concentrations must be reduced. This can be done by reducing CO_2 emissions and increasing carbon sinks. The SOC dramatically dropped as a result of farming methods because more of the soil's C was being oxidised. One of the soil issues addressed in the Soil Thematic Strategy is loss of soil's total organic carbon content, an essential indication of soil quality that affects a variety of soil functions, including primary productivity, climate control, and ecosystem services. Restoring degraded soils with the use of soil carbon sequestration can increase agricultural yield.

Soil management practices for carbon sequestration

The quantity of carbon stored in cropland soils has a huge potential to increase with improved agricultural methods. Adopting recommended management strategies helps agriculture to achieve goals for soil conservation, water quality, increasing soil organic carbon levels, and reducing the effects of CO_2 emissions on climate change. SOC concentrations in soils represent the long-term equilibrium between organic carbon contributions and losses. This long-term equilibrium was disturbed by introduction of extensive soil cultivation, and as cultivation progressed, more and more of the C in the soil's organic matter was exposed to oxidative reactions. Crops are grown on 20% of the planet's land, therefore agricultural practices have a significant impact on the amount of C retained in soil and emitted as CO_2 into the atmosphere. SOC rises when more carbon enters the soil than is lost to oxidation and the atmosphere. Increasing the resistant or non-labile percentage of SOC, sequestering SOC in the formation of organo-mineral complexes and increasing stable aggregation, and deep depositing SOC in sub-soil horizons are all soil aggrading activities that improve SOC. Conversely, soil degradation processes with a negative effect on SOC include mineralization, leaching, and erosion.

1. Conservation tillage practices

Tillage techniques have an impact on SOC by influencing both aggravating and degrading processes. Traditional tillage practices like mechanical ploughing erode soil aggregates on the soil surface, exposing previously protected soil organic matter (SOM) to microbial degradation. Additionally, it encourages soil erosion and depletes SOC reserves. Conservation tillage, a general term for a variety of tillage techniques that use crop residue mulch to protect against raindrop impact and reduce soil and water losses in comparison to conventional or plow-based tillage methods, increases SOC by enhancing soil aggrading processes and reversing soil degrading processes. Conservation tillage typically benefits soil fauna activity and species variety. Due to mixing and deep placement, soil fauna activity typically has a positive impact on SOC. The activity of soil fauna that burrows makes it easier for SOC to move from the surface to the subsoil. Additionally, conservation tillage enhances the stability and aggregation of aggregates. SOC contents in the topsoil of fields grown using minimal or no tillage practices were found to be higher than those grown using traditional tillage methods like mouldboard ploughing. Tillage techniques had no effect on SOC storage as soil depth increased, though. Additionally, techniques that demand less energy, such as no-till as opposed to conventional tillage, typically lead to fewer fuel inputs and, as a result, reduced emissions of CO_2 into the atmosphere per area under cultivation. For instance, ploughing a field uses more fuel than spraying it with pesticide. Anytime it is possible to reduce the number of trips across the field, fuel usage is also reduced.

2. Residue retention

The quantity of SOC is dependent on the rate at which SOC decomposes as well as the volume and make-up of crop wastes, plant roots, and other organic material that has been incorporated back into the soil. Crop residues and other organic materials are a significant resource for managing soil surface, producing energy, and other purposes. In order to increase the SOC content, it is crucial to use above-ground agricultural residues, below-ground root biomass, and weed biomass overall. The quantity, quality, and management of the residue, as well as the characteristics of the soil, all influence the rise in SOC content that results from the return of the C in crop leftovers and roots to the soil. The equilibrium level of SOC in a cropping/farming system can be connected linearly to the amount of crop residue put to the soil, and it has been found that increased residue lignin content also positively influences SOC accumulation. The amount of SOC that has previously been incorporated into the soil determines the net rate of accumulation (i.e., the size and capacity of the reservoir). Because they come into contact with soil microorganisms and soil water less frequently than residues that are absorbed through tillage, surface applied residues typically degrade more slowly.

3. Cover crop

The incorporation of cover crops into cropping systems is a viable strategy for sequestering carbon in agricultural soils. Cover crops, also known as inter-crops or catch crops, are plants that are sown in place of bare fallow during the winter and are ploughed under as green manure before the next major crop is sown. When compared to alternative management techniques that boost SOC, cover crops have the advantage of not reducing yields like intensification or causing carbon losses in other systems like organic manure applications. When utilised as mulch cover in water-constrained systems, cover crops have been found to improve biodiversity in addition to reducing soil erosion and drought stress for the crop that follows.

4. Addition of organic inputs

The SOC pool is influenced by organic amendments in the following ways: In order to fix atmospheric carbon through photosynthesis, organic fertilization, increases net primary output and adds to the pool of SOC already present, has the potential to accelerate SOC biodegradation in a manner similar to mineral fertilization. Utilizing external carbon sources, however, might not help to mitigate climate change. When organic fertilizers are applied, the majority of what happens is a displacement, with high concentrations of organic carbon at some sites but low amounts at donating sites. Net sequestration will happen (a) when organic fertilizers are produced for a specific farmland field or (b) when the carbon of the current fertilizer would otherwise be lost, such as by burning or with food wastes, to the environment. Overall, alternate uses for organic material are vital. Farmyard manure also seems to decompose quickly in soil, which could lead to less SOC stock due to increased microbial activity (priming effect). Farmyard manure application is supposed to improve soil structure and water holding capacity in agriculturally managed soils in addition to accelerating biodegradation.

5. Land use management

When compared to single crop rotational systems, diverse crop rotational systems can increase the soil's ability to sequester carbon. Mixed or polycultures have the potential to significantly increase the relatively low biomass produced by monoculture grain crops (e.g., agroforestry or agro-pastoral systems). The use of tree-based farming techniques can effectively sequester carbon. Agroforestry systems, which replace treeless land uses like croplands, pastures, and natural grasslands, have a greater potential to absorb atmospheric CO_2 than other land uses. However, the effects of these systems' parameters on SOC can vary significantly depending on their biophysical and socioeconomic properties. Particularly the addition of trees enhances the characteristics of the soil and can increase net C sequestration. Trees can delve deeply into the mineral soil due to extensive root systems. In deeper soil horizons, the root-derived C inputs are important sources for the SOC pool. Moreover, physicochemical interactions with soil particles are more likely to preserve root-derived C in the soil than shoot-derived C. In addition to decreasing losses and enhancing SOC pool, ley farming systems with regulated grazing and low stocking rates are also effective.

Conclusion

By increasing agro-ecosystem productivity, soil fertility, and carbon sequestration, improved soil management techniques are essential for combating climate change and ensuring food security. The addition of external carbon sources (farmyard manure, compost, etc.) and conservation tillage techniques can increase the amount of carbon in agricultural lands. Farmers can minimize the purposeful removal of crops (retention of crop residues), prevent soil erosion (cover crops, reduced tillage), or manage CO_2 from mineralization (reduced/no-tillage) to reduce organic carbon losses from soils. Site-specific carbon sequestering soil management techniques can subsequently be adopted based on this increased information.