Agri Articles
(e-Magazine for Agricultural Articles)
Volume: 03, Issue: 05 (SEP-OCT, 2023)
Available online at http://www.agriarticles.com

Soil Carbon Sequestration: Sustainable Practice

(*Om Prakash Sharma[1], Dheerendra Singh[1], Sunil Prajapati[2] and Subhash Mandloi[2])
[1]Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior, M.P.
[2]ICAR-Indian Institute of Soil Science, Bhopal. M.P.
*Corresponding Author's email: agriculturescientific1995@gmail.com

Abstract
Improper soil and crop management practices have resulted in loss of soil carbon. Worldwide, about 1417 Pg of soil carbon is stored in first meter soil depth, while 456-Pg soil carbon is stored in above–below ground vegetation and dead organic matter. Healthy soils can be helpful in combating the climate change because soils having high organic matter can have higher CO_2 sequestration potential. Main agronomic practices responsible for soil carbon loss include improper tillage operations, crop rotations, residue management, fertilization, and similarly no or less use of organic fertilizers that have resulted in the loss of soil organic matter in the form of CO2. The share of agriculture sector in the entire emissions of global GHGs in the form of CO_2, N_2O, and CH_4 is about 25–30%. Studies have shown that by adapting proper tillage operations, the use of such kind of crop rotations that can improve soil organic matter and similarly the application of organic fertilizers, i.e., FYM, compost, and other organic amendments such as humic acid, vermicompost, etc., can be useful in soil carbon sequestration.

Keywords: Soil Carbon, Agronomic Practices, Tillage, Crop Rotation, Crop Residues, Organic Fertilizers

Introduction
Part of what makes up soil is decomposed plant materials. This indicates that a significant amount of the carbon they contain was absorbed by the plants from the atmosphere during their life. Soils can "sequester" or store this carbon for a very long time, particularly in colder locations where decomposition is slower. The primary greenhouse gas responsible for climate change, carbon dioxide (CO_2), would be released back into the atmosphere if soil hadn't been there. However, transforming forested areas into farms affects the structure of the soil, releasing a large amount of carbon trapped there and accelerating climate change. Carbon is found in all living organisms and is the major building block for life on Earth. Carbon exists in many forms, predominately as plant biomass, soil organic matter, and as the gas carbon dioxide (CO_2) in the atmosphere and dissolved in seawater. Carbon sequestration is the longterm storage of carbon in oceans, soils, vegetation (especially forests), and geologic formations. Although oceans store most of the Earth's carbon, soils contain approximately 75% of the carbon pool on land three times more than the amount stored in living plants and animals. Therefore, soils play a major role in maintaining a balanced global carbon cycle.

Sequestration of Carbon in Soil
"Carbon farming," "regenerative agriculture," and other terms referring to the practise of managing land—especially farmland—so that soils absorb and retain more carbon are examples of soil carbon sequestration. Several strategies can be used to increase soil carbon:

(1) Lowering soil disturbance by planting perennial crops or using low-till or no-till techniques;
(2) Altering planting schedules or rotations, such as by planting cover crops or double crops rather than leaving fields fallow;
(3) Controlling livestock grazing; and
(4) Applying compost or crop residues to fields.

These methods can remove carbon dioxide (CO_2) from the atmosphere and store it in soils, which makes them a type of carbon removal in addition to offering local economic and environmental benefits.

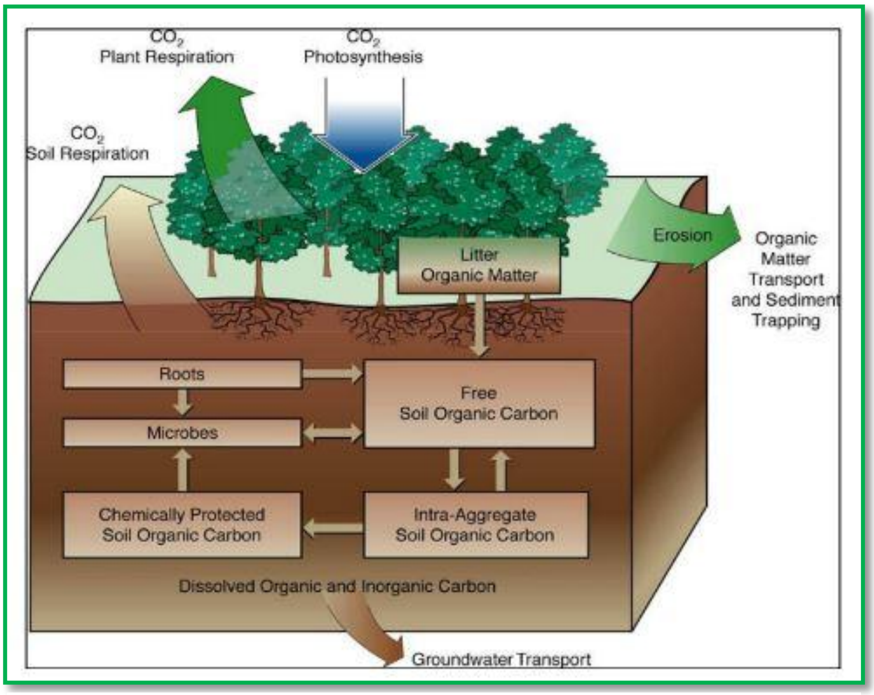

Fig 1: Soil carbon sequestration process

Storing carbon in agricultural soils

Scientists have estimated that soils mostly, agricultural ones could sequester over a billion additional tons of carbon each year. This has led policymakers to increasingly look to soil-based carbon sequestration as a "negative emissions" technology that is, one that removes CO_2 from the air and stores it somewhere it can't easily escape.

Cropland, which takes up 10% of the Earth's land, is a major target for soil-based carbon sequestration. Farmers can add more carbon to agricultural soils by planting certain kinds of crops. For example, perennial crops, which do not die off every year, grow deep roots that help soils store more carbon. "Cover crops" like clover, beans and peas, planted after the main crop is harvested, help soils take in carbon year-round, and can be ploughed under the ground as "green manure" that adds more carbon to the soil. Farmers can also do less intensive tilling. By breaking up the soil, tilling prepares land for new crops and helps control weeds, but also releases a lot of stored carbon.

Proponents argue that farming practices that store more carbon can also improve soil health and food production.

Co-Benefits and Concerns

- **Improved soil health**: soil carbon sequestration helps restore degraded soils, which can improve agricultural productivity.
- **Increased climate resilience**: healthier soils make farms more resilient against both droughts and heavy rainfall.
- **Reduced fertilizer use**: healthier soils require less fertilizer, saving farmers money and reducing environmental impacts
- **Saturation**: soils can only hold a finite amount of carbon; once they are saturated, societies will no longer be able to capture more carbon using soil carbon sequestration.
- **Reversibility**: the carbon captured via soil carbon sequestration can be released if the soils are disturbed; societies would need to maintain appropriate soil management practices indefinitely.

- **Difficulty of measurement**: monitoring and verifying carbon removal via soil carbon sequestration is currently difficult and costly.

Advantages and Possible Expenses of Managing Soils to Improve Carbon Sequestration

In agricultural systems, the management of the soil resource primarily determines the amount and duration of carbon storage. There are numerous agricultural techniques that have been suggested to improve carbon storage. When making judgements on management, it is important to take into account both the advantages of these different practises and any potential hidden costs. There might be direct or indirect financial costs and benefits for farmers to use these strategies, albeit they are not covered here.

Advantages of Carbon Sequestered in Soil

Improving soil carbon storage has several important benefits, one of which is removing CO_2 from the environment. Increasing the quantity of carbon retained in agricultural soils may lead to improved soil and water quality, decreased nutrient loss, reduced soil erosion, higher water conservation, and increased crop productivity. The following management strategies are effective in creating a net carbon sink in soils:

- Conservation tillage reduces or completely does away with soil modification for crop production. Mulch tillage is one of its practises; it involves leaving crop remains on the soil's surface. These methods often raise topsoil carbon concentrations, decrease soil erosion, and enhance water use efficiency. Additionally, conservation tillage can lower the quantity of fossil fuel that farming operations use. It is thought to be capable of sequestering a sizable quantity of CO_2.
- The practise of growing crops like tiny grains and clover between regular crop-production intervals for soil protection and improvement is known as cover cropping. By strengthening soil structure and enriching the soil with organic matter, cover crops increase carbon sequestration.
- A series of crops cultivated on the same plot of land in a regularly occurring succession is known as crop rotation. It is a more accurate representation of the diversity of natural ecosystems than intense monoculture methods. You can raise the amount of organic matter in the soil by changing the crops that are produced. Crop rotation periods and types, however, have an impact on how effective it is.

Techniques for reducing CO_2

Significant amounts of deforestation and the burning of fossil fuels have converted vast reservoirs of fossil carbon (coal and oil) into atmospheric carbon dioxide. Planting trees, planting soil carbon sequestration, and ocean carbon sequestration are some of the strategies used to reduce CO_2 in the atmosphere. Other technological approaches to lower carbon inputs include creating fuels with higher energy efficiency and working to create and use non-carbon energy sources. By lowering CO_2 levels in the atmosphere, these initiatives collectively can lessen global warming.

Potential Costs of Soil Sequestration of Carbon

Some agricultural practices that have been proposed as methods for sequestering carbon have hidden costs including the following:

Nitrogen fertilizer can increase soil organic matter because nitrogen is often limited in agroecosystems. However, the CO_2 released from fossil fuel combustion during the production, transport and application of nitrogen fertilizer can reduce the net amount of carbon sequestered. Nitrogen from fertilization can also run off agricultural lands into nearby waterways where it may have serious ecological consequences.

Growing plants on semiarid lands has been suggested as a way to increase carbon storage in soils. However, the fossil fuel costs of irrigating these lands may exceed any net gain in carbon sequestration.

Additionally, in many semi-arid regions surface and groundwater contain high concentrations of dissolved calcium, and bicarbonate ions. As these are deposited in the soil, they release CO_2 into the atmosphere.

Fig 2: Practical things you can do to help keep carbon in your soil: low or no-till, mulching, using perennials and mowing at the right height

Management for carbon sequestration affects other gases that influence climate such as atmospheric concentrations of nitrous oxide and methane. Changes in these gases must also be factored into management strategies for carbon storage. Furthermore, surface and groundwater in many semi-arid locations have significant quantities of dissolved calcium and bicarbonate ions. These emit CO_2 into the atmosphere as they are buried in the soil.

Methane and nitrous oxide concentrations in the atmosphere are two more gases that are impacted by carbon sequestration management. Management techniques for carbon storage must also take into account changes in these gases.

The Role of Forests in Reducing Atmospheric Carbon

As forests grow, they store carbon in woody tissues and soil organic matter. The net rate of carbon uptake is greatest when forests are young, and slows with time. Old forests can sequester carbon for a long time but provide essentially no net uptake. When forests are cut, the carbon they contain may be quickly returned to the atmosphere if the woody tissue is burned or converted to products, such as paper, that are short-lived. If the wood is used for construction or furniture, then those products retain carbon during their lifetimes and act as carbon sinks. A post harvest approach that reduces waste and puts most of the wood into long-lived products is an effective strategy to help reduce global atmospheric carbon. However, the net sink for carbon in long-lived wood products is still relatively small, so forest cutting ultimately acts to reduce the storage of carbon on land.

How are scientists attempting to comprehend the sequestration of carbon in soil?

The subject of carbon sequestration still has a lot to be learned. The following topics are being studied in researches:

• The effects of land management and use on soil carbon sequestration and strategies for extending the period of time that carbon is stored in the soil.

• The fundamental processes governing carbon storage and soil structure. Numerous biological, chemical, physical, mineralogical, and ecological processes are among them.

• The connections between increased nitrogen deposition in carbon storage, atmospheric CO2 levels, and biodiversity.

Limitations of soil-based carbon storage

There are hundreds of millions of farmers around the world, mostly farming small plots of land. To take full advantage of soil-based sequestration as a climate solution, we would need many of them to change the way they farm, now and for hundreds of years in the future. This is a big social and economic challenge, and experts debate how much soil-based sequestration is really possible over the long term.

Climate change is also making it harder for soils to naturally store carbon. The warming of the planet could lead to widespread soil carbon losses by speeding up the decay of soil organic matter. We are already seeing this happen in the Arctic as permafrost, or permanently frozen soil, thaws. This release of CO_2 to the atmosphere could become a self-reinforcing feedback loop, where lost soil carbon warms the Earth, causing soils to release even more carbon.

Ultimately, scientists say soil-based carbon sequestration, like other negative emissions technologies, can help fight climate change, but cannot take carbon out of the atmosphere as fast as we are currently adding it. To stop global warming, these efforts to store carbon must be coupled with drastic cuts in greenhouse gas emissions.

References

1. Wickings K, Grandy AS, Read SC, Cleveland CC. The origin of litter chemical complexity during decomposition (Njohnson Ed.). Ecology Letters. 2012;15(10):1180-1188
2. Syswerda SP, Corbin AT, Mokma DL, Kravchenko AN, Roberson GP. Agricultural management and soil carbon storage in surfaces vs deep layers. Soil Science Society of America Journal. 2011;75(1):92
3. Yeboah S, Zhang R, Cai L, Li L, Xie J, Lou Z, et al. Tillage effect on soil organic carbon, microbial biomass carbon and crop yield in spring wheat –field pea rotation. Plant, Soil and Environment. 2016;62(6):279-285
4. Trivedi A, Nandeha N and Mishra S. 2022. Dryland Agriculture and Farming Technology: Problems and Solutions. Climate resilient smart agriculture: approaches & techniques: 35-51.