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Carbon sequestration in agricultural soils: Practices and policies

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Abstract

Carbon sequestration in agricultural soils has emerged as a promising strategy to mitigate climate change while enhancing soil health and agricultural productivity. This paper provides a comprehensive review of the practices and policies that promote soil carbon sequestration, focusing on their potential to reduce atmospheric carbon dioxide (CO₂) levels and contribute to sustainable agriculture. The paper covers key practices such as conservation tillage, cover cropping, agroforestry, organic amendments, and crop rotation, as well as the role of policy frameworks in incentivizing carbon sequestration. Recent studies and case studies are analyzed to highlight the effectiveness of these practices and policies. The paper concludes with recommendations for scaling up soil carbon sequestration efforts and integrating them into global climate mitigation strategies.

Keywords: Carbon sequestration, practices and policies, climate change, soil health and agricultural productivity

1. Introduction

Climate change, driven by increasing atmospheric concentrations of greenhouse gases (GHGs), particularly carbon dioxide (CO₂), is one of the most pressing challenges of the 21st century. Agriculture is both a contributor to and a victim of climate change, accounting for approximately 25% of global GHG emissions while also being highly vulnerable to its impacts, such as extreme weather events, droughts, and shifting growing seasons. However, agricultural soils have the potential to act as a significant carbon sink, offering a dual benefit of mitigating climate change and enhancing soil health and productivity.

Carbon sequestration in agricultural soils involves capturing atmospheric CO₂ and storing it in soil organic matter (SOM) through various management practices. This process not only reduces GHG emissions but also improves soil health, water retention, and crop productivity. Despite its potential, soil carbon sequestration remains underutilized due to a lack of awareness, economic barriers, and insufficient policy support. This paper reviews recent advancements in soil carbon sequestration practices and policies, emphasizing their role in climate mitigation and sustainable agriculture. The review is structured into sections covering key practices, policy frameworks, challenges, and future directions (fig. 1).

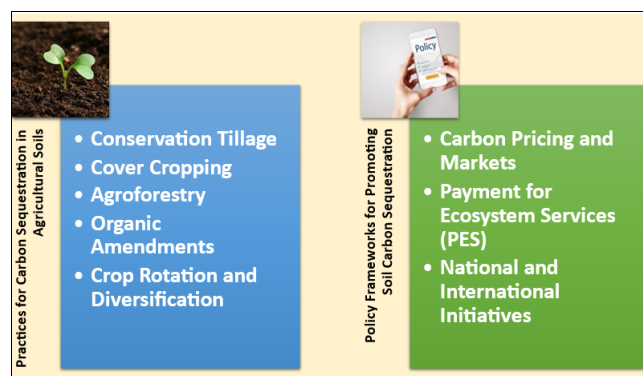


Fig 1: Practices and Policy Frameworks for Promoting Soil Carbon Sequestration in Agricultural Soils

2. Practices for Carbon Sequestration in Agricultural Soils

2.1 Conservation Tillage

Conservation tillage, including no-till and reduced-till practices, minimizes soil disturbance, thereby reducing carbon loss through erosion and oxidation. Traditional tillage practices expose soil organic matter to oxygen, accelerating its decomposition and releasing CO₂ into the atmosphere. In contrast, conservation tillage maintains soil structure, reduces erosion, and enhances carbon storage. Studies have shown that conservation tillage can increase soil organic carbon (SOC) stocks by 0.1-0.5 Mg C ha⁻¹ yr⁻¹ (Lal, 2004) ^[1]. For example, a meta-analysis by Powlson *et al.* (2022) ^[2] found that no-till farming increased SOC by 12% compared to conventional tillage. However, the effectiveness of conservation tillage varies depending on soil type, climate, and crop management practices.

2.2 Cover Cropping

Cover cropping involves growing crops during off-seasons to protect and enrich the soil. Cover crops, such as legumes, grasses, and brassicas, enhance carbon sequestration by adding organic matter to the soil and reducing erosion. They also improve soil structure, water infiltration, and nutrient cycling. Recent research (Peng *et al.*, 2023) ^[3] demonstrated that cover cropping can sequester 0.2-0.5 Mg C ha⁻¹ yr⁻¹, depending on climate and soil type. For instance, legume cover crops fix atmospheric nitrogen, reducing the need for synthetic fertilizers and further contributing to climate mitigation.

2.3 Agroforestry

Agroforestry integrates trees and shrubs into agricultural landscapes, enhancing carbon storage in both aboveground biomass and soil. Trees and shrubs sequester carbon through photosynthesis and store it in their biomass, while their roots contribute to soil organic matter. Agroforestry systems, such as alley cropping, silvopasture, and windbreaks, provide multiple benefits, including improved biodiversity, water regulation, and crop yields. A study by Nair *et al.* (2021) ^[4] reported that agroforestry systems can sequester 2-4 Mg C ha⁻¹ yr⁻¹, making them one of the most effective practices for soil carbon sequestration.

2.4 Organic Amendments

The application of organic amendments, such as compost, manure, and biochar, enhances SOC by increasing the input of organic matter. Compost and manure improve soil fertility and

microbial activity, while biochar, a stable form of carbon produced from biomass pyrolysis, has gained attention for its long-term carbon storage potential. Biochar is highly resistant to decomposition and can remain in the soil for centuries. A meta-analysis by Wang *et al.* (2023) ^[5] found that biochar application increased SOC by 20-40% in temperate and tropical soils. However, the effectiveness of organic amendments depends on their quality, application rate, and soil conditions.

2.5 Crop Rotation and Diversification

Crop rotation and diversification improve soil health and carbon sequestration by enhancing microbial activity and organic matter input. Monoculture systems deplete soil nutrients and reduce carbon stocks, while diversified crop rotations promote nutrient cycling and soil organic matter accumulation. A study by Witcombe *et al.* (2023) ^[6] showed that diversified crop rotations increased SOC by 0.3-0.6 Mg C ha⁻¹ yr⁻¹ compared to monoculture systems. For example, integrating legumes into crop rotations enhances nitrogen fixation and reduces the need for synthetic fertilizers, further contributing to climate mitigation.

3. Policy Frameworks for Promoting Soil Carbon Sequestration

3.1 Carbon Pricing and Markets

Carbon pricing mechanisms, such as carbon taxes and cap-and-trade systems, incentivize farmers to adopt carbon sequestration practices by providing financial rewards for reducing GHG emissions. Carbon markets allow farmers to earn carbon credits for sequestering carbon in their soils, which can be sold to industries and organizations seeking to offset their emissions. For example, the California Cap-and-Trade Program has successfully integrated agricultural carbon offsets, including soil carbon sequestration projects (Paustian *et al.*, 2021) ^[7]. However, the success of carbon markets depends on accurate measurement, reporting, and verification (MRV) of carbon sequestration.

3.2 Payment for Ecosystem Services (PES)

PES programs compensate farmers for adopting practices that enhance ecosystem services, including carbon sequestration. These programs recognize the value of ecosystem services provided by agricultural landscapes, such as carbon storage, water regulation, and biodiversity conservation. The European Union's Common Agricultural Policy (CAP) has incorporated PES schemes to promote sustainable land management (Marques *et al.*, 2024) ^[8]. For example, farmers in the EU receive payments for maintaining permanent grasslands, which have high carbon sequestration potential (Subash Sunar *et al.*, 2022) ^[10].

3.3 National and International Initiatives

Several national and international initiatives aim to promote soil carbon sequestration. The "4 per 1000" initiative, launched at the 2015 Paris Climate Conference, seeks to increase global SOC stocks by 0.4% annually to offset anthropogenic CO₂ emissions (Padarian *et al.*, 2022) ^[9]. Similarly, the U.S. Department of Agriculture's (USDA) Conservation Reserve Program (CRP) provides incentives for farmers to adopt conservation practices that enhance soil carbon storage. These initiatives highlight the importance of global cooperation in addressing climate change through soil carbon sequestration.

4. Challenges and Barriers (fig. 2)

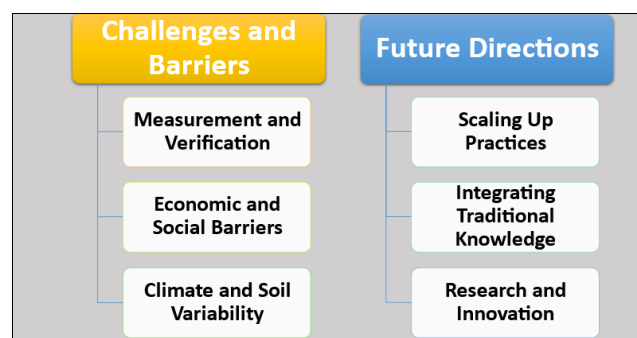


Fig 2: Challenges and Barriers in Soil Carbon Sequestration and Future Directions for Promoting Soil Carbon Sequestration in Agricultural Soils

4.1 Measurement and Verification

Accurately measuring and verifying changes in SOC stocks remains a significant challenge due to spatial and temporal variability. Traditional soil sampling methods are labor-intensive and costly, while remote sensing and machine learning technologies offer promising solutions for large-scale SOC monitoring (Viscarra Rossel *et al.*, 2021) ^[10]. However, these technologies require further development and validation to ensure their accuracy and reliability.

4.2 Economic and Social Barriers

High upfront costs and limited access to resources often hinder the adoption of carbon sequestration practices, particularly among smallholder farmers. Policy interventions, such as subsidies, technical assistance, and capacity-building programs, are needed to overcome these barriers (Amundson *et al.*, 2022) ^[11]. Additionally, farmers may be reluctant to adopt new practices due to perceived risks and lack of knowledge.

4.3 Climate and Soil Variability

The effectiveness of carbon sequestration practices varies depending on climate and soil conditions. For example, practices that work well in temperate regions may not be suitable for tropical or arid regions (Lal, 2004) ^[1]. Tailoring practices to local conditions and integrating traditional knowledge with modern scientific approaches can enhance their effectiveness.

5. Future Directions (fig. 2)

5.1 Scaling Up Practices

Scaling up soil carbon sequestration practices requires coordinated efforts among governments, researchers, and farmers. Public-private partnerships and farmer cooperatives can play a crucial role in promoting widespread adoption (Paustian *et al.*, 2021) ^[7]. For example, partnerships between governments and private companies can provide funding and technical support for large-scale carbon sequestration projects.

5.2 Integrating Traditional Knowledge

Integrating traditional knowledge with modern scientific approaches can enhance the effectiveness of carbon sequestration practices, particularly in developing countries (Nair *et al.*, 2021) ^[4]. Indigenous and local communities have valuable knowledge of sustainable land management practices that can complement modern technologies.

5.3 Research and Innovation

Continued research is needed to develop innovative practices and technologies for enhancing soil carbon sequestration. For example, bioengineering soil microbes to increase carbon

storage is an emerging area of interest (Wang *et al.*, 2023) ^[5]. Additionally, research on the long-term impacts of carbon sequestration practices on soil health and crop productivity is essential for their widespread adoption.

6. Conclusion

Carbon sequestration in agricultural soils offers a dual benefit of mitigating climate change and enhancing sustainable agriculture. By adopting practices such as conservation tillage, cover cropping, agroforestry, and organic amendments, farmers can significantly increase SOC stocks. However, the widespread adoption of these practices requires supportive policy frameworks, including carbon pricing, PES programs, and international initiatives. Addressing challenges related to measurement, economic barriers, and regional variability is essential for scaling up soil carbon sequestration efforts. Collaborative efforts among stakeholders are crucial to realizing the full potential of soil carbon sequestration in achieving global climate mitigation goals.

7. References

- Lal R. Soil carbon sequestration to mitigate climate change. *Geoderma*. 2004;123(1-2):1-22.
- Powlson DS, Poulton PR, Glendining MJ, Macdonald AJ, Goulding KW. Is it possible to attain the same soil organic matter content in arable agricultural soils as under natural vegetation? *Outlook Agric*. 2022;51(1):91-104.
- Peng Y, Rieke EL, Chahal I, Norris CE, Janovicek K, Mitchell JP, *et al.* Maximizing soil organic carbon stocks under cover cropping: insights from long-term agricultural experiments in North America. *Agric Ecosyst Environ*. 2023;356:108599.
- Nair PR, Kumar BM, Nair VD, Nair PR, Kumar BM, Nair VD. Carbon Sequestration and Climate Change Mitigation. In: Nair PR, Kumar BM, Nair VD, editors. *An Introduction to Agroforestry: Four Decades of Scientific Developments*. 2021. p. 487-537.
- Wang L, Chen D, Zhu L. Biochar carbon sequestration potential rectification in soils: Synthesis effects of biochar on soil CO₂, CH₄ and N₂O emissions. *Sci Total Environ*. 2023;904:167047.
- Witcombe AM, Tiemann LK, Chikowo R, Snapp SS. Diversifying with grain legumes amplifies carbon in management-sensitive soil organic carbon pools on smallholder farms. *Agric Ecosyst Environ*. 2023;356:108611.
- Paustian K, *et al.* Carbon markets and soil carbon sequestration: Opportunities and challenges. *Environ Res Lett*. 2021.
- Marques A, Bonn A, Castro AJ, Chaudhary AR, Felipe-Lucia MR, Kastner T, *et al.* The role of nature's contributions to people in sustaining international trade of agricultural products. *People Nat*. 2024;6(2):410-421.
- Padarian J, Minasny B, McBratney A, Smith P. Soil carbon sequestration potential in global croplands. *PeerJ*. 2022;10:e13740.
- Sunar S, Sapkota D, Dumre A, Bhattarai I, Sharma DR, Sapkota MM. Status of farm mechanization on rice production: A case study of Banganga Municipality, Kapilvastu, Nepal. *Int J Agric Extension Social Dev*. 2022;5(1):28-31. DOI:10.33545/26180723.2022.v5.i1a.120
- Viscarra Rossel RA, *et al.* Advances in soil carbon monitoring using remote sensing and machine learning. *Remote Sens Environ*. 2021.
- Amundson R, Buck H, Lajtha K. Soil science in the time of climate mitigation. *Biogeochemistry*. 2022;161(1):47-58.