



Carbon Sequestration

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Growing concerns regarding global warming and carbon emissions have spurred interest in techniques for carbon sequestration, aimed at capturing and storing carbon released from the burning of fossil fuels. Human activities already have a significant impact on almost half of the terrestrial biological carbon cycle (Hughes and Benemann, 1997). Effectively managing this cycle could make a substantial contribution to CO₂ mitigation (Farrelly et al., 2013). A significant portion of the carbon dioxide (CO₂) emissions generated by human activity stems from the combustion of fossil fuels for energy production. The adverse effects of elevated CO₂ levels in the atmosphere on the environment are widely acknowledged. Consequently, we are progressively increasing the concentration of carbon in the atmosphere, which ultimately leads to global warming and climate change (Soon *et al.*, 1999; Farrelly et al., 2013). Various approaches can be explored to reduce carbon in the atmosphere and mitigate the negative impacts of climate change. One such approach is carbon sequestration, which can range from being affordable and straightforward to expensive and intricate. This includes natural carbon sequestration as well as geological carbon sequestration.

Carbon sequestration

Carbon sequestration is a fundamental process aimed at mitigating climate change by capturing carbon dioxide (CO₂) emissions from the atmosphere and storing them in long-term reservoirs. This process assumes great significance due to the role of CO₂ as a primary contributor to global warming. Lal (2007) defines soil carbon sequestration as the process of capturing atmospheric CO₂ and securely storing it within the pedosphere, thereby enhancing its mean residence time (MRT) while minimizing re-emission sources. It is widely acknowledged that carbon sequestration plays a crucial role in the battle against climate change. However, to achieve substantial reductions in atmospheric CO₂ levels, a combination of diverse methodologies may be necessary. Ongoing research and development efforts in the field of carbon sequestration technologies remain indispensable in meeting the challenges posed by climate change.

Important sources and methods of carbon

1. Forests as a carbon sink: Afforestation, reforestation, plantation, and agroforestry are all practices that contribute to carbon sequestration. These approaches involve the uptake of atmospheric carbon through photosynthesis, which is then stored in the form of biomass or wood. The success of carbon sequestration in these practices relies on ensuring that the carbon does not return to the atmosphere through burning processes.

2. Wetland restoration: Wetland soils serve as significant natural carbon pools or sinks. Globally, wetlands retain approximately 14.5% of the soil carbon, despite covering only 6% of the Earth's land area.

3. Oceans as a carbon sink: Oceans act as absorbers of carbon dioxide from the atmosphere, primarily due to the higher concentration of CO₂ in the atmosphere compared to that in the oceans. The difference in CO₂ partial pressure between the atmosphere and oceans leads to the absorption of CO₂ into the world's oceans (Raghuvanshi et al., 2006).

4. Subterranean injection or geological sequestration: Carbon dioxide can be injected into depleted oil and gas reservoirs, geological formations, or deep ocean regions, a process known as subterranean injection. This method of carbon sequestration involves selecting appropriate sites for injecting CO₂, such as depleted oil and gas reservoirs, to securely store the carbon dioxide (Dhanwantri et al., 2014).

These scientific approaches contribute to the understanding and implementation of carbon sequestration strategies, playing a crucial role in mitigating the impacts of carbon emissions and addressing climate change.

The key reasons why carbon sequestration is so important

1. Mitigating greenhouse gas emissions: Carbon sequestration plays a vital role in mitigating greenhouse gas emissions, particularly by reducing the concentration of carbon dioxide (CO₂) in the atmosphere. By effectively removing CO₂ from the atmosphere, carbon sequestration contributes to mitigating the impacts of climate change, such as rising global temperatures, altered precipitation patterns, and increased frequency of extreme weather events. This is essential for safeguarding ecosystems, reducing vulnerabilities, and preserving biodiversity.

2. Advancing sustainable land management: Numerous carbon sequestration methods necessitate changes in land use, such as afforestation, reforestation, and sustainable agricultural practices. These land management strategies not only facilitate carbon capture but also promote sustainable land use practices. They help protect and restore ecosystems, enhance soil quality, preserve water resources, and support the livelihoods of local communities. By integrating carbon sequestration into land management practices, we can achieve multiple environmental and socio-economic benefits.

3. Enhancing soil fertility and productivity: Soil carbon sequestration enhances soil health, which has direct implications for plant growth, nutrient cycling, and overall agricultural productivity. Increased carbon content in soils improves soil structure, water retention capacity, and nutrient availability, fostering optimal conditions for plant growth. By enhancing soil fertility, carbon sequestration practices contribute to sustainable agriculture, food security, and the resilience of agricultural systems in the face of climate change.

4. Fostering technological innovation: Carbon sequestration is a rapidly evolving field, constantly exploring new technologies, methodologies, and monitoring techniques. Investing in carbon sequestration research and development promotes technological innovation, driving advancements in carbon capture, storage, and utilization. This fosters the growth of a green economy, stimulates job creation, and catalyzes the emergence of novel solutions for addressing climate change challenges.

5. Meeting international climate targets: Carbon sequestration constitutes a critical component of international climate agreements and commitments, such as those outlined in the Paris Agreement. By actively implementing carbon sequestration strategies, countries can contribute to achieving their emission reduction targets, promoting sustainable development, and transitioning towards a low-carbon future. The integration of carbon sequestration into climate policies and strategies strengthens global efforts to limit global warming and mitigate the impacts of climate change.

The objectives of soil carbon sequestration encompass various scientific considerations, including:

- 1. Offsetting anthropogenic emissions:** Soil carbon sequestration aims to counterbalance carbon emissions originating from activities such as fossil fuel combustion, cement production, and deforestation. By capturing and storing carbon in the soil, it mitigates the net increase in atmospheric CO₂ concentration and helps maintain carbon equilibrium.
- 2. Reducing atmospheric CO₂ concentration and pool:** An important objective of soil carbon sequestration is to curtail the rise in atmospheric CO₂ levels, which surpassed 400 parts per million by volume (ppmv) in 2013. Additionally, efforts are directed towards expanding the soil carbon pool, which currently stands at approximately 800 petagrams of carbon (PgC).
- 3. Enhancing soil organic carbon concentration:** Soil carbon sequestration endeavors to elevate soil organic carbon (SOC) concentration above the critical threshold range of 1.5-2.0%. Higher SOC levels promote soil fertility, augment nutrient cycling dynamics, and improve water retention capacity. These enhancements contribute to enhanced soil quality and bolster ecosystem functions.
- 4. Restoring soil quality and ecosystem functions:** Soil carbon sequestration initiatives prioritize the restoration of soil quality and the associated functions and services it provides. This includes the preservation and promotion of biodiversity, heightened nutrient retention capabilities, improved water infiltration rates, and the reduction of soil erosion and nonpoint source pollution.
- 5. Improving water and nutrient retention capacity:** An objective of soil carbon sequestration is to enhance the soil's ability to retain water and nutrients. This improvement increases the efficiency of resource utilization in managed ecosystems, leading to sustainable agricultural practices with reduced losses of valuable inputs.
- 6. Creating climate-smart soils and agroecosystems:** Soil carbon sequestration contributes to the development of climate-smart soils and agroecosystems. These systems exhibit resilience to climate change, actively mitigate greenhouse gas emissions, and enhance carbon storage while ensuring sustainable food production.
- 7. Increasing productivity and advancing food security:** By implementing effective soil carbon sequestration practices, it is possible to augment and sustain agronomic productivity. This achievement has far-reaching implications for food security, particularly in regions where agricultural productivity is hampered by degraded soils.

In summary, soil carbon sequestration aligns with a range of scientific objectives. By offsetting anthropogenic emissions, reducing atmospheric CO₂ concentrations, enhancing soil organic carbon levels, restoring soil quality, improving resource efficiency, fostering climate resilience, and promoting food security, it emerges as a scientifically informed approach to address climate change and foster sustainable development.

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