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Soil Carbon Sequestration and Carbon Trading: A Sustainable Pathway for Climate Change Mitigation and Agricultural Development

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Soil carbon sequestration is a key strategy for mitigating climate change while enhancing soil fertility and agricultural sustainability. Soil carbon trading enables farmers to earn carbon credits by adopting sustainable land management practices that increase soil organic carbon (SOC). These credits can be traded in carbon markets, creating economic incentives for climate-smart agriculture. This paper reviews the mechanisms of soil carbon sequestration, carbon trading frameworks, and their integration with climate policies. It also highlights opportunities, challenges, and future prospects, especially in developing countries like India. The study concludes that strong policy frameworks, technological innovations, and farmer participation are essential for scaling soil carbon trading systems.

Introduction

Climate change is a major global challenge driven by increasing greenhouse gas (GHG) emissions. Agriculture contributes significantly (around 25–30%) to global emissions, but it also offers mitigation opportunities through soil carbon sequestration. Soil acts as a **carbon sink**, capturing atmospheric CO_2 and storing it as soil organic carbon (SOC). Carbon trading mechanisms have emerged as market-based solutions where carbon sequestration activities are rewarded economically. A **carbon credit** represents **one metric tonne of CO_2 equivalent removed or reduced**, which can be traded in carbon markets.

Soil Carbon Sequestration: Concepts and Mechanisms

Soil carbon sequestration is the process of capturing atmospheric CO_2 and storing it in soil organic matter through biological and physical processes.

[1] **Mechanisms**

- Photosynthesis → CO_2 fixation
- Root biomass addition
- Microbial transformation into humus
- Stabilization in soil aggregates

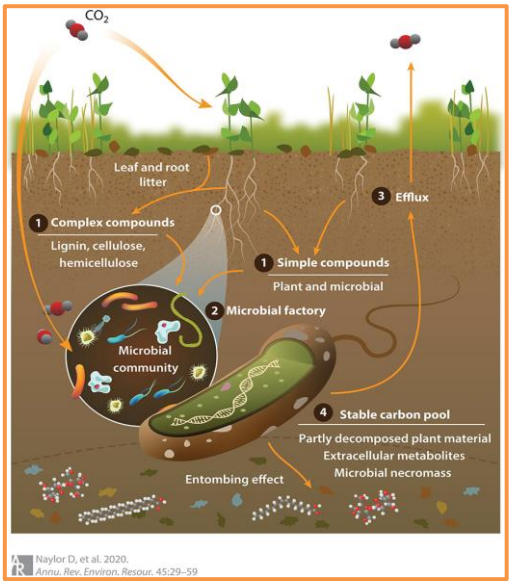
Soil organisms convert plant residues into stable SOC through microbial processes.

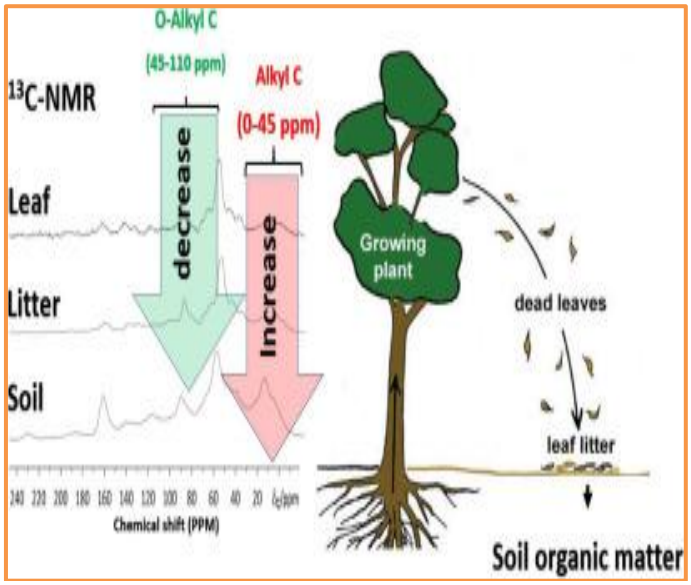
[2] **Sequestration Potential**

- SOC increase: **0.4–1.2 Mg C ha^{-1} $year^{-1}$** under improved practices
- Major contributing practices:

✓ Conservation agriculture
✓ Agroforestry
✓ Biochar application
✓ Crop residue management

Soil Carbon Sequestration Process



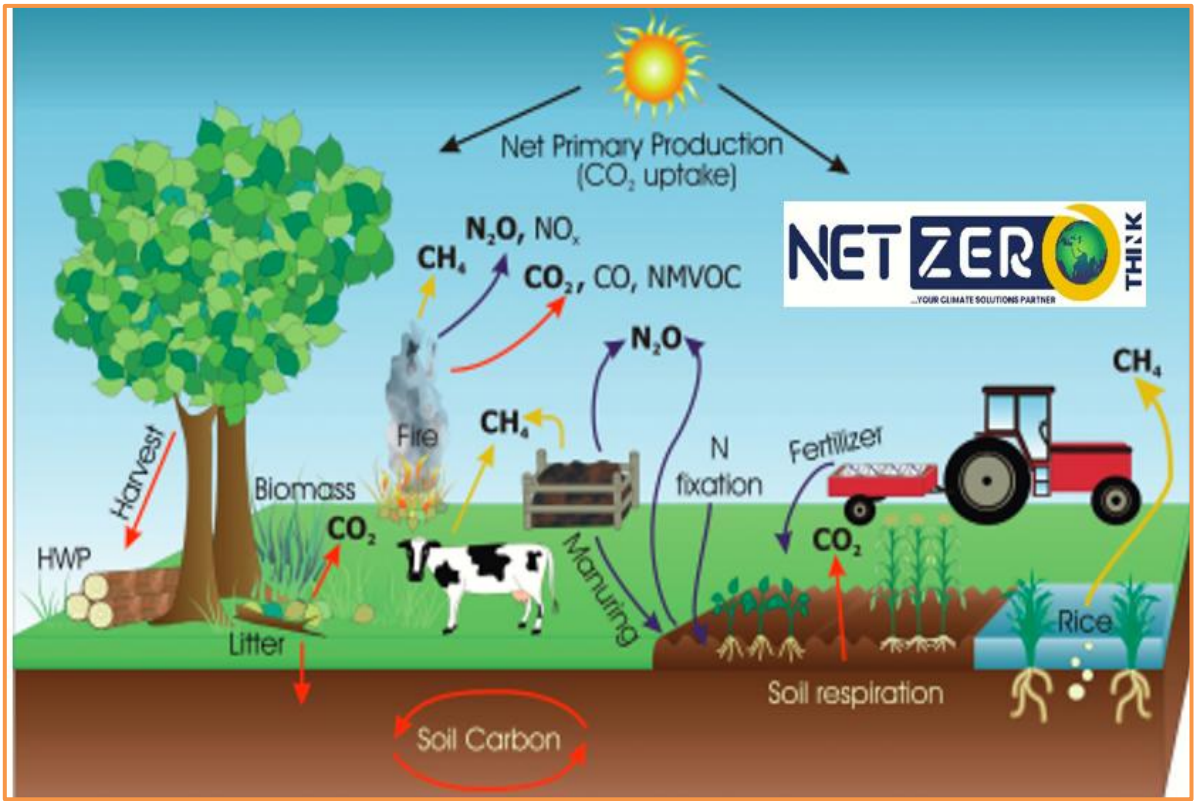


Soil Carbon Trading

Soil carbon trading involves generating and selling carbon credits through increased SOC storage.

[1] **Mechanism**

1. Adoption of sustainable practices
2. Measurement of SOC increase
3. Verification & certification
4. Issuance of carbon credits
5. Trading in carbon markets



Carbon trading is considered a **market-based instrument** to reduce emissions while promoting sustainability. In agriculture, voluntary carbon markets are more common due to flexibility and lower regulatory barriers.

Carbon Farming Practices


Key practices include:

- No-tillage / conservation tillage
- Cover cropping
- Crop rotation
- Organic amendments (FYM, compost)
- Agroforestry

These practices improve both **soil fertility and carbon sequestration**

Opportunities of Soil Carbon Trading

- Climate change mitigation
- Improved soil health and productivity
- Additional income for farmers
- Sustainable agriculture promotion

Carbon farming is considered a **win-win solution** for productivity and climate mitigation.

Challenges and Limitations

1. **Scientific Challenges**
- Measurement uncertainty
- Carbon permanence issues
- Variability due to climate

2. **Economic Challenges**
- High transaction costs
- Low carbon prices
- Unequal benefits for small farmers

3. **Policy Challenges**
- Lack of stable policies
- Weak institutional frameworks

Participation depends on **policy stability, incentives, and trust systems**.

Soil Carbon Trading in India

India has high potential due to:

- Large agricultural land
- Low SOC levels

Carbon trading in agriculture is gaining attention as a tool for emission reduction and sustainable farming.

Initiatives include:

- Climate-smart agriculture
- Carbon credit pilot projects
- ICAR-led research

Future Prospects

- AI & remote sensing for SOC monitoring
- Blockchain for carbon trading transparency
- Integration with precision agriculture
- Global carbon market expansion

However, improving **measurement accuracy and policy frameworks** is critical.

Conclusion

Soil carbon trading offers a promising pathway for achieving climate mitigation and agricultural sustainability. While scientific and policy challenges exist, advancements in technology and supportive policies can enhance its adoption. Developing countries like India can significantly benefit from integrating soil carbon sequestration into climate policy frameworks.