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Role of Organic Farming in Carbon Sequestration for Healthy Soil, Healthy Climate

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Soil health is fundamentally linked to climate regulation, agricultural productivity and ecosystem sustainability. Rising atmospheric carbon dioxide (CO₂) concentrations have intensified global climate change, threatening food security and environmental stability. Soil carbon sequestration has emerged as a practical and cost-effective mitigation strategy. Organic farming systems, characterized by residue recycling, diversified cropping, organic manuring, and reduced chemical inputs, enhance soil organic carbon (SOC) stocks while sustaining productivity. This review synthesizes current knowledge on the mechanisms, management practices and carbon sequestration potential of organic farming systems, particularly under Indian agro-ecological conditions. Evidence suggests that organic agriculture improves soil carbon dynamics, enhances microbial activity, increases aggregate stability, and contributes to climate resilience. Integrating organic farming with agroforestry and conservation agriculture strengthens the soil–climate nexus and promotes sustainable development.

Introduction: From Climate Threat to Farming Opportunity

In recent years, farmers across India have been experiencing unusual weather patterns delayed monsoons, sudden heavy rains, prolonged dry spells, and rising temperatures. These changes are not accidental; they are strongly linked to increasing levels of carbon dioxide (CO₂) and other greenhouse gases in the atmosphere. Agriculture both influences and is influenced by climate change. While farming activities contribute to greenhouse gas emissions through fertilizer use, livestock, and residue burning, agriculture also has tremendous potential to become part of the solution.

One of the most promising solutions is carbon sequestration, which means capturing carbon dioxide from the atmosphere and storing it safely in soil and vegetation. When farmers improve soil health through organic and conservation practices, they are not only improving crop productivity but also helping to reduce the impact of climate change. Soils represent the largest terrestrial carbon reservoir, storing approximately 1500–2000 gigatonnes (Gt) of carbon in organic and inorganic forms. Even small increases in soil organic carbon can substantially reduce atmospheric CO₂ concentrations. Soil carbon sequestration, therefore, provides a dual benefit—climate change mitigation and improved soil fertility.

Organic farming, by promoting biological processes and minimizing soil disturbance, offers significant potential to enhance SOC stocks. This review examines the scientific basis, mechanisms, and practical implications of carbon sequestration under organic farming system

Mechanisms of Carbon Sequestration in Organic Farming

Organic farming enhances carbon sequestration through multiple pathways:

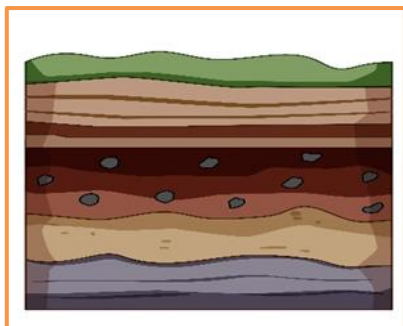
- ✓ **Enhanced Biomass Production and Recycling:** Organic systems emphasize residue retention, green manuring, and compost application. Increased organic inputs raise carbon inflow into soil.
- ✓ **Reduced Soil Disturbance:** Many organic systems adopt reduced tillage practices, minimizing oxidation of soil carbon.
- ✓ **Improved Microbial Activity:** Organic amendments stimulate soil microbial biomass and enzymatic activity, leading to humus formation and stable carbon pools.
- ✓ **Aggregate Formation and Carbon Protection:** Organic matter promotes formation of macro- and micro-aggregates that physically protect organic carbon from rapid decomposition.
- ✓ **Diversified Cropping Systems:** Crop rotation and inclusion of legumes increase root biomass diversity, enhancing below-ground carbon inputs.

Understanding Soil Organic Carbon: The Foundation of Healthy Farming

Soil is much more than a medium to hold plants. It is a living system containing roots, microorganisms, and decomposed organic matter. A major component of soil health is **Soil Organic Carbon (SOC)**, which forms about 58 percent of soil organic matter. This carbon originates from crop residues, roots, manures, and decomposed plant materials.

When soil contains adequate organic carbon, it becomes fertile, loose, and capable of retaining water. Such soils support strong root growth, better nutrient absorption, and higher resistance to drought. In contrast, soils low in organic carbon become compact, lose moisture quickly, and require higher fertilizer inputs to maintain yields.

Increasing soil carbon is therefore not merely an environmental activity—it is directly connected to farm productivity and profitability.



How Carbon Sequestration Happens in Agriculture

Plants absorb carbon dioxide from the air during photosynthesis and convert it into plant biomass. A portion of this carbon remains stored in plant stems, leaves, and roots. When plant residues fall onto the soil or roots decompose, part of that carbon becomes stabilized within the soil as organic carbon. If soil is managed carefully, this stored carbon remains locked in the soil for many years.

However, intensive ploughing, residue burning, and poor land management accelerate the breakdown of organic matter and release carbon back into the atmosphere. Therefore, proper soil management is essential to ensure that carbon input is greater than carbon loss.

Organic Farming Practices Contributing to Carbon Sequestration

✓ Composting and Farmyard Manure

The application of compost, farmyard manure (FYM), and vermicompost increases soil carbon inputs and stimulates microbial processes. Long-term experiments in India have demonstrated higher SOC stocks under integrated nutrient management compared to sole chemical fertilizer use.



✓ Cover Cropping and Green Manuring

Cover crops reduce erosion, enhance nitrogen fixation, and increase carbon inputs through root biomass. Legumes such as sunhemp and cowpea improve soil organic matter and stabilize carbon pools.



✓ Agroforestry Integration

Agroforestry systems integrate trees with crops, significantly enhancing above-ground and below-ground carbon storage. Trees act as long-term carbon sinks, storing carbon in woody biomass and deep root systems. Studies report carbon sequestration rates ranging from 0.3 to 15 t C ha⁻¹ yr⁻¹ depending on species and management.



✓ Biochar Application

Biochar is a stable, carbon-rich product obtained through pyrolysis. It resists microbial decomposition and remains in soil for extended periods. Biochar improves soil physical properties and contributes to long-term carbon storage.

Carbon Sequestration Potential in Indian Conditions

India's diverse agro-climatic zones provide significant scope for SOC restoration, especially in degraded and dryland areas. Long-term experiments indicate that organic and conservation practices can increase SOC by 0.2–0.8 t ha⁻¹ yr⁻¹ under favorable conditions. Research from dryland systems in southern India has demonstrated enhanced carbon input-output balance under conservation tillage and cover crop integration. Agroforestry systems such as *Melia dubia* and custard apple-based models show promising carbon accumulation trends.

Benefits Beyond Carbon: Soil Health and Productivity

Increasing SOC provides multiple co-benefits:

- Improved nutrient availability
- Enhanced soil structure and porosity
- Greater drought tolerance
- Reduced erosion
- Increased microbial biodiversity
- Improved crop yield stability

Healthy soils buffer climatic variability and reduce production risks.

Challenges and Limitations

Despite its benefits, carbon sequestration through organic farming faces certain challenges:

- Slow rate of SOC accumulation
- Need for long-term management
- Initial yield transition phase
- Limited awareness among farmers
- Inadequate policy incentives

Sustained institutional support and extension efforts are required.

Policy and Future Directions

Global initiatives such as the “4 per 1000” initiative emphasize increasing global soil carbon stocks annually. In India, integrating organic farming with national missions on sustainable agriculture can strengthen climate mitigation strategies.

Future research should focus on:

- Quantifying long-term SOC changes
- Developing carbon credit systems for farmers
- Integrating remote sensing and modelling tools
- Enhancing farmer awareness and training

Conclusion: Farmers as Climate Guardians

Carbon sequestration in agriculture is not an abstract scientific concept. It is a practical, field-level approach that directly benefits farmers. By improving soil organic carbon, farmers can achieve better crop yields, greater drought tolerance, and reduced dependency on costly inputs. Agriculture has the potential to shift from being a contributor to climate change to becoming a powerful solution. Through conservation agriculture, organic manuring, agroforestry, and improved soil management, Indian farmers can act as climate guardians while securing their own livelihoods. The future of sustainable farming lies beneath our feet—in the carbon stored within our soils.

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