



Soil Carbon Sequestration for Climate Mitigation: Strategies, Challenges and Policy Implications for India

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Soils are the largest terrestrial reservoir of organic carbon, holding an estimated 2,300 gigatonnes, far more than the atmosphere or all living vegetation combined. When land is ploughed intensively, left bare, burnt or eroded, part of this carbon returns to the air as carbon dioxide. When it is managed well, the process reverses: plants capture CO₂, and a fraction is converted into stable soil organic matter. This is soil carbon sequestration. For India, the idea is more than a climate measure. It speaks to three national priorities at once: food security, farmer incomes and the country's commitment to reach net-zero emissions by 2070. Healthy, carbon-rich soil holds more water, supplies nutrients more efficiently and buffers crops against heat and erratic monsoons.

The Indian Context: Large Potential, Depleted Starting Point

India has roughly 140 million hectares of cropland and about 59.3 million hectares of degraded land. Years of intensive cultivation, residue burning, nutrient-imbalanced fertiliser use and erosion have left many soils low in organic carbon. A commonly cited figure, repeated in policy commentary, is that more than 60 per cent of Indian soils have organic carbon below 0.5 per cent, against a level of 1.5 to 2 per cent considered favourable for productive agriculture. This low baseline is, paradoxically, the opportunity. Soils far from carbon saturation can absorb more carbon than soils already near their ceiling. Peer-reviewed estimates suggest that the total soil organic carbon sequestration potential of India lies between about 78 and 106 million tonnes of carbon per year, with the largest shares coming from erosion control, secondary carbonate formation, agricultural intensification and restoration of degraded soils (Purakayastha, 2016). Other analyses offer different figures depending on assumptions, which is itself an important message: the numbers are indicative, not guaranteed.

Strategies: What Works on the Ground

- 1. Conservation agriculture.** Reduced or zero tillage, permanent soil cover and crop diversification limit the oxidation of soil carbon. Studies cited for Indian conditions report accumulation of up to about 1.8 tonnes of carbon per hectare per year in the first decade of adoption, though results vary widely with climate and soil type.
- 2. Integrated nutrient management.** Combining balanced chemical fertiliser with farmyard manure has been shown to build carbon at roughly 0.95 tonnes per hectare per year under rainfed conditions.
- 3. Organic amendments and green manuring.** Compost, farmyard manure, crop residues and green manure crops such as dhaincha add the raw material for stable soil organic matter. Natural farming programmes in Andhra Pradesh have reported increases in soil organic carbon over a few years, although these figures need independent, long-term verification.
- 4. Agroforestry and tree-based systems.** Trees on farm boundaries and within fields store carbon in biomass and add leaf litter and root carbon to the soil, while diversifying farm income.

5. Residue management instead of burning. Retaining or incorporating residues, particularly in the rice-wheat belt of the Indo-Gangetic Plain, returns carbon to the soil and reduces air pollution.

6. Biochar and restoration of degraded land. Biochar, produced by heating biomass with limited oxygen, resists microbial decomposition and can lock carbon away for long periods. Reclamation of degraded lands through watershed management, afforestation and soil conservation delivers carbon and yield gains together.

Challenges: Why Progress Is Harder Than It Looks

Climate limits. Soils in arid and semi-arid regions, which cover a large part of India, generally accumulate carbon more slowly than soils in humid regions because of limited biomass production and high temperatures.

Saturation and reversibility. Soil carbon gains plateau over time and can be lost quickly if good practices are abandoned. Unlike a forest that is protected by law, soil carbon depends on continued management.

Measurement, reporting and verification (MRV). Soil carbon changes slowly and varies from one patch of a field to another, so detecting real change requires careful sampling, laboratory analysis and often years of data. This makes credible carbon accounting costly, especially for India's small farms.

Smallholder structure. Most Indian farms are small, so aggregating thousands of farmers into a project is complex and transaction costs can swallow the benefits.

Competing demands for biomass. Crop residues are also used as animal fodder and fuel, so returning them to the soil involves trade-offs.

Incentive distortions. Heavy subsidies on urea have encouraged nutrient-imbalanced fertiliser use, with limited support for organic inputs.

Carbon market integrity. Voluntary soil carbon markets have drawn scepticism worldwide because of concerns about permanence, additionality and over-estimation of credits. Developers and white papers describe large potential for soil carbon credits in India, but such claims should be treated cautiously until independently verified.

Policy Landscape and Implications

India already has several building blocks in place. The Soil Health Card scheme has issued crore of cards to farmers, giving crop-specific nutrient advice. The National Mission on Natural Farming, the Green India Mission and the Carbon Credit Trading Scheme point toward integrating soil and land management into climate policy. India has also pledged to create an additional carbon sink as part of its nationally determined contribution, and recent modelling suggests that land-based sequestration could play a meaningful, though uncertain, role in the country's net-zero pathway.

Recommendations for Policymakers

1. **Set a national soil organic carbon baseline.** Build on soil health data to create a regularly updated, geo-referenced carbon map.
2. **Invest in affordable MRV.** Support research institutions, remote sensing and low-cost laboratory networks so smallholders can participate credibly.
3. **Reform input subsidies.** Gradually tilt support toward balanced nutrition, compost, bio-inputs and conservation practices.
4. **Pay for outcomes and practices.** Combine public incentives with well-regulated carbon markets, ensuring that farmers receive a fair and transparent share.
5. **Protect integrity.** Establish national standards on permanence, additionality and monitoring, with buffer reserves against reversal.
6. **Strengthen farmer extension.** Training through Krishi Vigyan Kendras and farmer producer organisations is essential, because practices only work when farmers understand and trust them.

7. **Prioritise co-benefits.** Frame soil carbon as a food security, water security and income strategy first, with climate mitigation as an additional return.

Conclusion

Soil carbon sequestration will not replace the need to cut fossil fuel emissions, and its scale and permanence should not be overstated. But for India, rebuilding soil carbon is one of the few climate actions that can also raise yields, save water and improve rural livelihoods. The task now is to move from promising estimates to measured results, through credible science, sound incentives and farmer-centred delivery.

References

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