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Biochar-Based Carbon Capture: A Sustainable Solution for Indian Agriculture

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Biochar and other bio-based carbon capture strategies are emerging as promising tools to address soil degradation, climate change, and low carbon sequestration rates in Indian agriculture. This article reviews the scientific basis, field applications, and potential benefits of biochar and other biological methods under Indian agro-climatic conditions.

Introduction

India faces critical agricultural challenges: declining soil organic carbon (SOC), frequent droughts, residue burning, and rising greenhouse gas (GHG) emissions. Bio-based carbon capture especially biochar, cover crops, composting, and microbial inoculants presents scalable solutions aligned with India's climate-smart agriculture goals. Biochar, produced through pyrolysis of crop residues, offers long-term carbon storage while improving soil fertility, water retention, and nutrient efficiency. With India generating over 500 million tons of agricultural biomass annually, converting residues into biochar rather than burning them could have transformative environmental and economic impacts. Sequestration of atmospheric carbon to the soil is a challenging task for the scientific community to mitigate the rising concentration of atmospheric carbon dioxide (CO_2). Biochar, due to its aromatic structure and long mean residence time in the soil (more than 100 years) has the potential for long-term carbon sequestration in the soil. The trend obtained from the meagre published literature raised our hopes of achieving the goal of enhancing the productivity of different crops along with environmental sustainability. According to an estimate, global production of black carbon has been reported between 50 and 270 Tg yr–1, with as much as 80% of this remaining as residues in the soil. Biochar decomposition rate is slow in the soil, which indicates that it could be the possible answer to mitigation of elevated atmospheric CO_2.

Scientific Basis of Biochar

Biochar is a porous, carbon-rich, thermally stable material. Its key scientific benefits include: Long-Term Carbon Sequestration: Biochar's aromatic carbon structure resists decomposition, storing carbon for hundreds to thousands of years.

Soil Fertility Enhancement

Biochar improves

- ✓ Cation exchange capacity (CEC)
- ✓ Water holding capacity
- ✓ Soil microbial habitat
- ✓ Nutrient retention and availability

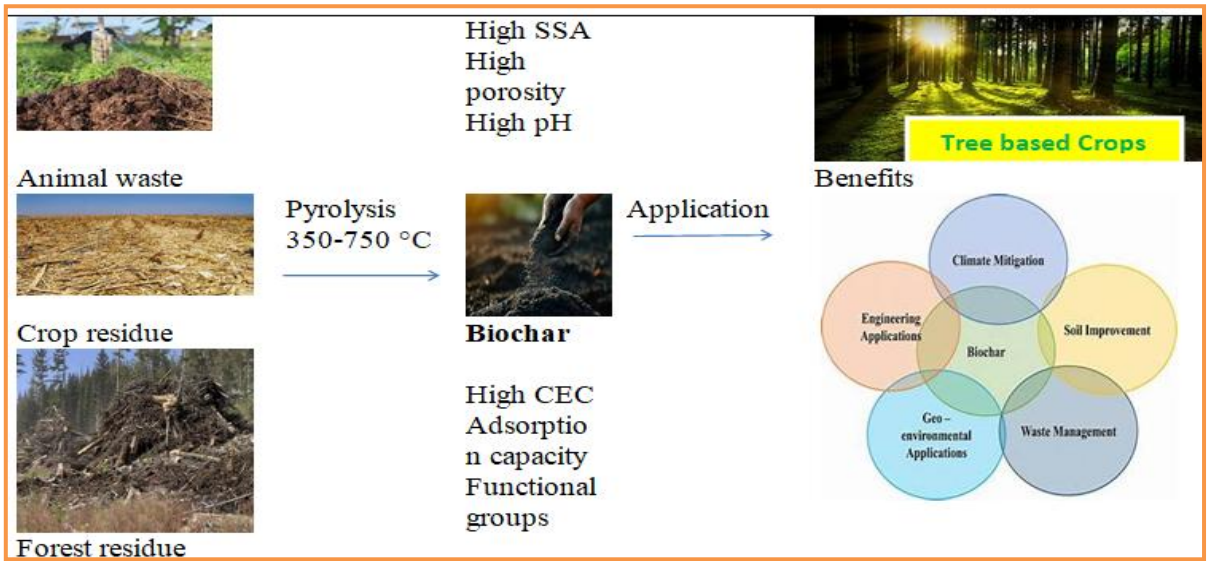

Fig. 1 Microscopic view of porous biochar and its incorporation into agricultural soil shows pore networks that help retain moisture and nutrients

Biochar in Indian Agro-Climatic Conditions Suitability across India

Arid and semi-arid regions (Rajasthan): Reduces moisture loss and enhances drought tolerance.

Acidic soils (Northeast India): Raises pH and improves crop productivity.

Alluvial soils (Indo-Gangetic Plains): Enhances soil organic content and reduces fertilizer losses.

Crop Residues for Biochar Production

India's major biomass sources include:

- ✓ Paddy straw
- ✓ Sugarcane trash
- ✓ Cotton stalks
- ✓ Groundnut shells
- ✓ Coconut coir

Converting these into biochar reduces residue burning and air pollution

Other Bio-Based Carbon Capture Techniques

Cover Crops and Green Manures: Leguminous cover crops (e.g., *Sesbania, Crotalaria, Vigna*) enhance root biomass carbon and reduce soil erosion.

Composting and Manure Management: Compost increases soil carbon pools and microbial diversity. Integrating biochar with compost (biochar-compost blend) increases carbon stability.

Microbial Carbon Stabilization: New microbial formulations (e.g., *Trichoderma, phosphate-solubilizing bacteria*) increase carbon stabilization through biological binding mechanisms

Benefits of Bio-Based Carbon Capture

Environmental Benefits

- ✓ Reduction in GHG emissions
- ✓ Increased soil organic carbon
- ✓ Improved soil biodiversity
- ✓ Reduced stubble burning

Agronomic Benefits

- ✓ Yield improvements in cereals, pulses, vegetables
- ✓ Reduced irrigation requirements
- ✓ Higher fertilizer-use efficiency

Economic Benefits

- ✓ Lower input costs (fertilizers, irrigation)
- ✓ Potential carbon credit earnings
- ✓ New rural enterprises (biochar units, biomass collection centers)

Recommendations for Farmers

Application Method

- ✓ Blend biochar with compost or manure before field application.
- ✓ Apply 2-10 tons ha^{-1} , depending on soil type and degradation level.

Pilot Demonstrations:

- ✓ Start with small-scale trials to test results under local field conditions.

Government and FPO Support

- ✓ Convergence with MIDH, RKVY, and state soil health programs.
- ✓ FPOs can operate shared pyrolysis units.

Conclusion

Biochar and other bio-based carbon capture strategies offer India a powerful combination of climate mitigation, soil rejuvenation, and sustainable agricultural productivity. Scaling up these methods could significantly improve national soil carbon stocks and rural livelihoods while contributing to India's climate commitments.

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