Can Biochar Save Degraded Indian Soils? A Discussion on Science, Field Reality and Farmer Benefits

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Introduction: The Soundless Calamity Beneath Our Feet

Soil rarely receives attention until something goes wrong. Farmers may discuss rainfall, market prices, seed varieties or fertilizer costs, but the slow weakening of soil often remains invisible until yields start to stagnate. Across India, declining soil organic carbon, nutrient imbalance, erosion, salinity, and long-term intensive cultivation have steadily reduced soil quality. What many farmers experience today rising input costs without comparative yield gains is often a sign of deeper soil fatigue.

Healthy soil is not just a growing medium; it is a living system. When organic matter decline, soils drop their ability to hold water, retain nutrients, and support helpful microbes. Rebuilding this biological and structural strength is now central to sustainable agriculture. In this context, biochar has attracted growing attention in Indian research institutions and agricultural universities. The real question is not whether biochar sounds hopeful in theory but whether Indian field research supports its use.

What Is Biochar?

Biochar is a carbon-rich material produced when crop residues, wood, husks, or other biomass are heated in limited oxygen — a process known as pyrolysis. The result is stable, porous materials that resemble charcoal but is designed especially for soil application.

Unlike ordinary charcoal, biochar is not produced for burning. Its porous structure and chemical properties let it to interact with soil water, nutrients, and microorganisms. Because it is quite stable, it can remain in soil for many years, contributing to long-term carbon build-up and structural improvement.

How Biochar Works in Soil

1. Improvement of Soil Structure

Biochar particles are highly porous. When included into soil, they can reduce bulk density, improve aggregation, and enhance root penetration. In degraded or compacted soils, this structural improvement is often the first visible advantage. Field trials in vertisol systems have shown reduced bulk density and better soil physical conditions following biochar application (*Fandi et al.*, 2025).

2. Increased Water Holding Capacity

One of the most realistic advantages of biochar in Indian conditions is its ability to improve soil moisture retention. Its pore spaces act as micro-reservoirs, storing water for the period of rainfall or irrigation and releasing it slowly to plant roots. In water-limited environments, this buffering capacity can help crops survive short dry spells.

3. Better Nutrient Retention and Use Efficiency

Biochar surfaces can adsorb nutrients, mainly nitrogen and potassium, reducing their loss through leaching. When biochar is enriched with fertilizers before application, it can function as a slow-release carrier. In direct-seeded rice systems, enriched biochar improved nitrogen uses efficiency and crop performance compared to conventional fertilizer application alone (*Roy et al.*, 2021).

4. Enhancement of Soil Biological Activity

Soil microbes take part in a critical role in nutrient cycling. Biochar provides protective microhabitats where beneficial microorganisms can increase. Studies involving microbial-enriched biochar have confirmed improved soil quality parameters alongside yield enhancement in sweet corn systems (*Singh et al.*, 2025).

What Indian Field Research Shows

Rather than relying on global meta-analyses, it is more meaningful to observe evidence generated under Indian agro-climatic conditions.

Direct-Seeded Rice Systems (Uttarakhand)

At G. B. Pant University of Agriculture & Technology, enriched biochar fertilizers applied to direct-seeded rice considerably improved plant growth, nutrient uptake, and nitrogen use efficiency (*Roy et al.*, 2021). This is particularly applicable for rice-based systems where nitrogen losses are common.

Sweet Corn Productivity

Research published in *The Indian Journal of Agricultural Sciences* demonstrated that microbial inoculant-enriched biochar, when incorporated with organic manures, enhanced sweet corn yield and improved soil organic carbon and nutrient availability (*Singh et al.*, 2025). The results show that biochar performs best when used as part of integrated nutrient management rather than as an individual amendment.

Maize-Based Vertisol Systems (Maharashtra)

In the vertisols of the Akola region, biochar application improved soil organic carbon, available nitrogen,

phosphorus and potassium while reducing soil bulk density. Maize yields improved under integrated biochar and fertilizer treatments (*Fandi et al.*, 2025). Such result are important for central Indian soils known for structural challenges.

Biochar as an Emerging Soil Amendment

A broader review focusing on Indian agricultural systems highlighted biochar's role in sustaining soil health and enhancing crop productivity when properly integrated with suggested agronomic practices (*Shiyal et al.*, 2022).

Benefits for Farmers

Yield Improvement

Yield gains vary depending on soil type and management practices. However, Indian field trials time after time show improved crop performance when biochar is combined with fertilizers or organic manures (*Roy et al.*, 2021; *Singh et al.*, 2025).

Improved Fertilizer Efficiency

Enhanced nitrogen use efficiency observed in rice system suggests potential savings in fertilizer input over time (*Roy et al.*, 2021). This is particularly important given rising fertilizer costs.

Long-Term Soil Carbon Build-Up

Unlike organic residues that decompose rapidly, biochar contributes stable carbon to soil. Increased soil organic carbon has been recognized in maize-based vertisol systems following biochar application (*Fandi et al.*, 2025).

Improved Soil Physical Properties

Reduction in bulk density and better aggregation in heavy soils support enhanced root growth and crop establishment (*Fandi et al.*, 2025).

Limitations and Precautions

In spite of promising evidence, biochar is not a universal remedy.

- Its usefulness depends on feedstock and production temperature.
- Application rates must be optimized.
- Biochar works best when incorporated with fertilizers or organic manures.
- Soil testing should head large-scale application.

Poor-quality biochar may offer limited benefit or bring in contaminants. Therefore, farmer training and extension support are important.

Practical Takeaways

- Begin with small field trials before large-scale adoption.
- Enrich biochar with nutrients or compost earlier to application.
- Use as part of integrated nutrient management.
- Prioritize degraded, low-organic-carbon soils.

Conclusion: From Degraded Soils to Resilient Systems

Indian soils are under stress from decades of intensive use. Restoring their health requires rebuilding organic matter, improving structure, and enhancing nutrient dynamics. Evidence from Indian agricultural universities and ICAR-affiliated research clearly indicate that biochar, when used considerately, can contribute to these goals.

It is not a miracle cure. But when integrated with sound agronomic practices, biochar offer a practical pathway toward rebuilding soil resilience and finally, securing the productivity of Indian agriculture for the future.

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