
FROM FARM SOIL TO CLIMATE SOLUTION:

India's Path to Carbon-Smart Agriculture Restoring soil carbon while protecting productivity, profitability and resilience

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1. Introduction

India's soils are carrying a hidden deficit. Estimates suggest that intensively cultivated regions have shed 30–40% of their original organic carbon stocks since the 1970s, driven mainly by deep tillage, residue removal, and continuous cereal cultivation. The consequences show up in ways farmers feel before they see them: waterlogging in some fields, moisture stress in others, and fertiliser doses that keep rising without proportionate yield gains. Average SOC across the Indo-Gangetic Plains - India's food bowl has fallen to around 0.3–0.5%, roughly one-third of the 1% threshold considered adequate for productive, climate-adaptive farming. A 20% reduction in water-holding capacity is one measurable consequence; higher irrigation requirements and declining fertiliser-use efficiency are two others.

The global picture adds a different kind of urgency. Improved cropland management could sequester 1.8–2.6 Gt CO₂ yr⁻¹ worldwide, and India's updated NDC has committed to creating an additional 2.5–3.0 Gt CO₂-eq carbon sink by 2030 through land-use improvements [3]. Soil carbon sits at the intersection of these two concerns - agronomic productivity and climate responsibility which is precisely why it deserves attention beyond the research station.

2. Key SOC-Restoration Practices

2.1 Zero Tillage and Residue Management

Every pass of a mouldboard or disc plough breaks apart the macro-aggregates that protect organic matter from microbial breakdown. The carbon released this way has been estimated at 0.1–0.3 t ha⁻¹ annually, a slow haemorrhage that compounds over decades. Zero-tillage interrupts this cycle simply by leaving the soil undisturbed. When combined with rice-straw retention (rather than burning), field trials across Punjab and Haryana showed annual SOC gains of 0.04–0.06%, modest in absolute terms but meaningful against a background of steady loss [4]. The Kapurthala pilot ran from 2019 to 2022; over those three seasons, SOC climbed from 0.38% to 0.61%, a 61% relative improvement that farmers on the project could see reflected in reduced waterlogging and softer seedbed conditions.

2.2 Biochar Amendment

Biochar is not a fertiliser in the conventional sense, it supplies almost no immediately available nutrients. Its value lies in persistence. The highly condensed aromatic carbon rings that form during pyrolysis (400–700 °C) resist microbial breakdown for centuries, effectively locking carbon into the soil profile [5]. In Betul district, Madhya Pradesh, ICAR-NIASM researchers applied biochar at 5 t ha⁻¹ to rainfed fields between 2020 and 2023. SOC rose from 0.52% to 0.79% over that period, water retention improved by 18%, and urea requirement fell by 12%.

For smallholders, perhaps the most relevant finding was the cost of production: simple pyrolysis kilns fabricated locally for under ₹15,000 per unit can convert paddy husk or cotton stalks, materials that farmers currently burn into a soil amendment with measurable long-term returns.

2.3 Cover Crops and Agroforestry

The window between Kharif harvest and Rabi sowing typically six to eight weeks, is often left as bare fallow. Sowing dhaincha or cowpea during this period costs little and returns a great deal: 60–120 kg N ha⁻¹ fixed biologically, plus 2–4 t of dry biomass that, when incorporated, feeds soil microbial communities over the following season [2]. Long-term IGFRl plots at Jhansi, where dhaincha had been incorporated for eight consecutive years, recorded a 0.28% absolute rise in SOC and a ₹4,200 ha⁻¹ yr⁻¹ reduction in fertiliser spending both of which hold up to scrutiny even after accounting for the cost of the seed. Agroforestry tells a similar story at a longer timescale. Tree-crop systems like poplar or moringa intercropped with wheat in Maharashtra, contribute 1.5–3.2 t C ha⁻¹ yr⁻¹ through root turnover and leaf litter, pathways that open-field monocultures cannot replicate. In Nashik district, poplar-wheat plots saw SOC rise from 0.41% to 0.68% across three years .

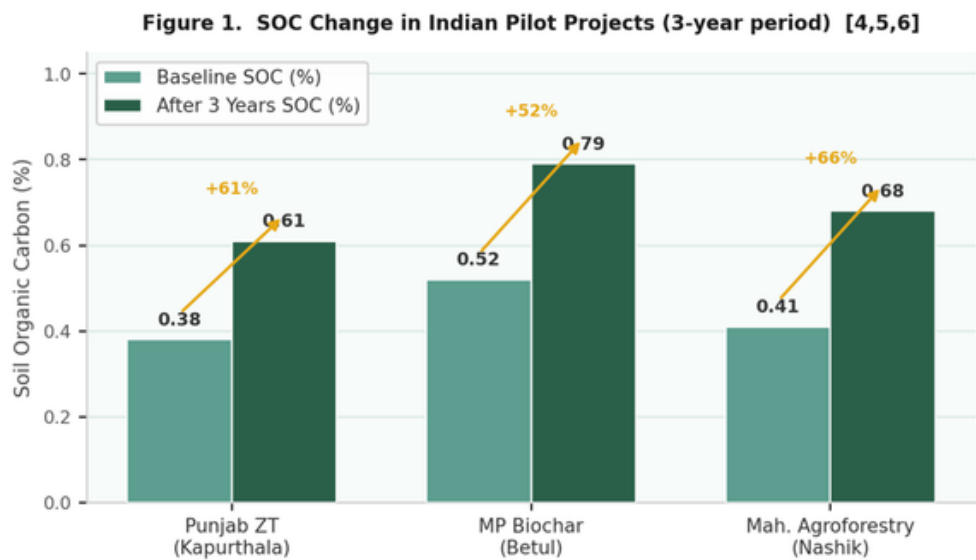


Figure 1. SOC change (%) at three Indian pilot project sites over a 3-year period. Hatched bars = baseline; solid bars = post-intervention

3. Comparative Practice Benefits

Table 1. Summary of SOC-building practices and their farm-level impacts in India.

Practice	SOC Gain (3 yr)	Yield Effect	Cost Change
Zero Tillage + Residue	0.23%	+5–10% wheat	–₹2,500/ha/yr
Biochar (5 t/ha)	0.27%	+8–15% maize	–12% urea
Cover Crop (dhaincha)	0.18%	N-saving equiv.	–₹4,200/ha/yr
Agroforestry (poplar)	0.27%	+timber income	+₹8,000/ha/yr

4. Government Schemes Supporting SOC Restoration

Several central government programmes already provide financial support for the practices described above, though farmers often do not realise they qualify [3,7]:

Table 2. Central government schemes with direct links to SOC-building in Indian agriculture

Scheme	SOC Linkage	Farmer Benefit
PM-PRANAM	Rewards states for chemical fertiliser reduction	State savings shared as incentive payments
NMSA (Soil Health)	Soil Health Cards; subsidises bio-inputs & organic amendments	Free soil testing; subsidy on bio-inputs
PMKSY (Watershed)	Watershed SOC builds water retention & reduces irrigation need	Lower irrigation cost; crop insurance rebates
RKVY-RAFTAAR	Funds zero-tillage machinery & biochar production units	Subsidy up to 80% for SC/ST farmers

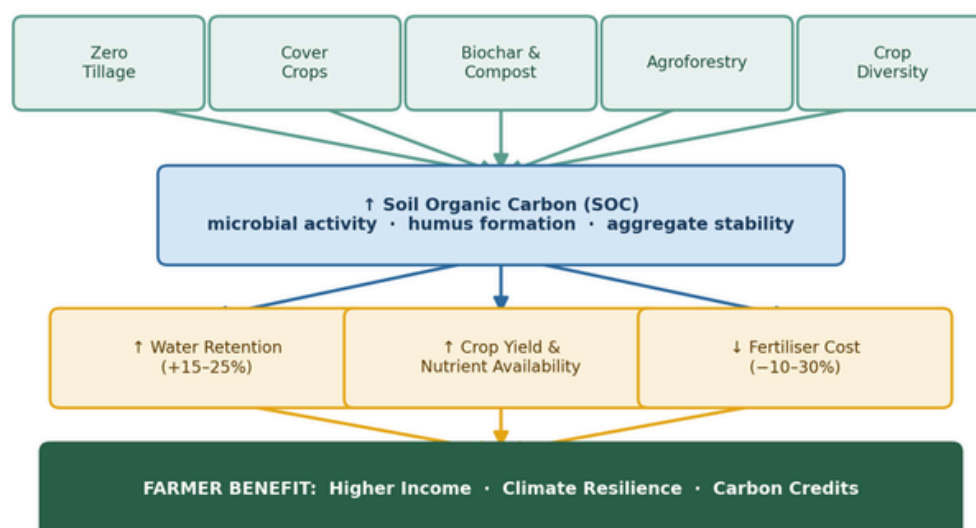


Figure 2. Conceptual flow of SOC restoration: from farm practices to farmer benefits

5. Adoption Pathway and Carbon Market Potential

Extension workers consistently report that farmers adopt new soil practices most readily when returns appear within a single season and inputs are locally available without complicated procurement [7]. Group biochar production, piloted by FPOs in Madhya Pradesh and Maharashtra, brought per-unit fabrication costs down by roughly 35% — enough of a reduction to shift the economics for small landholders. These same FPOs have begun aggregating carbon credits through Verra VCS and Gold Standard, an option that individual farmers on 1–2 ha plots cannot realistically pursue on their own.

The scale numbers are worth stating plainly. A 0.2% SOC improvement across 50 million ha of Indian cropland translates to roughly 200 Mt CO₂-eq sequestered. At voluntary market prices of \$5–15 per tonne, that opens a supplementary income stream in the range of ₹40,000–1,20,000 crore annually — on top of the yield and input-cost gains the same practices already deliver. Whether these projections survive contact with actual carbon accounting protocols is an open question, but the directional case for serious policy attention is hard to dismiss.

6. Conclusion

Soil does not feature prominently in India's climate policy conversations, yet the field data reviewed here makes a strong case for putting it there. Farmers in Kapurthala, Betul, and Nashik achieved 38–65% SOC gains over three growing seasons — without subsidised technology and, in one case, while cutting their fertiliser bill by over ₹4,000 per hectare annually [2,4,5,6]. The barriers to wider adoption are real: patchy extension coverage, fragmented landholdings, and carbon markets still learning how to reliably verify soil sequestration. None of these is unfamiliar territory, and none is beyond the reach of institutions that already exist — PM-PRANAM, NMSA, and FPOs that have already shown they can aggregate what individual smallholders cannot access alone [7]. A deliberate policy decision to treat soil carbon with the same seriousness currently given to solar or EV deployment would, in effect, give India's 140 million ha of farmland two jobs at once: producing food, and drawing down carbon.

References

