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Declining Soil Organic Carbon in the Indo-Gangetic Plains: Causes and Remedies

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The Indo-Gangetic Plains form the food basket of the Indian sub-continent, yet the organic carbon reserve of these soils has been shrinking steadily for several decades. Continuous rice-wheat cultivation, the burning of crop residues, imbalanced fertilisation, the near disappearance of organic manures and a warm climate that hastens decomposition are together draining the soil carbon bank faster than it is being refilled. The result is stagnating yields, poorer soil structure and a growing dependence on external inputs. This article explains why soil organic carbon is so important, traces the main reasons behind its decline in the region, describes the consequences for farmers, and outlines practical, field-tested measures such as residue retention, conservation agriculture, integrated nutrient management, crop diversification and organic amendments that can help rebuild it.

Keywords: Soil organic carbon, Indo-Gangetic Plains, rice-wheat system, conservation agriculture, residue management, soil health.

Introduction

The Indo-Gangetic Plains (IGP) stretch across the northern part of the sub-continent and, within India, cover the states of Punjab, Haryana, Uttar Pradesh, Bihar and West Bengal. Blessed with deep fertile alluvial soils and assured irrigation, this belt produces a very large share of the country's rice and wheat and is rightly called the food bowl of India. The success of the Green Revolution was written largely on this land. Yet the productivity of these soils rests heavily on a quiet and often ignored resource, namely soil organic carbon (SOC). Soil organic carbon is the carbon held within soil organic matter, and it acts as the storehouse of nutrients, the glue that binds soil particles into stable aggregates, and the food source for the vast community of microbes that keep the soil alive. Unfortunately, most soils of the IGP already carry low organic carbon, commonly below 0.5 per cent, and long-term observations show that this level has been drifting downward (Bhattacharyya et al., 2015). A shrinking carbon reserve weakens soil health from within and quietly threatens the very foundation of the region's remarkable productivity.

Why Soil Organic Carbon Matters

Soil organic carbon is far more than a laboratory number. It improves soil structure by encouraging the formation of stable aggregates, which in turn improve aeration, root penetration and resistance to erosion. It greatly increases the ability of the soil to hold water and nutrients, so crops can withstand short dry spells and make better use of applied fertilisers. It serves as a slow-release reservoir of nitrogen, phosphorus and sulphur, and it raises the cation exchange capacity, which helps the soil retain plant nutrients rather than losing them to leaching. It supports the earthworms, fungi and bacteria that drive nutrient cycling and disease suppression, and it buffers the soil against sudden changes in acidity. Beyond the field, soils store more carbon than the atmosphere and vegetation combined, so building soil carbon also helps remove carbon dioxide from the air and moderate climate change. For all these reasons, a decline in SOC is an early warning signal that the productive capacity of the land is being eroded from the ground up. As a rough guide, soil organic matter contains a little over half its weight as carbon, and soils holding organic carbon well above the commonly cited critical level tend to be more fertile, more forgiving and more responsive to good management than soils that have slipped below it.

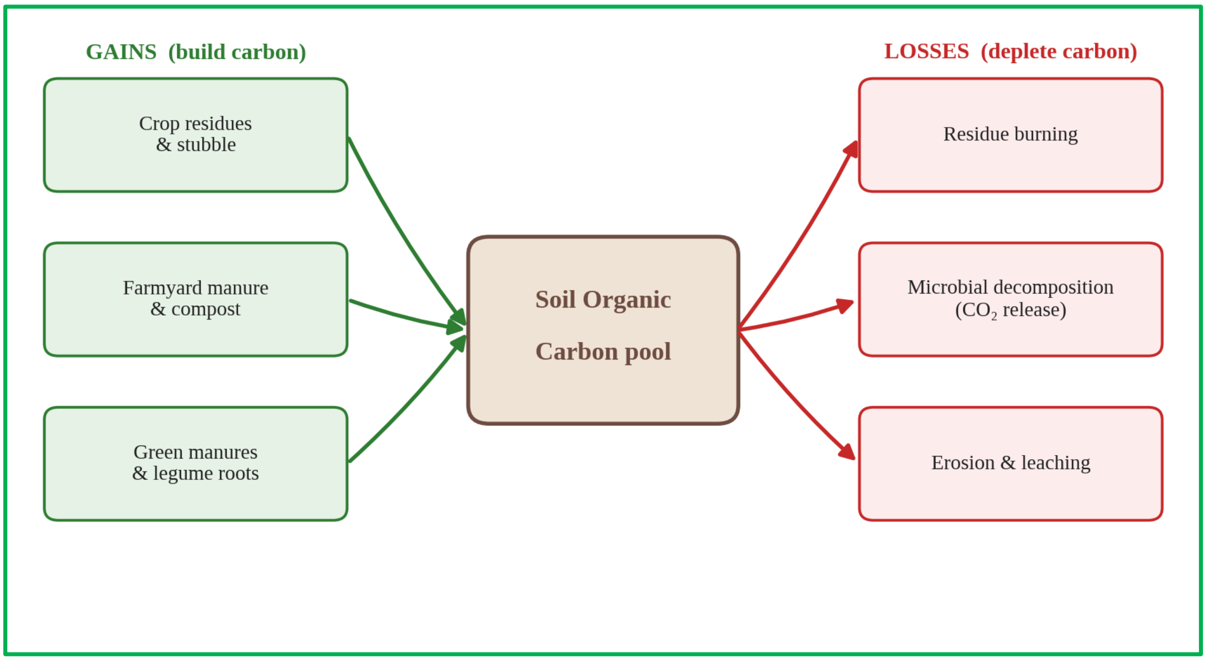

Figure 1. The soil organic carbon balance – practices that add fresh organic matter build the carbon pool, while burning, decomposition and erosion deplete it.

The Extent of the Problem

The rice-wheat cropping system of the Indian IGP is practised on roughly ten million hectares, making it one of the largest and most intensive food-production systems in the world. Because these are young alluvial soils formed under a warm climate, their inherent organic matter content was never very high to begin with. Decades of intensive cultivation have pushed carbon levels lower still (Benbi et al., 2015). Long-term fertiliser experiments across the region tell a consistent story: where crops are grown continuously on mineral fertilisers alone, without any return of organic matter, soil organic carbon slowly falls, whereas plots that receive farmyard manure or crop residue along with fertiliser are able to hold or even raise their carbon (Mandal et al., 2013). Many soils today sit below the level of organic carbon generally considered adequate for a healthy, responsive soil. The decline is usually gradual and easy to miss from one season to the next, which is precisely why it is so dangerous: by the time the effects on yield and soil workability become obvious, a great deal of carbon has already been lost and the soil has become harder to manage. The eastern part of the plains, with its higher rainfall and lighter-textured soils, faces additional losses through leaching and erosion, while the western and north-western parts struggle with intensive tillage and residue burning. In short, the problem is real, it is widespread across the whole belt, and it has been building up quietly over a long period.

Causes of the Decline

The loss of soil carbon in the IGP is not the result of any single factor but of several pressures acting together.

1. Intensive rice-wheat cropping. The dominant rice-wheat rotation is grown year after year with little rest and almost no fallow period. Two heavy-feeding cereals in succession mine large quantities of nutrients and remove huge amounts of biomass, leaving little to be returned to the soil.
2. Burning and removal of crop residues. Instead of being returned to the field, a large part of the straw, especially paddy straw, is burnt to clear the land quickly for the next crop.

Burning destroys in a few minutes the carbon and nutrients that the residue would otherwise have added to the soil, and it also pollutes the air.

3. Imbalanced fertiliser use. Many farmers rely heavily on nitrogenous fertilisers such as urea while neglecting balanced nutrition and organic sources. Continuous mineral fertilisation without organic inputs stimulates microbes to break down the soil's existing organic matter faster than it is replaced.
4. Declining use of organic manures. Farmyard manure, compost and green manures were once common, but their use has fallen sharply as animal dung is diverted to fuel, as livestock numbers change, and as labour becomes scarce and costly.
5. Removal of biomass for fodder and fuel. Crop residues that could enrich the soil are frequently taken away to feed animals or to burn as household fuel, so very little organic material actually finds its way back into the field.
6. A warm climate and rapid mineralisation. The warm, moist conditions of the region favour rapid microbial decomposition, so organic matter breaks down quickly and carbon is lost to the atmosphere as carbon dioxide.
7. Intensive tillage and puddling. Repeated ploughing and the puddling of soil for transplanting rice break down soil aggregates and expose protected carbon to oxidation, accelerating its loss.

Table 1 brings these pressures together and shows, for each one, the way in which it drains the soil carbon bank.

Table 1. Major causes of declining soil organic carbon in the Indo-Gangetic Plains and how each depletes the carbon pool

Cause of decline	How it depletes soil organic carbon
Intensive rice–wheat cropping	Two heavy-feeding cereals in succession remove large amounts of biomass and nutrients, with little returned to the soil.
Burning of crop residues	Straw that would have added carbon and nutrients is burnt off in minutes, and the smoke also pollutes the air.
Imbalanced fertiliser use	Heavy reliance on urea without organic inputs speeds up microbial breakdown of existing organic matter.
Declining use of organic manures	Farmyard manure, compost and green manures are applied far less as dung is diverted to fuel and labour grows scarce.
Removal of biomass for fodder & fuel	Residues are carried away to feed livestock or burnt as household fuel, so little organic material returns to the field.
Warm climate & rapid mineralisation	Warm, moist conditions favour fast decomposition, releasing soil carbon to the air as carbon dioxide.
Intensive tillage & puddling	Repeated ploughing and puddling break soil aggregates and expose protected carbon to oxidation.

Consequences for Soils and Farmers

The steady drain of organic carbon shows up in the field in many ways. Soil structure deteriorates and compaction increases, making tillage harder and root growth poorer. The water-holding capacity falls, so crops suffer sooner during dry periods and irrigation must be applied more often, adding to cost and to the strain on groundwater. Fertiliser use efficiency drops, which means farmers spend more on inputs for the same or even lower yields. Deficiencies of micronutrients such as zinc, iron and manganese become widespread, and the population of beneficial microbes weakens. Together these changes are among the reasons for the yield stagnation reported in parts of the IGP despite ever-rising input use. When more inputs buy less output, both farm profitability and long-term food security come under pressure, and the resilience of the whole system to drought and heat is reduced. A soil poor in organic carbon is also a fragile soil: it crusts over after rain, it seals and runs off instead of absorbing water, and it recovers slowly from stress. In this way the loss of a resource that cannot be seen with the naked eye gradually undermines everything that is visible above the ground.

Practices to Rebuild Soil Organic Carbon

The encouraging news is that soil organic carbon can be restored through a combination of practices that add fresh organic matter and slow down its loss. No single measure is a complete answer; the greatest gains come from using several together. The table below summarises the main options.

Table 2. Key practices for restoring soil organic carbon in the Indo-Gangetic Plains.

Practice	How it helps build soil carbon
Crop residue retention / incorporation	Returns straw and stubble to the soil instead of burning; the Happy Seeder and Super Seeder allow wheat to be sown directly into standing paddy residue.
Conservation agriculture (zero / reduced tillage)	Minimises soil disturbance, keeps residue as a surface mulch, and protects the carbon held inside soil aggregates.
Integrated nutrient management	Combines mineral fertilisers with farmyard manure, compost and biofertilizers so that organic matter is continually replenished.
Green and brown manuring	Ploughing in dhaincha (Sesbania) or sunhemp, or knocking down a legume in situ, adds a large flush of fresh organic matter and nitrogen.
Crop diversification with legumes	Introducing pulses, oilseeds and fodder legumes in the rotation adds organic matter and relieves the strain of continuous cereals.
Organic amendments and biochar	Compost, vermicompost and biochar made from crop residue add stable carbon that resists rapid decomposition (Purakayastha et al., 2019).

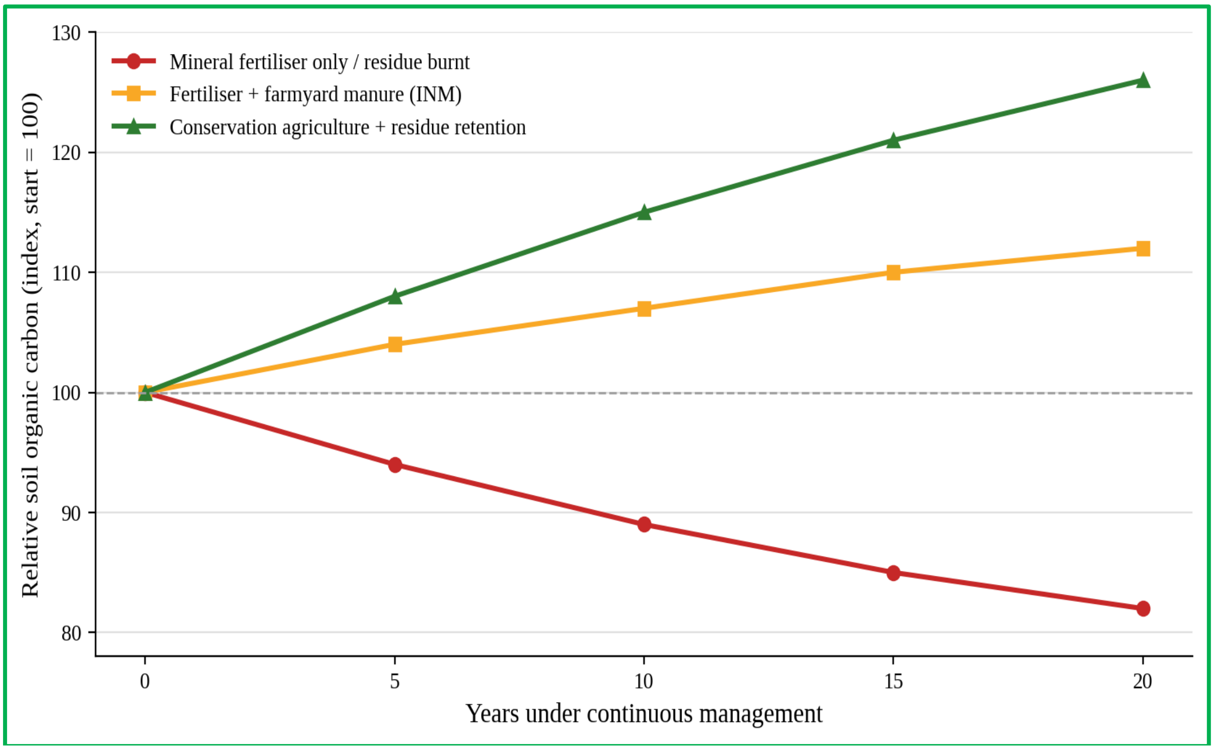

Figure 2. Illustrative long-term trends in relative soil organic carbon under different management practices, based on the general pattern reported from long-term experiments in the Indo-Gangetic Plains

Adopting these measures together works far better than relying on any one of them alone. For example, retaining residue under a zero-tillage system while also applying farmyard manure and rotating in a legume creates several sources of fresh carbon at the same time while cutting the losses caused by repeated ploughing. Biofertilizers and microbial inoculants can further support this process by improving nutrient availability, and site-specific nutrient management guided by soil testing, the leaf colour chart or nutrient-recommendation tools ensures that fertilisers are used efficiently rather than wastefully. Agroforestry and boundary plantations add another layer of organic matter and lock away carbon in woody biomass over the long term.

The Way Forward

Rebuilding soil carbon is a gradual process that rewards patience and consistency, and it needs support from more than just the individual farmer. It is important to be realistic: because organic matter breaks down quickly in this warm climate, carbon is built up slowly, often over several years, and the gains can be lost again if good practices are abandoned. This makes steady, year-after-year effort far more valuable than a single season of change. Regular soil testing under the Soil Health Card programme helps farmers know the actual carbon and nutrient status of their fields and plan accordingly. Wider availability and affordability of machines such as the Happy Seeder, along with awareness campaigns against residue burning, can shift farmers away from the burning habit. Emerging ideas such as carbon farming and carbon credits may, in time, offer farmers a direct economic reward for the extra carbon they store in their soils (Nayak et al., 2019). When good agronomy, appropriate machinery, sound policy and farmer awareness come together, the decline in soil organic carbon can be slowed, halted and eventually reversed.

Conclusion

Soil organic carbon is the living heart of the fertile soils of the Indo-Gangetic Plains, and its slow decline is a warning that must not be ignored. The message for the farming community is a hopeful one: the trend can be reversed. By stopping the burning of crop residues and returning them to the field, by moving towards conservation agriculture, by blending organic manures and green manures with balanced mineral fertilisers, and by bringing legumes and other break crops back into the cropping system, farmers can gradually rebuild the carbon reserve of their soils. These practices protect yields, cut input costs, save water and, at the same time, help in the fight against climate change. Investing in soil organic carbon today is, in the truest sense, an investment in the productivity and prosperity of tomorrow.

References

1. Benbi, D.K., Brar, K., Toor, A.S. and Singh, P. (2015). Total and labile pools of soil organic carbon in cultivated and undisturbed soils in northern India. Geoderma, 237-238: 149-158.
2. Bhattacharyya, R., Ghosh, B.N., Mishra, P.K., Mandal, B., Rao, C.S., Sarkar, D. et al. (2015). Soil degradation in India: challenges and potential solutions. Sustainability, 7(4): 3528-3570.
3. Mandal, B., Majumder, B., Bandyopadhyay, P.K., Hazra, G.C., Gangopadhyay, A. and Samantaray, R.N. (2013). Potential of double-cropping system in sequestering carbon in Indian soils. Agriculture, Ecosystems and Environment, 174: 42-50.
4. Nayak, A.K., Rahman, M.M., Naidu, R., Dhal, B., Swain, C.K., Nayak, A.D. et al. (2019). Current and emerging methodologies for estimating carbon sequestration in agricultural soils: a review. Science of the Total Environment, 665: 890-912.
5. Purakayastha, T.J., Bera, T., Bhaduri, D., Sarkar, B., Mandal, S., Wade, P. et al. (2019). A review on biochar modulated soil condition improvements and nutrient dynamics. Chemosphere, 227: 345-365.