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Soil Health First: The New Foundation of Sustainable Crop Production in India

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INTRODUCTION

Soil is the fundamental natural resource that sustains agricultural productivity, yet it is increasingly under stress in India. Modern agriculture has significantly improved food grain production, but it has also led to long-term soil degradation due to intensive cropping, excessive chemical fertiliser use, and declining organic matter. India supports nearly 18% of the global population on just 2.4% of the world's land resources, placing immense pressure on soil systems. Recent assessments show that soil degradation is now widespread, affecting productivity and ecological stability.

Table: Soil Health Status in India

Aspect	Status in India	Why it matters
Nitrogen (N)	Varies across Indian soils.	Low or imbalanced nitrogen reduces crop growth and yield
Phosphorus (P)	Varies across Indian soils	Phosphorus affects root development and overall plant vigour.
Potassium (K)	Indian soils are generally sufficient in potassium.	Adequate potassium supports plant strength and stress tolerance.
Zinc (Zn)	Major deficiency reported, especially in Bihar, Uttar Pradesh, and Odisha.	Zinc deficiency can lower crop productivity and nutrient quality.
Iron (Fe)	Shows variability across soils in India.	Boron is important for flowering, fruiting, and cell development.

Source: www.pib.gov.in

According to national-scale analyses, approximately 147 million hectares of land in India are affected by soil degradation, including erosion, salinity, acidification, and nutrient loss. Water erosion alone accounts for nearly 94 million hectares of degraded land, making it one of the most serious threats to agricultural sustainability.

A key indicator of soil quality—Soil Organic Carbon (SOC)—is also alarmingly low. The average SOC level in Indian soils is around 0.54%, which is considered sub-optimal for sustaining long-term fertility and microbial activity. In many agricultural regions, SOC has dropped below 0.5%, which directly impacts soil structure, nutrient retention, and water-holding capacity. Even more concerning is the imbalance in nutrient availability. Recent Soil Health Card-based assessments indicate that 64% of soil samples in India are low in nitrogen, while nearly 48.5% are deficient in organic carbon. This shows that Indian soils are not just low in fertility but are also biologically weakened. These trends clearly indicate that soil health has become the central limiting factor for sustainable crop production in India.

Soil Degradation Patterns and Agricultural Impacts

Soil degradation in India is not uniform; it varies across regions and cropping systems. Intensively cultivated regions such as Punjab, Haryana, and western Uttar Pradesh face nutrient depletion due to continuous rice-wheat monocropping. In contrast, rainfed and semi-arid regions face issues such as moisture stress, erosion, and declining organic matter.

One of the most critical concerns is the declining efficiency of fertilisers. Studies show that fertiliser use efficiency in India has declined dramatically from approximately 1:10 in the 1970s to nearly 1:2.7 in recent years, indicating that increasing

fertiliser input is producing diminishing yield returns. This inefficiency is largely driven by soil degradation and nutrient imbalance.

Another major issue is nutrient imbalance in fertilisation practices. The ideal NPK ratio recommended for Indian agriculture is 4:2:1; however, actual usage in many regions has been reported around 7.7:3.1:1, reflecting over-dependence on nitrogen fertilisers. This imbalance leads to soil acidification, reduced microbial diversity, and long-term fertility decline.

Soil Health Card data further reveals that out of more than 1.3 crore soil samples tested (2023–2025), a majority showed multiple nutrient deficiencies, highlighting the systemic nature of soil degradation.

The consequences of degraded soil are visible in crop productivity fluctuations, increased input costs, and reduced resilience to climate stress. Poor soil structure reduces root penetration, while low organic carbon reduces water retention capacity, making crops more vulnerable to drought conditions. Additionally, nearly 32% of India's land is currently degraded, and around 25% is undergoing desertification, posing a serious threat to long-term food security and rural livelihoods.

Pathways to Soil Health Restoration and Sustainable Agronomy

Despite these challenges, India has strong scientific, institutional, and policy frameworks that can drive soil restoration and sustainable agriculture.

A major national intervention is the Soil Health Card Scheme, which provides farmers with soil nutrient status and fertiliser recommendations based on scientific testing. This initiative has improved awareness about soil fertility management and encouraged balanced fertiliser use.

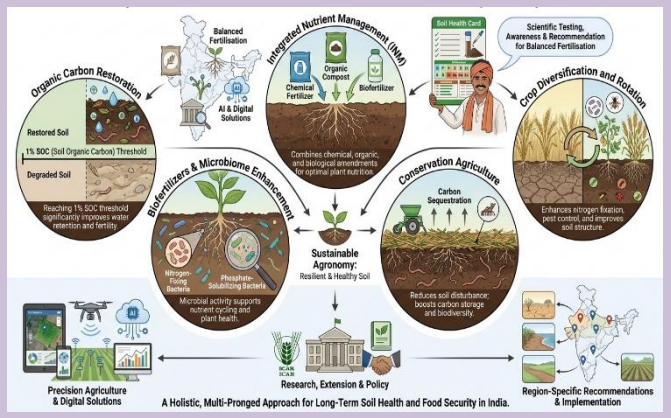

Figure: Pathways to Soil Health Restoration and Sustainable Crop Production in India

Improving soil health requires a shift from chemical-intensive farming to integrated soil management systems, which combine biological, chemical, and physical approaches. Key strategies include:

1. Integrated Nutrient Management (INM)

Combining chemical fertilisers with organic manures, compost, and biofertilizers helps restore soil organic matter while maintaining productivity.

2. Crop Diversification and Rotation

Monocropping systems exhaust soil nutrients rapidly. Crop rotation improves nitrogen fixation, pest control, and soil structure recovery.

3. Conservation Agriculture

Reduced tillage, residue retention, and minimal soil disturbance help improve soil carbon sequestration and microbial diversity.

4. Biofertilizers and Soil Microbiome Enhancement

Beneficial microbes such as nitrogen-fixing bacteria and phosphate-solubilising organisms enhance nutrient availability naturally.

5. Organic Carbon Restoration

Increasing soil organic carbon above even 1% significantly improves soil water retention, microbial activity, and nutrient cycling. Many degraded soils in India currently remain below this threshold.

Technological innovations are also transforming soil management. Precision agriculture tools, satellite-based soil mapping, and AI-driven nutrient recommendation systems are enabling data-driven soil management at scale. Institutions like the Indian Council of Agricultural Research (ICAR) are actively promoting soil-first strategies through research, extension programs, and region-specific soil management practices.

CONCLUSION

The evidence is clear—soil health is the foundation of sustainable crop production in India. With over 64% of nitrogen-deficient soils, nearly half of soils low in organic carbon, and widespread land degradation, the need for soil restoration is urgent. Improving soil health is not just an agronomic requirement; it is a national necessity for ensuring food security, climate resilience, and farmer profitability. A transition toward soil-centric agriculture—supported by scientific management, policy interventions, and modern technology—can transform Indian farming systems into more resilient and sustainable ecosystems. Healthy soil means stable yields, reduced input costs, and a secure agricultural future. In essence, the future of Indian agriculture depends on how well we restore and protect our soils today.