5. Soil Health - Geography

Recently, the Indian Council of Agricultural Research (ICAR) has revealed alarming evidence that unscientific fertilizer use and climate change are causing significant degradation of organic carbon in India's arable soils

Background and Context

About the Study - The Indian Council of Agricultural Research (ICAR) recently conducted a nationwide study assessing soil organic carbon (SOC) levels and the impact of fertiliser use, temperature, and rainfall on soil health.

Core Finding - The study revealed a steady decline in soil carbon across several regions of India due to imbalanced fertiliser usage, climate stress, and unsustainable cropping systems.

Significance - Soil organic carbon (SOC) is a key indicator of soil fertility, biodiversity, and climate resilience. SOC depletion threatens agricultural productivity, food security, and India's commitments to climate mitigation and land restoration under the UNCCD and SDG 15 (Life on Land).

Key Findings of the ICAR Study

1. Unbalanced Fertiliser Use and Soil Degradation

Excessive Urea and Phosphorus Use - The study found that heavy reliance on nitrogen (urea) and phosphorus-based fertilisers, with inadequate use of organic manure and micronutrients, has degraded soil organic matter.

Regional Impact - Severe Decline - Haryana, Punjab, and Western Uttar Pradesh — regions with intensive cultivation and high input use.

Relatively Stable - Bihar — due to more balanced fertiliser practices and a mix of crop types.

Consequences - Continuous chemical inputs disturb microbial balance, reduce soil carbon retention, and increase nitrogen leaching, harming soil biodiversity.

Correlation Between Organic Carbon and Elevation

Topographical Patterns - Soils in hilly and forested regions (e.g., Uttarakhand, Himachal Pradesh, Northeastern states) showed higher SOC due to dense vegetation and slower organic matter decomposition.

Lowland Depletion - Plains and intensively farmed regions showed carbon loss, primarily due to erosion, tillage, and irrigation-based mineralisation.

Climate Feedback - Low soil carbon leads to higher albedo (heat reflection). This contributes to surface heating, amplifying the greenhouse effect and climate instability.

Rising Temperature's Negative Impact

Thermal Decomposition - Increased temperatures accelerate microbial breakdown of organic matter, leading to faster carbon release.

Regional Effects - Rajasthan and Telangana reported lower SOC due to high evapotranspiration and poor organic retention capacity. Warmer soils also lose moisture balance, worsening soil degradation cycles.

Climate Linkage - This creates a vicious cycle—warming reduces SOC, and lower SOC in turn reduces carbon sequestration, worsening climate change impacts.

Rainfall, Cropping Systems, and Soil Carbon Dynamics

Cropping System Influence –

Rice–Pulse Systems - Maintain higher SOC levels due to continuous waterlogging, microbial activity, and nitrogen fixation from pulses.

Wheat and Coarse-Grain Systems - Show lower SOC because of less biomass residue and lower soil moisture.

Rainfall Dependency - High-rainfall zones tend to retain carbon better due to vegetative cover, whereas arid and semi-arid regions lose carbon through oxidation and erosion.

Why Soil Health Matters

1. Agricultural Sustainability - Over 54% of India's workforce depends on agriculture. Healthy soil

supports higher yields, better nutrient content, and reduced dependence on chemical inputs.

2. Food and Nutritional Security - SOC enhances nutrient cycling and water retention, producing resilient and nutritious crops. Degraded soils threaten India's food security goals, especially amid climate variability.

3. Environmental Regulation - Soils act as carbon sinks, regulate water cycles, and maintain biodiversity. They mitigate floods and droughts, absorb greenhouse gases, and sustain ecological balance.

4. Economic Significance - Declining soil fertility leads to higher input costs and reduced yields, directly affecting farm incomes and national GDP. Soil degradation costs India an estimated 2.5% of GDP annually (as per NITI Aayog estimates).

Government Efforts and Related Initiatives

1. Soil Health Card (SHC) Scheme – 2015

Objective - To provide farmers with soil-specific nutrient management advice.

Features - Farmers receive biannual soil health reports. Recommends balanced fertiliser usage and integrated nutrient management.

Supportive Measures - Mobile Soil Testing Labs for remote villages. School Soil Health Programmes to create awareness. Digital Soil Data Platforms for monitoring.

Soil Health Management (SHM) under NMSA

Implemented under the National Mission for Sustainable Agriculture (NMSA).

Focus areas –

1. Integrated Nutrient Management (INM).
2. Promotion of organic farming and bio-fertilisers.
3. Composting units and vermicompost pits for on-farm carbon cycling.

Integration with Rashtriya Krishi Vikas Yojana (RKVY) - SHC and SHM merged into "Soil Health & Fertility" component of RKVY. Aims for better coordination, resource utilisation, and monitoring outcomes through real-time data.

Policy Recommendations from the Study

1. Organic Carbon Sequestration Programs - Prioritise soils with <0.25% organic carbon for carbon restoration. Introduce crop rotation, residue management, and micro-irrigation to enhance sequestration.

2. Carbon Credit Incentives - Farmers adopting sustainable soil practices (zero tillage, cover crops, composting) should receive carbon credit payments. Link with emerging domestic carbon markets under India's National Carbon Registry.

3. Climate-Resilient Crop Management - Develop region-specific strategies integrating climate-smart agriculture (CSA), crop diversification, and water-efficient irrigation.

4. Nationwide Vegetative Cover and Agroforestry - Promote plantation drives, cover cropping, and agroforestry systems to reduce erosion and increase soil organic matter. Encourage bamboo and nitrogen-fixing trees on farm boundaries.

Additional Measures for Soil Carbon Restoration

Biochar Application - Introduce biochar (carbon-rich residue from biomass pyrolysis) to enhance soil structure and carbon retention.

Reduced Tillage Practices - Encourage conservation agriculture to minimise soil disturbance and protect microbial activity.

Compost and Farmyard Manure - Promote on-farm organic waste recycling to enhance microbial biodiversity and nutrient retention.

Digital Soil Mapping - Create GIS-based soil carbon maps for district-level planning under the Digital India Land Records Modernization Programme (DILRMP).

Conclusion

The ICAR study serves as a warning that India's soil organic carbon is under critical stress, especially in agriculturally intensive zones. Without corrective measures, India risks losing its soil fertility

base, undermining its food security, agricultural productivity, and climate resilience. The path forward lies in balanced fertiliser application, integrated nutrient management, organic farming, and climate-adaptive cropping. Restoring soil carbon is not just an agricultural goal—it is a national environmental priority, linking directly with India's climate commitments, rural livelihoods, and sustainable development agenda.

Source - https - //www.thehindu.com/sci-tech/energy-and-environment/climate-change-imbalance-in-fertiliser-use-kill-soils-organic-carbon-icar-study/article70257059.ece