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Soil Health Indices for Sustainable Crop Production in Indian Agro-Ecosystems

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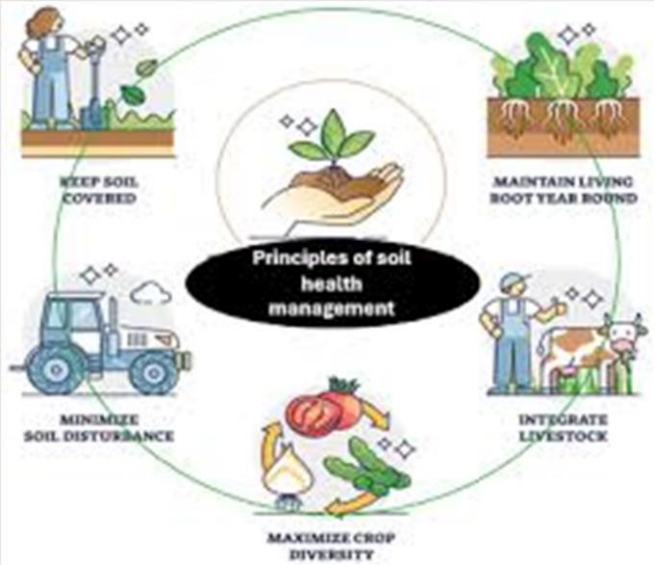
INTRODUCTION

Soil health is the sustained ability of the soil to support life for plants, animals, and humans, besides maintaining environmental qualities. Soil health is of utmost importance for maintaining agricultural productivity in India, especially with the onset of population growth, declining land sizes, climate change, and resource scarcity. India varies in agricultural ecosystems, from arid to semi-arid climates, humid tropical to mountains, with distinctive soil types, cropping systems, and challenges of sustainability. Monitoring the health of the agricultural ecosystem through sustainable indicators is important for sustainable agricultural production. Soil health indicators would provide information to the farmer for sustainable productivity with resource conservation. An understanding of these indicators is important for sustainable agricultural production.



(Source, Omer et al., 2024)

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2. Soil Health & Sustainability Concepts

Soil health is an ever-changing characteristic that depends on land use patterns, agricultural intensification, climate, and management systems. A healthy soil allows for good root development, nutrient utilization efficiency, microbial activities, and soil structure. Sustainable agricultural systems strive to improve soil health by promoting productivity along with protecting the environment and ensuring economic viability. In the context of India, improving soil health is crucial for dealing with problems such as reduced levels of organic carbon, inequalities between nutrient supplies, soil salinity, acidity, and erosion. Soil health indicators are attributes that provide indicators for measuring the sustainability of agricultural systems.

3. Key Indicators of Soil Health

An array of indicators is used to reveal the health of the soil, which is broadly categorized into physical indicators, chemical indicators, or biological indicators. These indicators make significant contributions in their respective capacities to the functioning of

4. Physical Soil Health Indicators

These factors affect root development, water movement, aeration, and soil stability, which directly influence crop productivity.

4.1 Soil Texture

Soil Texture: Soil texture is primarily determined by the relative percentage of sand, silt, and clay. Soil water-holding capacities, nutritional values, and workability are dependent on soil texture. Well-drained loamy soils are regarded as ideal for almost all crops in Indian agro-ecosystems, whereas sandy soils in arid areas need organic fertilizers and water management.

4.2 Soil Structure & Aggregation

Soil Structure is related to the grouping of soil particles into aggregates. Well-aggregated soils provide good resistance to erosion, improve aeration, and increase the availability of nutrients. Heavy tillage and lower organic matter in the soil are major factors responsible for poor soil structure in many farmlands in India.

4.3 Bulk Density

Bulk density of the soil helps in determining the porosity or compactness of the soil. When the soil is of high density, it hinders root development. Soil compaction is viewed as one of the major factors brought about by poor agricultural practices like the frequent use of heavy agricultural machinery. This is especially observed in rice-wheat cropping systems.

4.4 Water Holding Capacity & Infiltration Rate

Water-holding capacity is the measure of the capability of the soil to retain water for the growth of crops, whereas infiltration rate measures the entry of water into the soil. Soil with low infiltration results in both runoff and erosion, but low water-holding capacity leads to drought conditions. These parameters are of great importance in the rainfall-based or semiarid areas of India.

5. Chemical Soil Health Indicators

Chemical indicators reveal the availability of nutrients, soil reaction, or general fertility levels.

5.1 Soil pH

Soil pH influences the availability of nutrients, microbial populations, and crop growth. An acidic soil is found in eastern and northeastern India, whereas alkaline as well as saline soil is found in arid areas. Such extremes lower the availability of nutrients and productivity.

5.2 Soil Organic Carbon (SOC)

Soil Organic Carbon is one of the important indicators of sustainable healthy soils. Lower Soil Organic Carbon levels in Indian soils owing to the practice of residue burning and intensive cropping are major challenges to sustainability.

5.3 Nutrients

A balanced availability of macronutrients (N, P, K), secondary nutrients (Ca, Mg, S), and micronutrients (Zn, Fe, Mn, Cu, B) is important for healthy plant growth. Nutrient deficiencies and doubly deficient conditions of nutrients are very common owing to the imbalanced application of fertilizers, especially nitrogenous fertilizers.

5.4 Electrical Conductivity

Electrical conductivity is an indication of the levels of salinity in the soil. This influences

water intake and crop growth. Such soils result in low productivity in irrigated areas, more so in the canal command zones.

6. Biological Soil Health Indicators

Biological indicators express the living aspect of the soil, which is very sensitive to any management practices.

6.1 Soil Microbial Biomass

Soil microbial biomass is the active pool of organic matter that is involved in microbial processes. Well-structured soil with high microbial biomass is essential for efficient microbial activities like the decomposition of organic matter.

6.2 Soil Enzyme

Dehydrogenase, phosphatase, urease, and other enzymes are important for nutrient cycling. These enzymes act as indicators of the onset of changes in the health of the soil.

6.3 Earthworm

Earthworms enhance soil aeration, aggregation, and decomposition. It is a positive indicator of good soil structure and biological activities. A reduction in earthworms is often an indicator of poor soil health and chemical usage.

6.4 Soil Bacteria

Various soil biota increases the stability of the ecosystem, enhance nutritional availability, and improve the resistance of the ecosystem to various stresses. Soil conservation practices ensure the conservation of biodiversity in agricultural systems in India.

7. Soil Health Indicators in Indian Agro-Ecosystems

Soil in India is challenged by factors like erosion, depletion of nutrients, salinization, and reduced organic contents in the soil. Soil health or condition indicators for respective areas of India can or do help in determining the limitations of soil properties. Soil Health Card schemes have been devised for balanced use of nutrients by the farm.

8. Management Strategies to Improve Soil Health

Ensuring better soil health calls for integrated management approaches.

8.1 Integrated Nutrient Management (INM)

When chemical fertilizers are mixed with organic manures, compost, green manures, or biofertilizers, it helps increase the availability of nutrients in the soil.

8.2. Conservation Agriculture

These practices include conservation tillage, straw retention, as well as crop rotation. These practices enhance the structure of the soil, improve the organic carbon levels of the soil, as well as reduce

8.3 Crop Diversification and Rotion

Adding beans, cover crops, and other diversified cropping systems helps improve soil nutrients, manage pests effectively, and boost biotic nitrogen fixation.

8.4 Organic Amendments

Using farmyard manure, vermicompost, crop residues, and biochar helps enhance the physical, chemical, and biological properties of the soil.

8.5 Water & Salinity Management

Watering systems that are water-efficient, effective drainage systems, as well as applications of gypsum, are some of the factors that ensure that salinity levels are controlled in irrigated land

9. Role of Soil Health in Sustainable Crop Production

Well-developed soil helps improve agricultural productivity, lowers the need for external applications, helps make better use of water, and is more climate-resilient. It is important to ensure that the soil remains healthy for sustained agriculture in India.

CONCLUSION

Soil indicators of health enable science-based assessment of the extent of soil health as a means of ensuring sustainable agricultural practices in Indian agricultural ecosystems. Soil indicators of physical, chemical, and biological properties provide information about the utility of the soil. It is important to manage the soil degradation issue by using various approaches. Promotion of conservation practices for enhanced agricultural productivity is important for ensuring healthy agricultural systems in India.

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