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Soil Health Indicators for Monitoring Organic Matter

Dr. Krishna Saharan[1], Mohd Anas[2]

Introduction:

The effects of climate change are increasingly putting pressure on agroecosystems. Soils in particular are susceptible to growing erosion, soil organic carbon (SOC) and nutrient loss, which are directly linked to decreases in soil health (IPCC, 2022) and food security. Even though protection of soil health (or soil quality) has been a research topic for more than two decades, interest has lately also been spurred in the broader society (Gutknecht *et al*., 2022). Soil Organic Matter (SOM) is an essential soil component consisting of decomposed plant and animal residues, living and dead microbial biomass, and products synthesized by soil organisms. It is a dynamic association of substances in different stages of decomposition and is the cornerstone of soil functioning. SOM affects almost all aspects of soil behavior, ranging from nutrient cycling to physical structure, microbial activity, and environmental stability. Soil organic matter can be separated into active (labile) fractions, which degrade in a short time and support microbial activity, and more stable (humified) fractions, which last longer and play a role in long-term soil fertility and structure (Cardoso et *al*., 2013). The European Commission has introduced the 2030 Biodiversity Strategy, which acknowledges the various advantages of biodiversity for society and, more generally, for life on Earth, as part of the EU Green Deal. Monitoring goals are part of the Mission Soil Health, and they are crucial for tracking advancement toward the goals in accordance with the goals of the Green Deal. The creation of reliable indicators to assess the state and changes in soil health and the ongoing ability of soils to support ecological processes for all living forms is a top goal. In turn, improvements in the application of soil health measures necessitate (i) a better scientific understanding of pertinent indicators and standardized methods; (ii) large-scale applicability for thorough monitoring; and (iii) raising farmers' awareness of efficient soil health assessment. Currently, the debate about which indicators are best suited for assessing

Dr. Krishna Saharan[1], Mohd Anas[2]

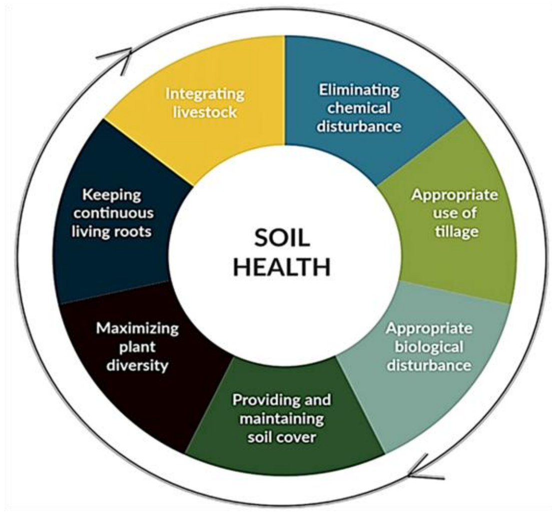
[1]Assistant Professor, College of Agriculture Jodhpur, Agriculture University Jodhpur (AUJ), Jodhpur

[2]Junior Research Fellow, Agroforestry Project, Agriculture University Jodhpur (AUJ), Jodhpur

soil health is still ongoing within the scientific community (Bagnall *et al*., 2020). The complex ity of soil ecosystems renders consensus difficult, not least because soil heterogeneity and individual management targets call for site- and context-specific interpretation of the chosen indicators.

Soil Health

The ability of a living soil to function, within the bounds of a natural or controlled ecosystem, to support plant and animal productivity, maintain or improve the quality of the water and air, and promote plant and animal health is known as soil health. Soil health can change over time due to natural events or human impacts. It is enhanced by management and land-use decisions that weigh the multiple functions of soil and is impaired by decisions that focus only on single functions, such as crop productivity. Thus, balance between soil function for productivity, environmental quality, and plant and animal health is required for optimal soil health. Criteria for indicators of soil quality and health relate mainly to their utility in defining ecosystem processes and integrating physical, chemical, and biological properties; their sensitivity to management and climatic variations; and their accessibility and utility to agricultural specialists, producers, conservationists, and policy makers.



Soil Health Indicator

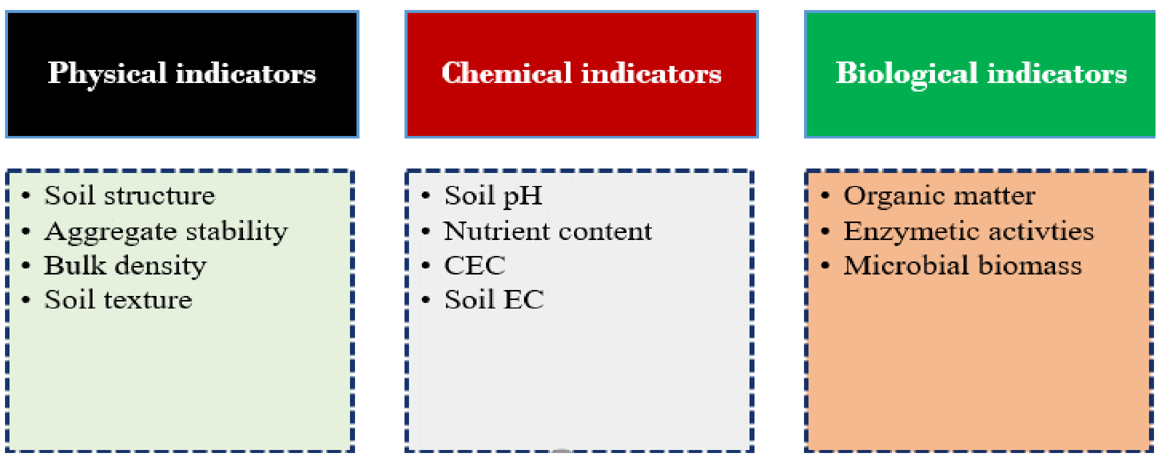
Soil health indicators are quantifiable attributes or measurements that describe the biological, chemical, and physical status of soil. Soil health indicators assist land managers, farmers, scientists, and policy analysts to determine the extent to which a soil is performing to promote plant growth, manage water, cycle nutrients, and sustain a diverse biological community. Soil health indicators form a framework for gauging the impacts of land management practices, environmental conditions, and agricultural interventions on a sustained basis (Ditzler *et.al*., 2002). Tracking soil health via these indicators ensures soils are productive and sustainable in the long term. All the constituents of the soil, Soil Organic Matter (SOM) is one of the most holistic and integrative indicators because it affects several soil functions.

Types of Soil Health Indicators

Physical Indicators : Physical signs exhibit the soil's structural state and water- and air-holding capacity. Examples are:

- **Soil structure:** Refers to the aggregation of soil particles
- **Soil texture:** The sand/silt/clay particle ratio
- **Bulk density and compaction:** High compaction restricts root growth and water penetration

Chemical Indicators : These indicators quantify the availability of major nutrients and the chemical makeup of the soil. Important chemical characteristics are:



- **Soil pH:** Affects nutrient availability and microbial activity
- **Cation Exchange Capacity (CEC):** The capacity of the soil to retain and exchange nutrients
- **Nutrient content:** Nitrogen, phosphorus, potassium, and micronutrient levels

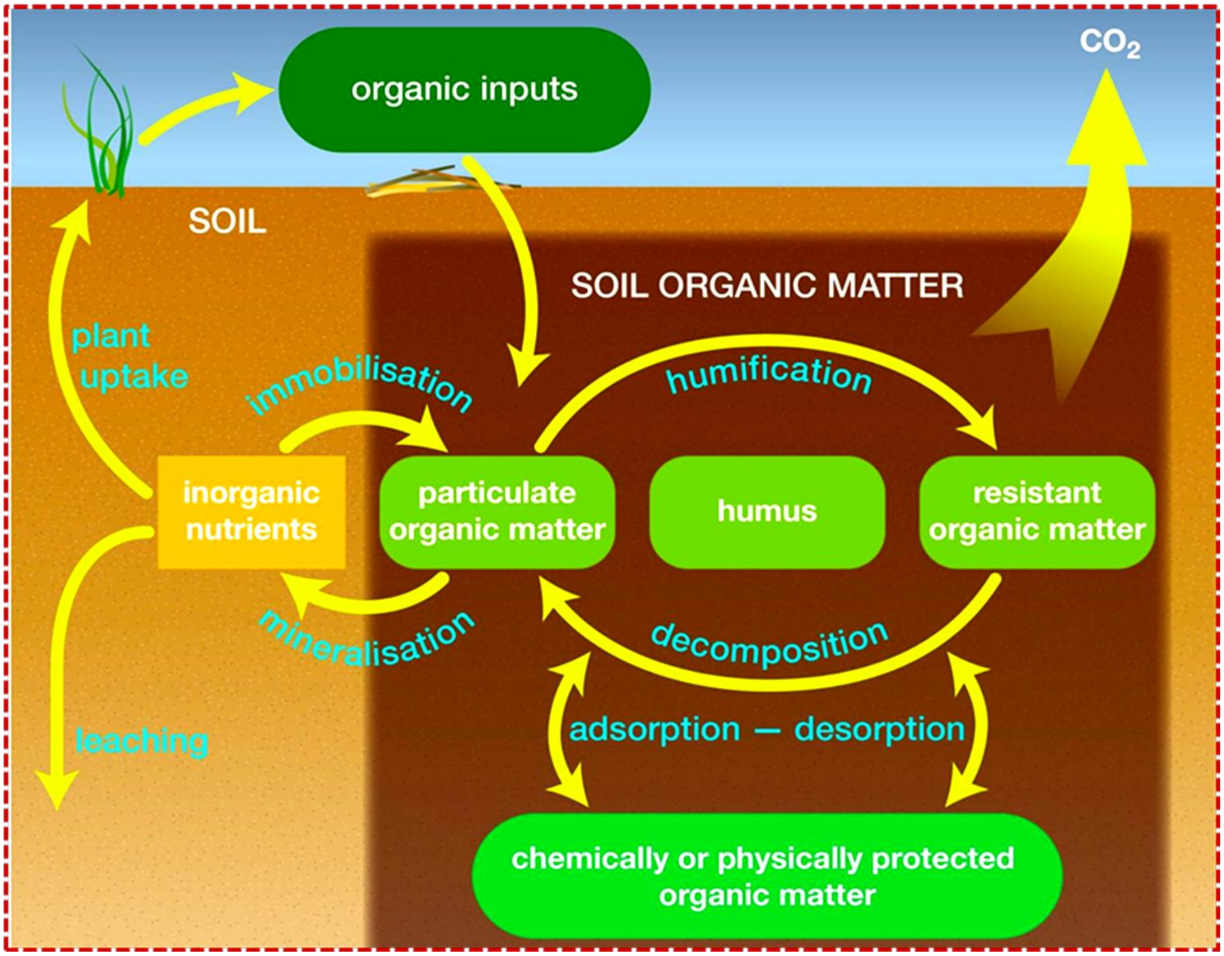
Biological Indicators : Biological indicators measure the activity and diversity of living organisms in the soil, such as microbes, fungi, and fauna. Examples are:

- **Microbial biomass:** The living portion of the soil organic matter.
- **Soil respiration:** Shows microbial activity and decomposition of organic matter.
- **Enzyme activity:** Indicates biochemical processes involved in nutrient cycling.

Monitoring Soil Organic Matter (SOM) Key Indicators

Effective monitoring of soil organic matter (SOM) necessitates the use of specific, reliable indicators that capture the quantity and quality of organic matter in the soil. In research and field monitoring, the following three indicators are most frequently used:

1. **Particulate Organic Matter (POM):** Particulate Organic Matter is formed of partially decomposed organic wastes that



are coarser in size and have a lower density than humified organic matter. The most labile (easily degradable) portion of SOM is POM, which is very susceptible to recent additions like compost or crop leftovers. POM exhibits the current availability of fresh organic substrates for microbial use and is a sensitive indication of changes in soil management because of its quick turnover period.

2. **Carbon to Nitrogen Ratio (C:N Ratio):** The ratio of carbon to nitrogen in organic matter is known as the C:N ratio. Decomposition rates and nutrient mineralization are significantly impacted by the C:N ratio. While a high ratio (over 25:1) slows down decomposition and immobilizes nitrogen, a low ratio (10:1 to 15:1) often results in faster microbial decomposition and nutrient release. The stability and ultimate lifetime of SOM in the soil are determined by the C:N ratio.

3. **Aggregate Stability:** Soil aggregates are aggregates of soil particles held together by microbial by-products and organic matter. Stable aggregates enhance water penetration, hinder erosion, and aid in root growth. High stability of aggregates

indicates favorable SOM content and the physical strength of the soil in different climatic and management conditions.

4. **Total Organic Carbon:** Total Organic Carbon (TOC) is the main constituent of SOM and is the quantity of carbon in organic constituents in the soil. It is an indicator of soil fertility, structural stability, and bioactivity. More TOC usually corresponds to greater nutrient availability and healthier soil. TOC is usually analyzed by dry combustion (for example, with a CHN analyzer) or spectroscopic analysis, giving a quantitative measurement of organic carbon content (Lal *et al*., 2004).

Conclusion

The soil organic matter is valued components of any sustainable production system. Considering its importance in the physical, Chemical and Biological function of the soil, soil organic matter is a necessary tool for assessing the level of degradation or otherwise of a soil. Tracking SOM utilizing several markers of soil health *viz.*, Total Organic Carbon, microbial biomass, respiration, particle organic matter, enzymes activities, and aggregate stability considers the entire function of soils and the sustainability of ecosystems. Indicators inform productive land management strategies, such as fertilizer management, tillage, rotations, and conservation practices. As long as there is a need for a single parameter indicator of soil degradation, it will remain relevant.

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