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Soil Health and Sustainable Agriculture

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Soil health has been defined by Doran and Zeiss (2000) as "the capacity of a soil to function as a vital living system within ecosystem and land use boundaries to sustain plant and animal production, maintain or enhance water and air quality, and promote plant and animal health." Soil health is an intrinsic characteristic of a soil. Soil quality, conversely, is an extrinsic characteristic of soils and changes with the desired use of that soil by humans. It may relate to agricultural output and capacity to support wildlife, to protect watershed, or provide recreational outputs. Agricultural sustainability is described as ability of crop production system to continuously produce food while minimising environmental harm. A healthy soil functions as a dynamic living system, providing many ecosystem services such as maintaining water quality and plant production, managing soil nutrient recycling decomposition, and absorbing greenhouse gases from the atmosphere. The main challenge in sustainable soil management is to preserve ecosystem service delivery while improving agricultural production. It is suggested that soil health is based on the preservation of four primary functions: carbon transformations, nutrient cycles, soil structure maintenance, and pest and disease management. Each of these functions is represented as an aggregate of a number of biological activities provided by a diversity of interacting soil organisms under the influence of the abiotic soil environment. Because soil microbial diversity and activity are key components of soil health, they are strongly linked to sustainable agriculture. Agricultural sustainability is described as ability of crop production system to continuously produce food while minimising environmental harm. Soil microorganisms such as Arbuscular mycorrhizal fungi (AMF), cyanobacteria, and beneficial nematodes improve water use efficiency and nutrient availability to plants, as well as phytohormone synthesis, soil nutrient cycling, and plant resistance to environmental stresses. Organic farming and tillage have been found to promote soil health by increasing the quantity and activity of microorganisms. The rapid projected increase in world population to 8.9 billion people by 2050 will lead to higher demands for agricultural products. High food demands and the shortage of new agricultural land development in the future will require doubling crop yield using sustainable means.

How Soil Health contribute to Sustainable Agriculture?

- The health of soil, plants, animals, people and the environment is one and indivisible. The strategy of restoring soils therefore has numerous benefits, especially in advancing the Sustainable Development Goals (SDGs).
- Sequestration of CO_2 in soil as organic and inorganic carbon – also called "carbon farming" – enables soil carbon stock to be traded as a farm commodity, just like corn, soybean, meat or milk.
- Carbon sequestration can also be rewarded by payments for ecosystem services. Increasing soil carbon stock is also essential for achieving global food and nutrition security. Not only it enhances food production in developing countries, it can help improve nutritional quality – especially with protein and essential micronutrients like iron, zinc and selenium.
- Carbon sequestration, through conservation agriculture (no-till farming with mulch and cover cropping), also helps to filter pollutants, renew fresh water supplies, increase plant-available water capacity, moderate soil temperature and improve soil resilience against agronomic droughts.
- Adopting such conservation agriculture approaches can therefore help make soil and agro-ecosystems more climate-resilient, as well being a cost-effective approach to reducing agriculture's carbon footprint. Plus, the restoration of degraded soils and adoption of systematic conservation agriculture – along with integration of crops with trees and livestock – can also help achieve land degradation neutrality.

Principles to Improve Soil Health

Minimize Disturbance:

- Limit tillage
- Optimize chemical input
- Rotate livestock

Maximize Soil Cover:

- Plant cover crops
- Use organic mulch
- Leave plant residue

Maximize Biodiversity:

- Plant diverse cover crops
- Use diverse crop rotations
- Integrate livestock

Maximize Presence of Living Roots:

- Reduce fallow
- Plant cover crops
- Use diverse crop rotations

How do we measure Soil Health? (Idowu *et al.* 2019)

Soil Physical Indicators	Soil Chemical Indicators	Soil Biological Indicators
Soil compaction level (in field)	Soil primary nutrients (N, P, K)	Soil organic matter
Soil bulk density (in field)	Soil micronutrients (Zn and Fe)	Enzyme activity
Dry aggregate size distribution	Soil salinity	Nitrogen mineralization
Wet aggregate stability	Soil sodicity (sodium problem)	Carbon mineralization
Soil texture	Soil pH	Total microbial biomass
Available water capacity		

Strategy towards Sustainable Agriculture

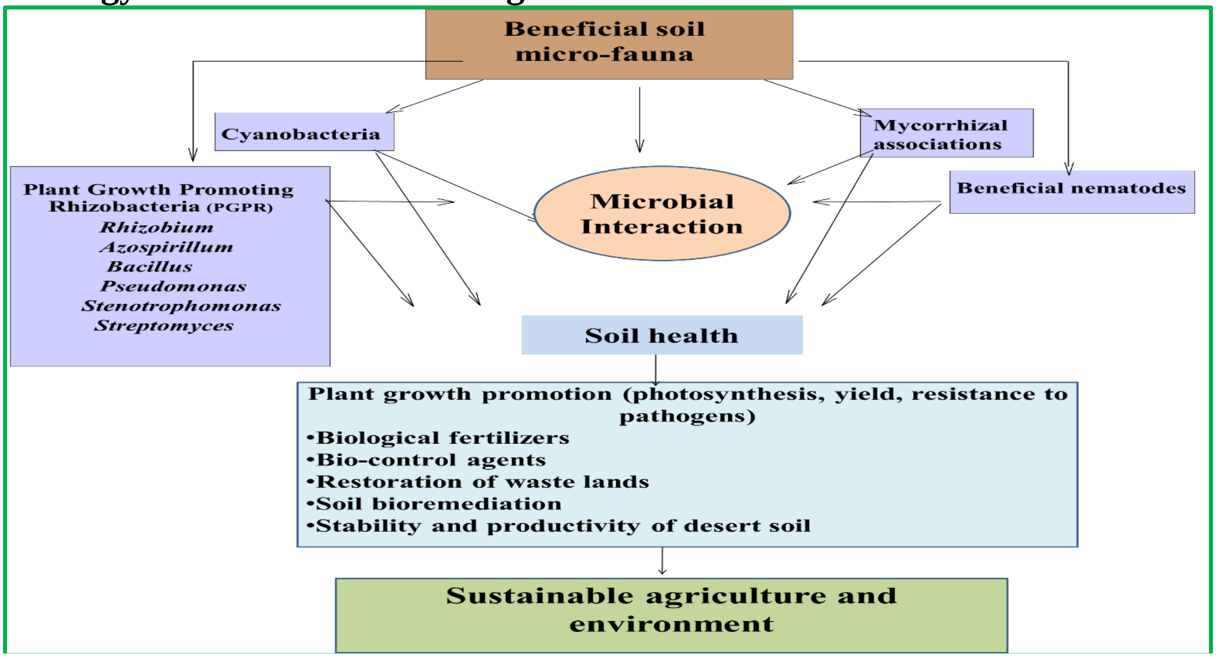

Figure 1. A conceptual theme demonstrating the role of beneficial soil microbes and their interactions for the development of sustainable agriculture and environment. (Singh *et al.* 2011; Tahat *et al.* 2020)

Conclusion

Soil health assessment and management will continue to play a prominent role in sustainable agricultural production systems. Healthy soil is more resilient against fluctuations in growing conditions. With climate change, the resiliency of the soil system needs to be enhanced to cope up with these variations. Soil health considers soil biota component such as microorganism abundance, diversity, activity, and community stability. The diversity and abundance of soil and rhizosphere microorganisms influence plant composition, productivity, and sustainability. Organic system increases soil nutrient mineralization, and microorganism abundance and diversity as well as soil physical properties. Interestingly, organic fertilizer source (plant- or animal-based) can potentially affect microorganism abundance and crop yield. For tillage practices, conservation tillage (no-tillage, reduced, and strip) improve soil health by enhancing soil fungi abundance and activity, earthworm diversity, organic matter, aggregate stability, and cation exchange capacity. There is a need for global attention on improving or restoring soil health. Assessment of soil health indicators is expected to enhance our understanding of the factors underlying processes that contribute to sustainable agriculture.

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