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Soil Quality and Soil Health

Ravinder Kumar*[1], and Priyanka Kumari[2]
[1]*Assistant Professor Soil, Abhilashi University Chailchowk Mandi
[2]Assistant Professor Agronomy, Abhilashi University Chailchowk Mandi

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Abstract

Soil health and soil quality are defined as the capacity of soil to function as a vital living system within land use boundaries. This function which sustains biological productivity of soil also maintains the quality of surrounding environment and human health. Thus the two terms are used interchangeably although it is important to distinguish that, soil quality is related to soil function, whereas soil health presents the soil as a finite non-renewable and dynamic living resource. Adverse effects on soil health and soil quality arise from nutrient imbalance in soil, excessive fertilization, soil pollution and soil loss processes that are increasingly becoming common in developing countries. This review will examine the development of soil health approaches as well as the content of soil health and soil quality information and its application to reduce negative impacts on agricultural productivity and long term sustainability.

Introduction

Soil health or soil quality is a concept that has increased in popularity over the past several years, especially since the early 1990s. It continues to gain traction among farming and ranching communities, soil managers, scientists, agricultural Extension specialists, and other groups that work with soil. "Soil health" is an important focus for many agricultural groups interested in regenerative and sustainable crop and livestock production as well as land management. While awareness of soil health is increasing, it is important to have a good understanding of what soil health entails, how it is measured, and how to manage it for optimal and sustainable delivery of the ecosystem services that soils provide. Soil, like air and water, is a fundamental natural resource supporting a variety of ecosystem goods and services to the benefit of the mankind. While production function of soil was recognized long

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back, importance of conservation and enhancement of ecosystem services rendered by soil (e.g., carbon sequestration, water purification, and recharge of ground water, control of populations of pathogens, biological nitrogen fixation and biodiversity conservation) has been realized only in the recent past. A concern for maintaing/improving soil quality arose long after that for water and soil. Soil processes are such that soil has been considered as an ecosystem by itself rather than a component of ecosystem. While criteria, indicators and standards of water and air quality are unambiguous and universally accepted, the concept of soil quality, further elaborated as soil health is still evolving, with soil quality legislations framed so far only in a few countries (Filip 2002, Nortcliff 2002).

Productivity and sustainability of any production system not only depend upon the management practices but also on the environment as well as on the soil quality. An agricultural soil with good quality promotes and sustains good agricultural productivity with less environmental impact and possesses utmost physical, chemical and biological attributes to fulfill these requirements (Reynolds et al. 2009). The quality and health of soil determine agricultural sustainability and environmental quality, which jointly determine plant, animal and human health (Haberern 1992, Doran 2002). Soil health appropriately, we need to consider the words that form "soil health." "Soil" is defined by the Soil Science Society of America (SSSA) as "the unconsolidated mineral or organic material on the immediate surface of the earth that serves as a natural medium for the growth of land plants." "Health" is defined by Merriam-Webster as "the condition of being sound in body, mind, or spirit." We can restructure this definition of health to apply to the soil. Combined with the SSSA's definition of soil, "soil health" can be defined as "the state of the soil being in sound physical, chemical, and biological condition, having the capability to sustain the growth and development of land plants." Incorporating all these elements is a holistic definition of soil health as "the capacity of soil to function as a vital living system, within ecosystem and land-use boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and promote plant and animal health" (Doran and Zeiss, 2000). Productivity and the function of soil sustainability can be illustrated by using soil quality indices (Griffiths et al. 2010).

Soil quality index is increasingly proposed as an integrative indicator of environmental quality (NRC 1993), food security and economic viability (Lal 2000).

Therefore, it would appear to be an ideal indicator of sustainable land management. It helps to assess changes in dynamic soil properties caused by external factors and is used for assessing the overall soil condition and response to management, or resilience towards natural and anthropogenic forces. Soil quality index may be inferred from various soil indices derived from physical, chemical and biological attributes that reflect its condition and response. Hence, the use of soil indices for evaluating soil quality or fertility at particular agricultural land is best to be taken as rational rather than absolute (Herrick 2000; Imaz et al. 2010). It means that the usage of soil indices would be able to give an earlier indication and information on the current status of soil health.

Soil indicators:

Indicators of soil quality can be categorized into four general groups: visual, physical, chemical, and biological. Visual indicators may be obtained from observation or photographic interpretation. Exposure of subsoil, change in soil color, ephemeral gullies, ponding, runoff, plant response, weed species, blowing soil, and deposition are only a few examples of potential locally determined indicators. Visual evidence can be a clear indication that soil quality is threatened or changing.

- **Physical indicators** are related to the arrangement of solid particles and pores. Examples include topsoil depth, bulk density, porosity, aggregate stability, texture, crusting, and compaction. Physical indicators primarily reflect limitations to root growth, seedling emergence, infiltration, or movement of water within the soil profile.
- **Chemical indicators** include measurements of pH, salinity, organic matter, phosphorus concentrations, cation-exchange capacity, nutrient cycling, and concentrations of elements that may be potential contaminants (heavy metals, radioactive compounds, etc.) or those that are needed for plant growth and development. The soil's chemical condition affects soil-plant relations, water quality, buffering capacities, availability of nutrients and water to plants and other organisms, mobility of contaminants, and some physical conditions, such as the tendency for crust to form.
- **Biological indicators** include measurements of microand macro-organisms, their activity, or byproducts. Earthworm, nematode, or termite populations have been suggested for use in some parts of the country. Respiration rate can be used to detect

microbial activity, specifically microbial decomposition of organic matter in the soil. Ergosterol, a fungal byproduct, has been used to measure the activity of organisms that play an important role in the formation and stability of soil aggregates. Measurement of decomposition rates of plant residue in bags or measurements of weed seed numbers, or pathogen populations can also serve as biological indicators of soil quality.

Table 1. Ecological functions of soil (FAO 1995) and their indicators

Ecological Functions of Soil	Indicators of Proper Functioning
Production function	High levels of crop yields and incomes
Biotic environmental function/living space function	High levels of species richness and functional dominance of beneficial organisms –High levels of crop yields and incomes and high quality food and habitation
Climate-regulative function/storage function	High levels of carbon stocks and slow rates of greenhouse gas emissions
Hydrologic function	Adequate availability of water/reduced risks floods
Waste and pollution control function	High levels of crop yields and incomes and high quality food and habitation

Table 2 Key soil indicators for soil quality assessment

Selected indicator	Rationale for selection
Organic matter	Defines soil fertility and soil structure, pesticide and water retention, and use in process models
Top soil-depth	Estimate rooting volume for crop production and erosion
Aggregation	Soil structure, erosion resistance, crop emergence an early indicator of soil management effect
Texture	Retention and transport of water and chemicals, modeling use
Bulk density	Plant root penetration, porosity, adjust analysis to volumetric basis

Infiltration	Runoff, leaching and erosion potential
pH	Nutrient availability, pesticide absorption and mobility, process models
Electrical Conductivity	Defines crop growth, soil structure, water infiltration; presently lacking in most process models
Suspected pollutants	Plant quality, and human and animal health
Soil respiration	Biological activity, process modeling; estimate of biomass activity, early warning of management effect on organic matter
Forms of N	Availability of crops, leaching potential, mineralization/ immobilization rates, process modeling
Extractable N,P and K	Capacity to support plant growth, environmental quality indicator

Conclusions

Although many indicators and indices of soil quality and soil health have been proposed a globally acceptable and applicable definition and methodology of assessment of soil quality or soil health are still not in place. Further, the existing knowledge provides a better understanding of the current capacity of a soil to function than of making predictions about capacity of the soil to continue to function under a range of stresses and disturbances. While simultaneous analysis of physical, chemical and biological characteristics of soil is required to evaluate sustainability/ unsustainability of different management practices, most studies in developing countries have looked at physical and chemical characteristics only.

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