12. IMPORTANCE OF ASSESSING MICROBIAL SOIL QUALITY PARAMETERS TOWARDS SUSTAINABLE AGRICULTURE

Alka Gupta, Murali Gopal and S. Paulraj

Microbiology section

Central Plantation Crops Research Institute

Kudlu P.O., Kasaragod – 671124, Kerala

Microorganisms are a component of the 'biological engine of the earth' and provide an integrated measure of soil quality, an aspect that cannot always be obtained with physical and chemical measures and/or analysis of higher organisms. Microorganisms are driving many fundamental nutrient cycling processes, soil structural dynamics, degradation of pollutants, various other services and respond quickly to natural perturbations and environmental stress due to their short generation time and their intimate relation with their surroundings, attributed to their higher surface to volume ratio. This allows microbial analyses to discriminate soil quality status, and shifts in microbial population and activity could be used as an indicator of changes in soil quality.

The living soil system is of primary importance in sustainable agricultural production. Soil quality is considered as an integrative indicator of environmental quality, food security and economic viability. In recent years, there has been an increasing awareness of soil quality to ensure a greater sustainability of agricultural soils. The definition of soil quality encompasses physical, chemical and biological characteristics, and it is related to fertility and soil health.

Many indicators can be used to describe soil quality and health, mostly the biological properties have been used as soil quality indicators, because of their relationship with organic matter content, terrestrial flora and fauna, microbial biomass or functional groups and their metabolic products Properties related to organic matter content, such as C/N ratio, organic carbon fractions (humic acids, fulvic fraction); enzymatic activity (β glucosidase, urease, phosphatises etc) or aggregate stability, can be used as soil quality indicators. They provide early information about mineralization processes, nutrient availability and fertility, as well as effects resulting from changes in land use, or agricultural practices.

Biological indicators include measurements of micro- and macro-organisms, their activities or functions. There are several biological soil properties that can be used as soil quality indicators, alone or in combination with other chemical or physical properties. Concentration or population of earthworms, nematodes, termites, ants, as well as microbial biomass, fungi, actinomycetes, or lichens can be used as indicators, because of their role in soil development and conservation; nutrient cycling and specific soil fertility. Quantitative and qualitative changes in the **population of soil microorganisms** reflect changes in soil quality. These changes are potentially useful as responsive indicators of the effects of crop and soil management.

Biological indicators also include metabolic processes such as respiration, used to measure microbial activity related to decomposition of organic matter in soil, and a commonly used index: the **metabolic quotient** ($qCO2$), defined as the respiration to microbial biomass ratio, which is associated to mineralization of organic substrate per unit of microbial biomass. Biological activities such as enzyme activity, particularly enzymes such as cellulases, arylsulfatase, phosphatases, related to specific functions of substrate degradation or mineralization of organic N, S or P. Soil enzymatic activity assays act as potential indicators of ecosystem quality being operationally practical, sensitive, integrative, described as "biological fingerprints" of past soil management, and relate to soil tillage and structure. Determination of rates of decomposition of plant debris and the presence of the population of pathogenic organisms can also serve as biological indicators of soil quality.

Soil organisms are sensitive indicators, and reflect the influence of human management and climate changes. Similarly, soil organisms are considered indicators of quality and health because the diversity and abundance may be related to functions such as decomposition of organic matter, plant and root development (competition), sequestration and detoxification of heavy metals, pesticides and other pollutants, disease-suppressive soil, and presence of pathogens in soil and plant.

Soil organic carbon (SOC) is a soil property considered one of the most important indicators of soil quality; it has positive effects on soil physical properties and promotes water infiltration, storage and drainage. It is directly related to the maintenance of soil structure, presence of different groups of microorganisms, mineralization of organic matter, and nutrient availability.

Soil properties associated with **soil organic matter** (SOM) have been recognized as key indicators and to have an effect on other properties. Soil organic matter defines the energy supply to microorganisms, availability and quality of substrates, and the biodiversity necessary to sustain many soil functions. Management practices such as minimum or conservation tillage. Factors such as N and C pools, including total and particulate organic C and N, soil microbial biomass C, clay or polysaccharides content that affect SOM decomposition, altering soil properties associated with soil quality. The particulate organic matter is more responsive to changes in management practices, than the total organic carbon, being related to aggregate stability and nitrogen mineralization.

Soil microbial biomass compared with that of superior organisms is a more sensitive indicator and is influenced by different ecological factors like plant diversity, soil organic matter content, moisture, and climate changes. Microorganisms provide information on the impact of intercropping, incorporation of organic matter, management practices, and tillage activities contributing to soil structure and stabilization. Microbial communities respond to environmental stress or ecosystem disturbance, affecting the availability of energetic compounds that support desired microbial population.

Phospholipid fatty acids (PLFAs) are a potentially useful biomarker molecule that is being used to elucidate structure of microbial community in soil because of their presence in all living cells and rapid degradation upon cell death. Fatty acid methyl ester (FAME) analysis, which directly extracts PLFAs from soil, is a biochemical method that does not rely on culturing of microorganisms and provides information on the microbial community composition based on groupings of the fatty acids used for determining gross community changes associated with soil management practices.

Functional diversity of microbial communities includes the range and relative expression of activities involved in functions namely decomposition of organic carbon, nutrient transformation, plant growth promotion/suppression and soil physical processes as influenced by microorganisms. The functional diversity of microbial communities has been found to be very sensitive to environmental changes. Among the functional diversity indicators, the carbon utilization pattern and the measurement of enzymatic activity profiles expressed by the whole bacterial community have been suggested as useful tools to evaluate the soils. The two most common methods of measuring substrate utilization patterns are the community-level physiological profiling by Biolog plates methods and in situ substrate-induced respiration (SIR).

Soil enzymes play biochemical functions in the overall process of organic matter decomposition in the system; they are important in catalyzing several reactions, necessary for the life processes of microorganisms in soils, the stabilization of soil structure, the decomposition of organic wastes, organic matter formation, and nutrient cycling, providing an early indication of the history of a soil and its changes in agricultural management. Thus, they have been studied as indicators of soil quality. Most commonly studied enzymes are detailed below:

β – Glucosidase

It is widely distributed in the environment, and its activity has been detected in soil, fungi and plants. It has been used as a key soil quality indicator due to its importance in catalytic reactions on cellulose degradation, releasing glucose as a source of energy to maintain metabolically active microbial biomass in soil. At the same time, it plays an important role in energy availability in the soil which is directly related to labile C content and with the ability to stabilize soil organic matter, showing low seasonal variability.

Phosphatase

Phosphorus is an essential nutrient for plant growth and crop yields; however a large portion is immobilized because of intrinsic characteristics of soils such as pH that affects the availability of nutrients and the activity of enzymes, altering the equilibrium of the soil solid phase. Soil microorganisms play a key role on phosphate solubilization with the release of low molecular weight organic acids and production of extracellular enzymes as phosphatases. Phosphatases are a group of enzymes that catalyze hydrolysis of esters and anhydrides of phosphoric acid. Phosphatase enzyme activity and soil properties such as pH, total N, organic P and clay content are strongly correlated.

Dehydrogenase

Dehydrogenase enzymes are an integral part of microorganisms and are involved in organic matter oxidation. Dehydrogenases are bound to living and active cells.

Dehydrogenase activity is considered as a soil quality indicator because it is involved in electron transport systems of oxygen metabolism and requires an intracellular environment (viable cells) to express its activity.

Urease

These enzymes are involved in urea hydrolysis into CO_2 and NH_3 and consequently with soil pH increase and N losses by NH_3 volatilization. Urease has been widely used to evaluate changes on soil quality related to management, since its activity increases with organic fertilization and decreases with soil tillage. Its activity depends on microbial community, physical, and chemical properties of soil, and its stability is affected by several factors. Urease activity is used as a soil quality indicator because it is influenced by soil factors such as cropping history, organic matter content, soil depth, management practices, heavy metals and environmental factors like temperature and pH.

Enzyme activities have been associated with indicators of biogeochemical cycles, degradation of organic matter and soil remediation processes, so they can determine, together with other physical or chemical properties, the quality of a soil. Enzymes are good indicators because: a) they are closely related to organic matter, physical characteristics, microbial activity and biomass in the soil, b) provide early information about changes in quality, and are more rapidly assessed.

Baseline parameters such as soil respiration, organic carbon pool, and soil enzymes are routinely utilized worldwide for monitoring soil quality. Many countries have developed their own microbiological indicators for monitoring of soil quality where microbial biomass and soil respiration are the most commonly used. In India, soil enzyme activities, respiration and microbial biomass are being used widely. This is important to improve soil management and retain or remediate soil quality and to determine if the soils have deteriorated or are deteriorating in terms of soil productivity or other critical soil functions. Then, based on the magnitude of soil deterioration, stakeholders can develop better practices to manage their soils and increase the sustainability of their agricultural practices.