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THEORETICAL AND METHODOLOGICAL BASIS FOR THE DETERMINATION OF SOIL QUALITY INDICATORS IN AGRICULTURAL SYSTEMS IN CENTRAL CUBA

FUNDAMENTOS TEÓRICOS Y METODOLÓGICOS PARA LA DETERMINAR LOS INDICADORES DE LA CALIDAD DE LOS SUELOS EN SISTEMAS AGRÍCOLAS DEL CENTRO DE CUBA

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ABSTRACT

Nowadays, agricultural systems represent a threat to soil degradation. Current conditions cause nutrient extraction and loss of biodiversity. In Cuba, agriculture is an important economic sector and is not exempt from the problems that cause soil degradation and the use of agricultural practices that improve soil quality are increasingly necessary as is the use of indicators to evaluate the effect of management in agroecosystems. Soil biota plays an important role as they participate in important biological processes such as organic matter decomposition and nutrient cycling. In recent years microbial biomass, enzyme activities and soil microbial community composition have been suggested as biological indicators sensitive to changes in agricultural management. However, numerous investigations underestimate the use of mesofauna and disease suppression despite the clear potential they offer. Therefore, in order to deepen this study, it is necessary to provide a theoretical and methodological basis for the use of soil quality indicators and the effect of agricultural management in Cuban agricultural systems.

Keywords: organic agriculture, soil quality, indicators, management, farming systems.

RESUMEN

Actualmente, los sistemas agrícolas representan una amenaza para la degradación de los suelos. Las condiciones actuales provocan la extracción de nutrientes y pérdida de la biodiversidad. En Cuba, la agricultura es un importante sector económico y no está exenta de los problemas que causan la degradación de sus suelos y el uso de prácticas agrícolas que mejoren la calidad del suelo son cada vez más necesarios como es el uso de indicadores para evaluar el efecto del manejo en los agroecosistemas. La biota del suelo desempeña un papel importante ya que participan en importantes procesos biológicos como la descomposición de la materia orgánica y el ciclo de los nutrientes. En los últimos años la biomasa microbiana, las actividades enzimáticas y la composición de la comunidad microbiana del suelo han sido sugeridas como indicadores biológicos sensibles a los cambios en el manejo agrícolas. Sin embargo, numerosas investigaciones subestiman el uso de la mesofauna y la supresión de enfermedades a pesar del claro potencial que ofrecen. Por tanto, para profundizar en este estudio es necesario fundamentar de forma teórica y metodológica sobre el uso de indicadores de la calidad del suelo y el efecto del manejo agrícola en sistemas agrícolas de Cuba.

Palabras clave: Agricultura orgánica, calidad del suelo, indicadores, manejo, sistemas agrícolas.

INTRODUCTION

Nowadays, agricultural production systems represent a threat to the degradation of soil resources. The current conditions of exploitation of agricultural systems lead to nutrient extraction, erosion and loss of soil biodiversity and with it the degradation of limited resources in agroecosystems globally (Keesstra ***et al***., 2016).

The changes brought about by the Cuban Revolution in 1959 put an end to private ownership of large farms, which were replaced by large state-owned enterprises. These productive forms caused a drastic increase in yields due to high agricultural intensification with high availability of inputs and overexploitation of soils. Subsequently, due to the enormous economic and agricultural crisis that the country suffered, the government triggered a reorientation of agriculture, which gave rise to a greater number of small, decentralized and diverse private agricultural entities. These farming systems are characterized by differences in land ownership, technological complexity and agricultural intensification (McCune ***et al***., 2011).

In this context each farming system manages its crops and soils differently causing different effects on soil properties. This has led to a deterioration of soil fertility, increasing the vulnerability of agricultural systems to changes caused by the impact of management practices. Therefore, the use of agricultural practices that improve productivity and maintain soil fertility is desirable creating conditions conducive to improve crop yields and food security (McCune ***et al***., 2011).

In this sense, there is little research that addresses the state of soil quality through a comprehensive assessment of its physical, chemical and biological properties. Moreover, the importance of soil biological properties has recently been recognized as important indicators to assess soil quality. This is because soil biological properties change rapidly in response to changes in management practices and different environmental conditions, so they have been considered critical indicators to assess the quality status and processes occurring in the soil (D'Hose et al., 2014). For this, it has been necessary to study the effect of management practices on the properties that determine the state of soil quality in agricultural systems.

Soil biota play an important role in soil as they actively participate in soil biological processes such as decomposition and nutrient cycling. Microbial biomass, enzyme activity and microbial community composition have been suggested as sensitive biological indicators due to changes in soil management practices in agroecosystems (Moeskops ***et al***., 2010).

Soil fauna play an important role in soil functioning, participating in the decomposition and mineralization of organic matter, improving soil fertility and regulating microbial populations (Rieff ***et al***., 2016). Soil fauna is the most diverse biological community in soil and its members have been increasingly included in studies of agroecosystems. These studies have suggested their use as reliable indicators of changes brought about by human activity (Bokhorst ***et al***., 2018).

Finally, soil suppression to diseases has also been pointed out as an indicator of quality. This is due to the relationship that exists between pathogens and soil properties which contribute to the development of a disease (van Bruggen & Semenov, 2000).

The use of these indicators to assess soil quality in agricultural systems has been the subject of numerous studies (Reeves, 1997), but differences in soil quality and performance as a result of various types of management in agricultural systems have been less explored. Therefore, the use of a system of effective (especially biological) indicators may become a powerful tool to support the development of policies that support the sustainability of agricultural systems.

The deterioration of soil quality in many Cuban agricultural systems has negatively affected yields and consequently food security. This implies that the country has to import more and more resources to supply these needs, so it is necessary to search for strategies to evaluate soil quality and provide the tools to outline soil recovery policies through the use of locally available resources as low cost alternatives for the evaluation of soil quality. Therefore, in order to deepen this study, it is necessary to provide a theoretical and methodological basis for the use of soil quality indicators and the effect of agricultural management in agricultural systems in central Cuba.

Soil quality indicators and the effect of agricultural management in farming systems

Soil quality is considered as a measure of its capacity to function adequately in relation to a specific use in agricultural systems. This quality is determined by the physical, chemical and biological properties of the soil, therefore, for these properties to be considered indicators of quality in agricultural systems, they must be easy to measure in field conditions, both by producers and specialists, and integrate the physical, chemical and biological processes of the soil that allow establishing changes and differences between agricultural systems. Furthermore, they should be sensitive to changes in the soil and reflect the sustainability attribute to be evaluated.

Importance of soil quality in agricultural systems: Definitions and concepts

Given that soil is a resource of vital importance for the provision of essential functions that support agricultural production, its exploitation for food production has caused serious problems that compromise the full development of crops and the sustainability of agroecosystems in general. Among the essential services that are related to the proper functioning of soil are those related to biochemical and biological cycles, climate change mitigation and biodiversity support (Keesstra ***et al***., 2016).

In recent times, the soil resource has been of great interest due to the need for agricultural systems to be able to produce enough food to meet an ever-increasing demand. This is due to the fact that the existence of industrialized agricultural models and the current exploitation conditions for agricultural production cause an accelerated increase in the degradation of this resource (Altieri & Nicholls, 2012). Such conditions have caused an imbalance of the physical, chemical and biological components that compose it and that are therefore essential to maintain the state of soil quality on which the sustainability of agricultural production will depend (Keesstra ***et al***., 2016).

Since soils are a fundamental resource for agriculture, the need to develop and manage healthy soils has been increasingly evident over time, with the concept of soil quality emerging in the late 1980s and early 1990s (Janvier ***et al***., 2007).

The term soil quality has been used by numerous authors, who have related it to the physical, chemical and biological parameters of the soil, capable of carrying out various functions (Doran & Zeiss, 2000). This author defined soil quality as “the ability of a soil to function, within natural or managed ecosystem limits, to sustain plant and animal productivity, amplifying soil fertility to include those soil services that are not directly agricultural, such as habitat provision, carbon management, and maintenance of soil structure”.

These properties are generally unaffected by human management, so the effects of management on soil quality cannot be directly compared between soil types. Inherent soil properties include texture and cation exchange capacity (CEC). However, dynamic soil properties are determined by soil use and management and can be measured over time. Dynamic soil properties include organic matter content, microbial biomass, enzyme activities, among others. Dynamic soil properties have been considered in numerous investigations to evaluate changes in soil quality (Karlen ***et al***., 2003).

To evaluate soil quality, the most critical parameters that reflect the desired objectives must be identified and measured. These parameters are called indicators, which can be defined as “a variable that provides information on other variables that are difficult to access... and that can be used as a reference to make a decision” (Janvier, 2007).

There is a wide variety of indicators that have been identified to measure soil quality. These indicators should be easy to measure and sensitive to variations caused by agricultural management. They should provide an integrated assessment of chemical, physical and biological soil properties and processes and should function equally well in different contexts and reliably reveal what problems exist and where (Janvier, 2007).

Indicators to assess soil quality

The selection of an appropriate set of indicators to assess the quality of a soil is necessary for the design of a strategy to judge soil functioning in a relevant way and thus define the effect of management on agricultural systems (Karlen et al., 2003). Such functions that influence soil quality must be related to physical, chemical and biological soil parameters and must show a high sensitivity to agricultural management practices and changes in the soil environment (Karlen et al., 2003).

- Physical soil indicators

The good physical condition of a soil promotes root growth, supplies water and maintains the mineral nutrients necessary for crop development. Such physical soil conditions provide retention of soil particles by plant roots and optimal gas exchange that prevent erosion by water or wind. On the other hand, soil structure describes the size and shape of soil aggregates, where the retention capacity of these aggregates has been indicated by the stability of soil aggregates. In addition, these properties are related to many other soil properties influenced by the organic matter content (Schoenholtz ***et al***., 2000).

Bulk density is another important physical indicator as it is related to soil compaction. This indicator is highly dependent on soil texture and particle densities of mineral material (sand, silt or clay), as well as soil organic matter. As a rule of thumb, a medium textured soil with about 50 % pore space will have a bulk density of 1.33 g/cm^3. Whereas silty or clayey soils are lighter, porous and richer in organic matter, so they have a lower bulk density. These soils have a finer texture with a good structure and a larger pore space; while sandy soils have a relatively high bulk density, since the total pore space is smaller (Arshad and Azooz, 1996).

Bulk density increases with soil depth, since subsurface layers have reduced organic matter content, as well as less root aggregation and penetration compared to surface layers, and therefore has less pore space. The relationship between bulk density and the different soil functions reflects the soil's ability to function as a structural support, as well as favoring the movement of water and solutes, thus improving soil aeration. Table 1 shows the effect of the relationship between bulk density and soil texture on crop development (Arshad & Azooz, 1996).

Table 1. General relationship of soil bulk density and root growth based on soil texture

Soil texture	Ideal Bulk Density for plant growth (g/cm^3)	Bulk density restricting plant growth (g/cm^3)
Sand	< 1,60	< 1,80
Silt	< 1,40	< 1,65
Clay	< 1.10	< 1,47

Sourse: Arshad & Azooz (1996)

- Chemical soil indicators

Soil organic matter (SOM) content has been considered an important indicator of soil quality, due to its link with other indicators also related to soil quality (Moeskops *et al*., 2010). Soil organic carbon (SOC) is an important indicator related to SOM. Therefore, SOC concentrations are determined by a balance between crop residue input and other sources of organic matter (Sleutel *et al*., 2005). The stability of SOC is influenced by the chemical structure that composes it and the existence of various protective mechanisms provided by soil minerals.

The availability of nutrients to plants depends on the balance between the exchange sites and the soil solution, which can be affected by soil acidity (pH). In addition, this parameter is linked to the activity of numerous microorganisms, responsible for the decomposition of organic matter and the transformations that occur in the soil profile. Therefore, soil acidity is also considered as a chemical indicator of soil quality. The ideal pH range for most soils is between 6.5 and 7.5, where nutrients are optimally available for plants as well as for the survival and functioning of most microorganisms (Table 2) (Smith & Doran, 1997).

Table 2. Optimal pH ranges and values for microbial groups

Microorganisms	pH range	Optimal pH
Bacteria	5-9	7
Actinomycetes	6,5-9,5	8
Fungi	2-7	5
Protozoa	5-8	>7

Source: adapted from Smith & Doran (1997)

Nutrient availability is essential for agricultural production to maintain adequate yield and crop quality. Phosphorus (P) is the second most common limiting nutrient. Its importance is due to the fact that this element governs the plant's ability to store and transfer energy, which is produced through photosynthesis. This energy is necessary for growth, reproduction and crop productivity. For these reasons, soils must maintain adequate levels of phosphorus to maintain their fertility (Smith & Doran, 1997). Available P is defined as the amount of P released to the soil solution during a relevant period of time to be taken up by plants for growth, although phosphorus in the soil solution is taken up by plants as inorganic phosphorus. Recent studies have shown that soil organic phosphorus can also contribute considerably indirectly to plant nutrition.

- Biological soil indicators

The regulation of services in agroecosystems takes place through the activity of a variety of organisms in the soil. These organisms are interrelated with each other and in equilibrium with the physical and chemical properties of the soil. This relationship indicates the soil's ability to function and its resistance to disturbance. The use of these organisms as biological indicators (bioindicators) makes it possible to obtain information on disturbances produced by agricultural activities on soil quality in a more integrated, easier and faster way (Alkorta ***et al***., 2003).

Microbiological soil indicators

In agricultural systems, the activity of microbial communities has a great influence on soil productivity and quality. Microorganisms in the soil participate in nutrient cycling through the decomposition of organic matter, releasing nutrients that are taken up by plants (Cookson ***et al***., 2008).

The soil microbial community has been defined as an indicator of quality and is composed of a group of soil-dwelling organisms that are generally approximately less than 10 µm in size. Within the microbial biomass, most attention is given to fungi and bacteria; as these two groups are the most important in terms of energy flow and nutrient transfer in terrestrial ecosystems. Both groups of microorganisms are generally dominant within the microbial biomass (Cookson ***et al***., 2008) and contribute to the decomposition of organic matter and the improvement of soil stability. However, some soil microorganisms also have the potential to suppress diseases or act as pathogens (Moeskops, 2010).

In recent decades, the soil microbial community has been a highly used indicator and has been assessed by microbial biomass carbon (MBC) analysis and phospholipid fatty acid biomarkers (PLFAs). The latter have also been used to determine the composition of microbial communities in soil (Moeskops, 2010).

- Microbial biomass: Microbial Biomass Carbon (MBC)

Microbial biomass is a measure of the living part of soil organic matter. Five percent of the total organic carbon and nitrogen in the soil comes from that microbial biomass, which are released to the soil in plant-available forms after the death of the microorganisms (Cookson ***et al***., 2008). Microbial biomass has a high dependence on soil organic matter, thus reflecting changes in agricultural management on soil quality and nutrient status.

Given its role within the soil profile, measurements of biologically active fractions of organic matter such as MBC could better reflect changes in soil organic matter and soil quality induced by agricultural management practices. This reflection is based on the rapidly changing capacity of C forms within the processes occurring within the soil profile (Figure 1)

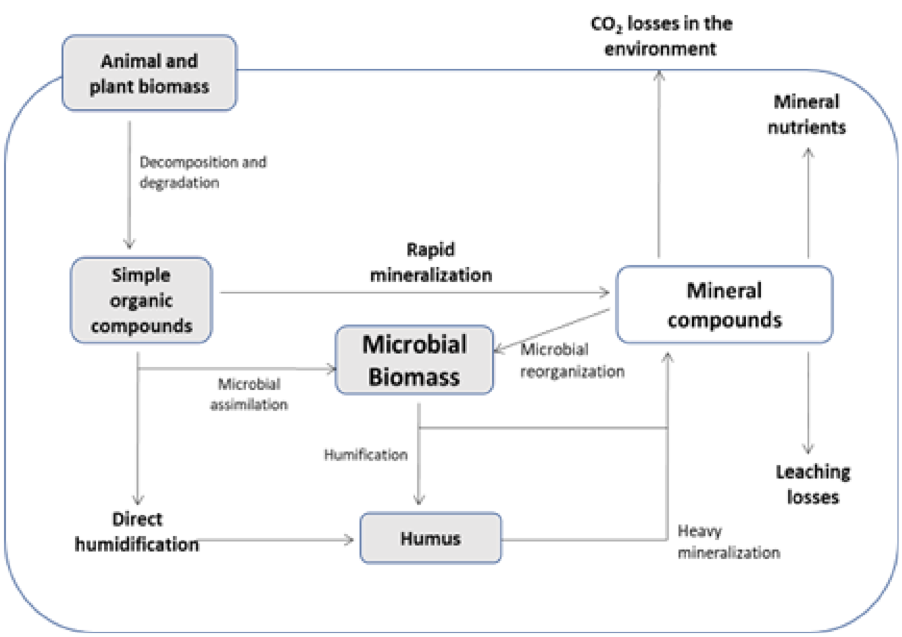

Figure 1: Role of microbial biomass in soil processes.

Source: Kara and Bolat (2008).

- Microbial composition: phospholipid fatty acids (PLFAs)

The phospholipid fatty acids associated to the soil are particularly useful biomarkers. They are essential components of every living cell with great structural diversity and biological specificity (Ratledge, 1994). These compounds have been used to identify microorganisms in situ and are a particularly attractive method, as the same compounds are widely used in the taxonomy of numerous microbial groups.

Biological specificity (type of microorganism) is determined by the different chain lengths and composition in response to environmental conditions, thus degrading rapidly after cell death. These biomarkers are considered viable within the soil microbial community. Among the great variety of microorganisms, fungi and bacteria stand out for their dominance within the microbial biomass and have been the most studied groups (Cookson *et al*., 2008). These microorganisms are characterized by PLFAs with a chain length of between 14 and 20 carbon atoms. Analysis of PLFAs cannot be used to identify individual microbial species; however, it can provide a global fingerprint of the different groups of microbial communities found in soils. In addition, they have been used, for example, to investigate changes caused by the impact of different management methods in agricultural systems (Moeskops, 2010).

- Soil fauna

Although soil decomposition processes are mainly mediated by microorganisms, the influence on soil composition and structure is also closely related to the soil invertebrate community. This community is extremely diverse and has been poorly understood in soil quality studies. The use of different mesofaunal groups as indicators to assess soil quality requires a selection of organisms, which must be present in all soil types and be dominant within the overall soil fauna (Yan *et al*., 2012). Members of the soil fauna must have high abundance and biodiversity, and also play an important role in soil functioning.

Due to the complex food web, soil fauna influence the decomposition of organic matter both directly, through selective feeding of microflora, and indirectly, by shredding plant residues, dispersing microbial propagules, and increasing nutrient availability, which in turn influence plant growth through the dispersal of microorganisms that stimulate plant growth or are antagonistic to pathogenic organisms (Rieff *et al*., 2016).

The soil fauna (mesofauna) is mainly composed of microarthropods, including mites (Acari) and springtails (Collembola) that are less than 2 mm in size. These groups are numerically abundant and species rich in soil organisms, in addition they respond rapidly to changes in soil habitat, so they have been used as indicators to assess changes caused by habitat disturbance and in soil quality in numerous agroecosystems (Reis *et al*., 2016).

It has also been shown that both groups (mites and springtails) favor complex processes in the soil such as the decomposition and mineralization of organic matter, improving soil fertility and regulating microbial populations, which favor the integrity of soil health (Rieff *et al.*, 2016). In addition, they favor the formation of soil microstructure through the construction of galleries in the soil that improve its physical properties, favoring aeration and water infiltration (Socarrás & Robaina, 2011).

The edaphic fauna, by participating in the decomposition of organic matter, selectively feeds on the microflora, crushing plant residues and increasing the availability of nutrients through their excretions, excretions and secretions; also facilitating the dissemination of spores, fungi and other microorganisms. The abundance and diversity of soil fauna increases with increasing soil organic matter content, while they show a high sensitivity to the impacts of external factors, so they have been considered good indicators of soil quality, but often underestimated (Reis *et al*., 2016).

Soil functions

Soil quality assessments are closely linked to crucial soil functions (D'Hose *et al*., 2014). These functions are affected by the effect of anthropogenic (soil management) and environmental factors (such as climate and topography) on inherent soil properties.

To result in high productivity, the soil must have a good quality that allows plant growth. Therefore, among the key processes required for the maintenance of soil quality are the supplies of water, oxygen and nutrients, as well as disease suppression. Although plant growth is the main objective that implies the importance of these processes as functions in the soil, nutrient cycling and disease suppression capacity have been incorporated in recent studies because of their direct relationship with soil microbial properties (Moeskops, 2010).

- Enzyme activity

While profiles of the structural composition of the microbial biomass provide information on functional diversity, soil enzyme activity provides information on the biochemical reactions involved in nutrient cycling. These reactions are catalyzed primarily by enzymes, which are produced mainly by microorganisms in the soil. Enzymes can generally be associated with viable cells that may be present in cellular debris in the soil solution (endo-enzymes), however, they have also been found associated with extracellular soluble molecules, temporarily absorbed in enzyme substrate complexes, absorbed to clay minerals or associated to organic colloids in the soil (exo-enzymes) (Alkorta ***et al***., 2003).

Extracellular enzymes produced by the biochemical activities of soil microbial communities have also been used as indicators to detect changes in soil quality due to the effect of agricultural management practices. These enzymes can be grouped into different types depending on the function they perform. First, the oxidoreductase group includes, among others, dehydrogenase. This enzyme participates in the oxidative phosphorylation processes of microorganisms and exists as a part of intact cells. Such metabolic processes occur in abundance when there is a favorable environment for microorganisms. This enzyme is found only in soil bacteria, specifically in the genus Pseudomonas. Its action could not take place without the presence of a bacterial host. Therefore, dehydrogenase can serve as a general measure of viable microbial activity, reflecting short-term changes caused by recent handling or seasonality (Alkorta ***et al***., 2003).

Among the enzymes involved in the decomposition of organic residues, β-glucosidase and β-glucosaminidase are among the best known. Both enzymes are involved in the decomposition of lignocellulose associated with organic matter in soil. The β-glucosaminidase is a common and predominant enzyme in soils and widely distributed among plants, animals, fungi and bacteria. This enzyme plays an important role as it participates in the carbon cycle and is associated in catalyzing the hydrolysis of various glycosides present in plant debris decomposing in soil. It is found in a limited range of enzymes involved in the microbial degradation of cellulose to glucose, these compounds being an important source of energy for the life of microorganisms in the soil (Alkorta ***et al***., 2003; Moeskops, 2010).

The β-glucosaminidase is one of the enzymes necessary for chitin degradation; its activity is negatively correlated with N immobilization (Sinsabaugh ***et al***., 1993). Chitin is a recalcitrant C and N containing fraction of soil organic matter; this enzyme probably participates in the catalysis of hydrolysis of amino sugars in soils, constituting 5-10 % of the organic N at the surface of most soils. This hydrolysis is considered important in the C and N cycle because it participates in the processes of transformation of chitin into amino sugars, which is one of the main sources of mineralizable N in soils. In addition, other enzymes that release plant-available nutrients such as phosphatase, arylsulfatase, urease and amidase have also been identified (Alkorta ***et al***., 2003).

- Nitrogen and Carbon Mineralization

Crop yield is related to soil nutrient availability and supply to plants. It is in turn directly related to soil mineralization potential as one of the key processes occurring in the soil during the decomposition of stored carbon. Soil mineralization potential is affected by climatic factors such as temperature and humidity, the latter being related to water retention processes in the soil. Soil is an important reservoir of N and C, so mineralization of both compounds are among the soil functions most used to evaluate the impact of management practices on soil quality (Schloter ***et al***., 2003).

The process of nitrogen mineralization is referred to as the conversion of organic N into simple inorganic forms. Available nitrogen is one of the key elements for plant growth, but at the same time it has been one of the most controversial elements in agriculture. Nitrogen compounds used in agriculture such as nitrate, nitrite or N_2O play an important role in environmental pollution, so understanding the key processes in the nitrogen cycle defines the ways of utilization for a highly productive and environmentally protective agriculture (Schloter ***et al***., 2003).

Likewise, carbon is another important element, and its contribution is made through surface and subway crop residues, such as manure and various organic amendments. Generally, soil carbon decreases with soil depth and is transported to the soil profile through various mechanisms; in soluble form with mass flow or diffusion and through bioturbation by soil animals. Nitrogen mineralization potential is negatively correlated with the carbon to nitrogen (C/N) ratio. Net mineralization is the result of two opposing processes, gross mineralization and immobilization, which depend on the proportional carbon and nitrogen requirements of the microbial biomass that will be incorporated into their tissues (Chu & Grogan, 2010).

- Soil suppression to diseases

Soil-borne diseases are generally difficult to control due to the hidden status of the causal agents, which is why they have been considered a serious problem in agriculture. The use of chemical pesticides to control these diseases has resulted in the destruction of the entire soil microflora and with it the loss of essential functions such as soil suppression to diseases. Therefore, soil suppression to plant diseases is increasingly considered an important soil function. Because of this the importance of establishing a link between disease suppression with soil quality indicators and agricultural management practices is increasingly promising in soil quality assessment studies in agroecosystems (Janvier ***et al***., 2007).

Disease suppressive soils have been defined as those "soils in which disease severity or incidence remains low, despite the presence of a pathogen, a susceptible host plant and favorable climatic conditions for disease development" (Janvier ***et al***., 2007).

Pathogenic activity in a soil is determined by the density and aggressiveness of the inoculum and soil factors affecting both, as well as other components leading to soil suppression to a disease (Janvier ***et al***., 2007).

In agricultural systems, some particular abiotic factors have been used for the control of some plant diseases. However, sterilization or soil amendments such as pH change usually affect soil suppressiveness to diseases directly or indirectly. This suppression occurs through interactions between pathogens and antagonistic soil microorganisms, involving mechanisms that lead to general or specific suppression, which are the main factors that suppress disease incidence (Figure 2)

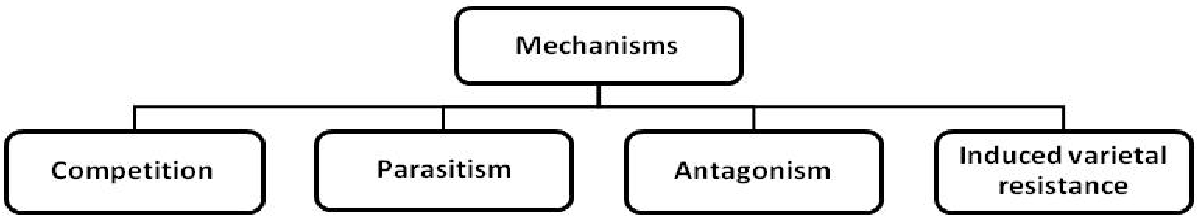

Figure 2: Mechanisms related to disease suppression (adapted from Stone ***et al***., 2004).

Spurce: Moeskops (2010)

General soil suppression to diseases plays an important role, but this is based on non-specific mechanisms, so it is expected to be effective against any pathogen. Although the influence of amendments on soil microbiota has been linked to soil suppression to multiple diseases, suppressive efficacy varies greatly, depending largely on the pathogen, however, specific suppression where individual microorganisms or selected groups of microorganisms interact to affect the growth or infection of a specific pathogen through a particular biological control mechanism (Figure 2). In the context of agricultural systems no specific microorganism is responsible for overall suppression, but the entire microbiota participates in generating a hostile environment that limits the development of a disease (Bonanomi ***et al***., 2010).

Soil quality indicators related to disease suppression capacity are interesting tools in the framework of risk forecasting and technical advice (Janvier ***et al***., 2007). This relationship highlights the importance of soil properties linked to suppressive mechanisms, mainly the potential of microbial communities, due to the complex interactions that exist. In addition, their relationship with soil fauna groups such as earthworms, nematodes, mites and springtails make them also good indicators related to the suppressive capacity of the soil. The fact that all these related parameters depend on soil organic matter demonstrates their importance in the suppression of soils to diseases and their use as a quality indicator in agroecosystems (van Bruggen & Semenov, 2000).

Impact of soil management on soil quality and functioning

The impact of different agricultural management practices has profoundly different effects on agricultural systems. Organic agriculture has been considered as the solution to meet the growing demand for food production, while reducing the negative impact of production systems on the environment; however, conventional agriculture could not meet this demand in the long term due to the environmental consequences caused by the management practices employed. In addition, in order to achieve increased yields, organically managed systems require larger extensions of land than conventional systems (Seufert ***et al***., 2012).

The uses of chemical fertilizers and organic amendments, pesticide application and tillage have been agricultural practices that have impacted soil functioning in agricultural systems. Although the list can be much longer, artificial drainage, salinization processes as a result of irrigation, and contamination by heavy metals or inorganic pollutants are among the main agricultural practices that can affect soil functioning. In contrast, organic amendments significantly improve soil properties, primarily biological properties that are closely related to numerous soil functions (Heidari ***et al***., 2016).

Crop tillage and fertilizer type are factors that also have influences on numerous soil properties. The use of minimum tillage practices can improve numerous soil properties such as structure, aggregate stability, nutrient availability, and diversity of microbial populations; however, the continued use of conventional practices produces changes that affect these properties. Under these conditions, microorganisms that play a crucial role in the processes occurring in the soil are less affected and increase their participation in the maintenance of soil structure, considerably improving the functions they perform in the soil profile (Lupwayi ***et al***., 2012). These aspects have been considered as important components of the impact of management on soil quality, functioning and fertility in agricultural systems (Heidari ***et al***., 2016).

- Conventional agricultural management

Conventional agriculture is based primarily on maximizing agricultural production. The consequences of this type of management on the ecological dynamics of agroecosystems have been of little importance; however, it has been demonstrated that this type of management has had long term negative effects. Conventional management is characterized in many cases by the use of intensive tillage, monoculture, and mechanized irrigation, application of inorganic fertilizers, chemical pest control and genetic manipulation of crop plants. These activities threaten the soil microbial community and, at the same time, the sustainability of agricultural systems (Moeskops, 2010).

Intensive tillage of soils under conventional agriculture creates ideal conditions for accelerated crop growth. However, the repeated passage of heavy machinery causes soil compaction and, in addition, the soil is left without cover for a certain period of time, leading to erosion and a reduction in soil organic matter (McCune ***et al***., 2011). On the other hand, the use of synthetic fertilizers has been another of the management practices used to make up for the short term deficit of nutrients in the soil; however, it is not taken into account that soil fertility is compromised in the long term (Gliessman, 1998).

On the other hand, the use of chemical pesticides has had a significant effect on pest populations, which are considerably reduced in the short term, but it also compromises the populations of their natural predators and competitors, which are also affected. Such conditions mean that after a period of time pest populations can emerge and come back, increasing crop losses as they find an environment free of predators and competitors. This means that farmers are forced to increase their use of pesticides, becoming more and more dependent on them. In addition, over time, pests become more resistant to pesticides (Gliessman, 1998).

- Organic agricultural management

Sustainable agriculture implies the management of agricultural resources in a satisfactory manner to meet human needs while maintaining and improving the quality of the environment and conserving natural resources for future generations (FAO, 2002). Such definition is in line with the concept of organic agriculture proposed by Seufert ***et al***. (2012) who define it as “a system aimed at producing food with minimal damage to ecosystems, animals or humans”.

In relation to conventional agriculture, organic agriculture has lower yields per unit area, so more land is needed to increase yields (Seufert ***et al***., 2012). However, when these yields are analyzed per unit of soil lost, per unit of water or per unit of energy used, organic yields are higher (Altieri & Nicholls, 2012).

These agricultural systems are related to sustainable agriculture as they have a high dependence on soil biological processes and soil biodiversity (Janvier ***et al***., 2007). For this, the adoption of sustainable management practices that are beneficial for the maintenance of soil quality is essential (FAO, 2002). Among the beneficial effects of these management practices are increased organic matter content, stimulation of biological activity, increased mineralization rate, soil conservation, decreased erosion, improved soil structure, and increased recycling and availability of nutrients (Altieri & Nicholls, 2012).

Evaluation of differences and changes in soil quality

Several investigations have confirmed the fact that organic practices increase the content of organic matter in the soil, promoting the diversity of the soil microbiological community (Alkorta ***et al***., 2003; Janvier ***et al***., 2007; Moeskops, 2010). This microbiological community is characterized by a high efficiency in the transformation of organic matter and leads to a greater availability of nutrients for plants, as well as contributing to the establishment of a diverse biota, which encourages an increase in the soil’s disease suppressive capacity (Moeskops, 2010; Pal & McSpadden, 2006).

The application of organic matter to the soil is crucial for the activation of numerous functions, and is also a key indicator that is linked to other soil quality indicators (Reeves, 1997). The use of organic inputs through crop management and minimum tillage in agricultural systems are best suited for sustainable management and enhancement of soil biological activities.

Organic practices increase soil microbial biomass and consequently increase essential functions such as soil enzymatic activities (Heidari ***et al***., 2016). However, soils in conventional agricultural systems that generally do not receive these amendments show a low availability of resources leading to a decrease in microbial biomass and thus their soil functions (Gliessman, 1998; Moeskops, 2010).

In general, changes in soil quality are influenced by agricultural practices which can have diverse effects on soil functioning. These effects can promote the development of microorganisms, which can increase, decrease or even show complex responses. In addition, the contribution of organic matter can contribute to the suppression of some associated pathogens (Bonanomi ***et al***., 2010).

On the other hand, the abundance and diversity of microarthropods in the soil has also been related to agricultural management practices and has been used as an indicator of soil quality. Edaphic fauna is closely related to the incorporation of organic amendments in crops, increasing soil microbiota that has been recognized as an important food source. These indicators also respond rapidly to changes in soil properties which are related to changes related to management practices in agricultural systems (Reis ***et al***., 2016).

CONCLUSIONS

In the historical development of agriculture, the use of soil quality indicators to achieve greater productivity has been defined with greater precision and breadth. The existing relationships between them make these resources available in the soil present a greater demand for the development and sustainability of agricultural systems. The accumulation and development of knowledge in general is related to the response to growing economic demands that have a wide repercussion for social development.

It is essential to develop a set of indicators that are adapted to the existing conditions in each place so that farmers can face the different types of problems that occur and thus generate conditions that enable the resilience of agricultural systems. For this, the foundation of theoretical bases that allow determining the indicators of soil quality in agricultural systems in central Cuba is a tool that will allow the development of future research based on the study of soil quality indicators under different agricultural exploitations. In addition, it is a way to incorporate the different actors in the research work and relate them to the reality they develop, thus promoting the discussion of agricultural production problems, from a multidisciplinary viewpoint, and thus favoring the conditions that configure a more solid change in thinking for the use of the indicators they will have to make their own decisions.

These aspects addressed here should be taken into consideration in the study of soil quality in agricultural systems. This type of research should be further developed, since it will serve as a basis for further study of the effect of agricultural management on soil quality indicators. In addition, the studies on this subject allow demonstrating the integrative analysis for the evaluation of soil quality in different agricultural systems through the use of the properties of brown soils with carbonates in central Cuba.

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