Research article

Interactions among Soil Physical, Chemical and Biological Properties under Different Farming Systems

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Received 14 December 2020 Accepted 9 July 2021 (*Corresponding Author)

Abstract The definition of soil quality has always been changing over time within the soil science community. At first, the study focused more on chemical and physical properties and less importance on a sustainable environment. Therefore, the definition of soil quality has changed in the last decade. The importance of biodiversity that exists both on the surface and within the soil began to be understood. These organisms have essential functions such as nutrient cycling, provision of plant nutrients, and modification of physical soil structure, water regimes, and suppression of undesirable organisms on cropland. It has defined soil quality as the function it has within the environment, sustaining productivity, maintaining environmental quality, and promoting health in plants and animals. However, the interaction between some microorganisms is still unknown, or how it could affect the different parameters in the biodiversity of an agro ecosystem. Furthermore, it is unknown what parameters are important in determining soil quality. Therefore, this study analyzed the biological, physical, and chemical properties of the soil of two farms whose practices is different. Water retention capacity, aggregate distribution, organic matter, total nitrogen, NO_3, NH_4, and biomass of microorganisms were measured. Soils were air dried and sieved to 2mm. They were analyzed after drying in an oven at 105° C for 24 h. The biomass of microorganisms was measured by the direct extraction method. The results indicated that there was a significant difference between the microorganisms but could not be found with physical and chemical properties. This result could indicate the importance of biological properties over other parameters to discuss soil quality. In addition, the differences observed could be explained by the different practices carried out on each farm.

Keywords soil quality, soil health, biomass of microorganisms, aggregates, total nitrogen

INTRODUCTION

Soil health is associated with soil biological parameters, such as biodiversity and its stability in the environment. When there are outbreaks of plant diseases, they are indicators of ecosystem instability and poor health. Thus, healthy soil has the ability of the biological community to suppress plant pathogens, the population of plant pathogens in the soil, and control the incidence and severity of diseases (Bruggen van and Grunwald, 1996). Accordingly, Cruz (2004) defines soil quality as dynamic, changing over time within the soil science community. At first, it was focused more on fertility, the yield of crops, and less importance on a sustainable environment. In other words, science has defined soil quality in chemical and physical parameters, such as the quantity or concentration of nutrients, organic matter, and water retention.

In the last few decades significant efforts have been made to increase agricultural productivity through increased fertilization and pesticide application, improved irrigation, soil management regimes and crops, and massive land conversions (Tilman et al., 2002). There is increasing concern, however, that agricultural intensification is placing tremendous pressure on the soil's capacity to maintain its other functions leading to largescale ecosystem degradation and loss of productivity in the long term (Tilman et al., 2001; Foley et al., 2005; Vitousek et al., 2009). Since microorganisms are involved in many soil processes, they may also give an integrated measure of soil health, an aspect that cannot be obtained with physical/chemical measures alone (Nielsen et al., 2002; Kibblewhite et al., 2008; Mueller et al., 2010; Sharma et al., 2011).

There have been a few reports that have indicated that organic farming practices have positive effects on soil microbial populations, processes and activities (Clark et al., 1998; Doran et al., 1996; Drinkwater et al., 1995). Applications of insecticides may promote changes in population biodiversity and dynamics by inhibiting or killing components of the soil microbial community. Fungicide application can cause significant changes to the relative sizes of the bacterial and fungal communities in soil (Sall et al., 2006; Sigler and Turco, 2002). Although most of the research has shown increased microbial diversity in soils from organic farming systems compared to conventional farming systems, some studies have found different results. Shannon et al. (2002) studied microbial communities in soils managed under organic and conventional regimes, and found conflicting evidence that the size, composition and activity of the soil microbial biomass were attributed to management practice. They found that differences in microbial communities in soils under different management practices were subtle rather than dramatic (Liu et al., 2007). Therefore this study focus on analyzing some physical, chemical, and biological (the microorganism communities) properties as indicator of soil quality / soil health of two agro ecosystem which have different practices. In addition, the discussion about what parameters could be important to determine soil health.

MATERIAL AND METHODS

Soils from 2 farms in Kanto Area, Japan, with a history of natural and conventional crop production were sampled. These were sampled at a depth of the upper 5 cm of the soil. Soils were air dried and sieved to 2mm. The dry weight of the soil was determined after drying in an oven at 105°C for 24 h.

The biomass of microorganism was measure by direct extraction method. Ten subsamples of 5.00 g of each soil were weighed separately into 50 ml centrifuge tubes and 20 ml of 0.5 M K_2SO_4 was added to each. To three subsamples, 0.5 ml of ethanol-free chloroform was added. Both the chloroform-exposed and the non-fumigated samples were capped and shaken simultaneously for 1 h. After shaking, the suspensions could settle for 10 min and the supernatants were filtered through Whatman No. 42 filter. For the sub-samples with chloroform, only the top 15 ml of the supernatant was filtered to reduce the amount chloroform in the filtrate. Filtrates from soils with and without chloroform were immediately bubbled with air for 30 min to remove any residual chloroform. Blanks were treated in the same manner. Dissolved organic carbon in all filtrates was determined after dichromate digestion by titrating with 0.033 M acidified ferrous ammonium sulphate (Anderson, et al. 1993). Chloroform labile C was calculated as the difference between the C extracted from the chloroform fumigated and the non-fumigated sample. All results are expressed on an oven-dry basis. No conversion factor (kEC) was used to convert chloroform labile C to microbial biomass C because the range of kEC values (0.41 - 0.58) is used in the literature and it has not been tested which is best suited for the soils used here (Setia et al., 2012).

In addition, number of culturable bacteria and fungus were quantified. The plate count methodology by plating is a widely used methodology (Hoben and So-masegaran, 1982), which consists of making 1:10 serial dilutions and spreading 100 µl of each dilution on a plate; plates are incubated until colonies are countable.

The chemical and physical properties were measured as aggregate size, water retention capacity, organic matter, total nitrogen, total phosphorus, nitrates, and ammonia. Soil samples analyzed the aggregate's stability and distribution to observe the resistance in the water. Stability is influenced by the physical and chemical properties of soils. In addition, the soil samples were evaluated for their relationship with the organic matter.

For NO_3 it was measured by nitration of salicylic acid (Cataldo et al., 1975) and for NH_4 with indophenol blue method described by Searle (1984). Statistical analysis with ANOVA was done for all the treatments.

RESULTS AND DISCUSSION

Soil Physical and Chemical Properties

In Fig. 1 it shows us the distribution of soil aggregates. Soil aggregates play an essential role in the formation of soil structure and soil health. In agriculture, the stability of the aggregates is important for the functioning of the agroecosystem. The pore spaces influence the storage of air and water and the gas exchange. They create a habitat for soil microorganisms and allow the development and penetration of plant roots. They also help in nutrient cycling and transportation.

It indicates that there are bigger aggregates in the conventional than in the natural one. Although, no significant difference was found between the different agroecosystems. Thus, both the Conventional and Natural ones mostly had aggregates greater than 0.5 mm.

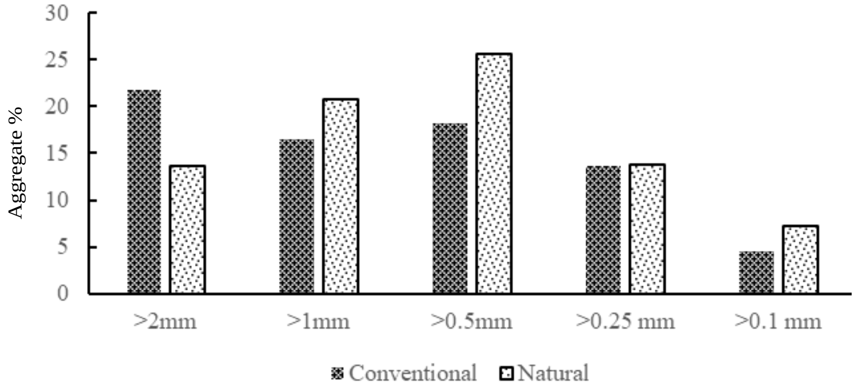

Fig. 1 Aggregates (%) in both agroecosystems

Table 1 Soil organic matter (SOM) and water holding capacity in both agroecosystem

Agroecosystem	SOM (%)	Water holding capacity (%)
Conventional	11.82	76.67
Natural	6.18	61.5

No significance difference

The amount of organic matter in the soil depends on many factors, such as its rate of chemical and biological oxidation, the rate of decomposition of organic matter already existing in the soil, soil texture, aeration, humidity and climatic factors. Crop management practices can also influence this parameter, since, for example, the use of mineral fertilizers accelerates the decomposition of the organic matter in the soil. The water holding capacity depends on its texture, its structure, and the depth of the roots. That is why the results relate to the fact that there is more organic matter, larger aggregates, and better retention in the conventional agroecosystem (Table 1).

These results may be related to conventional agricultural management. They use synthetic fertilizers, fungicides, and pesticides, but they also make crop rotations and incorporate animal manure as an organic amendment. On the other hand, in Natural Farm for many years, no amendments have been incorporated, only making crop rotations.

Table 2, total nitrogen analysis measures N in all organic and inorganic forms. Nitrate nitrogen (NO_3-N) is important because it is the primary form of nitrogen available to trees and, therefore, an indicator of nitrogen soil fertility. However, soil concentrations of NO_3-N depend upon the biological activity and may fluctuate with changes in soil temperature, soil moisture, and other conditions. Nitrate is also easily leached with rainfall or irrigation. Most ammonia is produced by bacteria in water and soil as a product of plant and animal waste decomposition. It is found in relatively low nontoxic concentrations in soil and provides a source of nitrogen for plants. Ammonium rarely accumulates in soil because bacteria will rapidly convert the ammonium that is not taken up by plant roots into nitrates (nitrification).

Table 2 Chemicals properties in both agro ecosystem

Agroecosystem	TN (mg/kg)	TP (mg/kg)	NO_3 (mg/kg)	NH_3 (mg/kg)
Conventional	2343.33	267.14	0.15	6.86
Natural	1563.33	370.00	0.13	5.57

No significance difference

Even the results are no significance difference, indicate that there was a higher level of nitrogen in the Conventional Farm than in the Natural ones, but, in the total phosphorus, the case was the opposite. P deficiency being common in weathered and tropical soils throughout the world, by rising costs of P fertilizer, and because efficiency of P use by plants from soil and fertilizer sources is often poor despite containing a relatively large amount of total P that is sparingly available to plants. Soil P exists predominantly in inorganic fractions that adsorb to mineral soil surfaces or appear as poorly available precipitates and in organic forms that adsorb, incorporate into biomass, or associate with soil organic matter (Richardson and Simpson, 2011). Although no significant difference was found, the value of TP in the Natural Farm is higher, which can indicate related to the microbial biomass. Thus, it can also be related to the organic content, which was higher in Conventional Farm. Other parameters need to be analyzed to be able to discuss them further.

Soil Biological Properties

Soil microorganisms affect attributes like aggregate formation and water movement. In addition to fertility, soil microorganisms also play essential roles in the nutrient cycles that are fundamentally important to life on the planet. The microorganisms that live in the soil and interact with the other components, varies greatly depending upon conditions and it is highly complex and dynamic. The most numerous microbes in soil are the bacteria, followed in decreasing numerical order by the actinomycetes, the fungi, soil algae and soil protozoa. Soil microorganisms are both components and producers of soil organic carbon, a substance that locks carbon into the soil for long periods. Abundant soil organic carbon improves soil fertility and water-retaining capacity.

Table 3 indicates that in the number of colonies formed in both fungi and bacteria there were more in the Natural agroecosystem. In addition, soil microbial biomass also it was found more in Natural agroecosystem than Conventional agroecosystem. Although with these results its richness and abundance of species cannot be determined, it could be thought that microorganisms are essential to maintain a healthy soil. This is because in the Natural Farm, for more than 20 years no type of amendments has been incorporated. It is that its maintenance of functioning in the soil depends 100 percent on the internal activity that exists between microorganisms, plants and organisms that live in the environment and soil. They could not be correlated with the chemical and physical properties, but this can be thought to be related to the management that the Conventional agroecosystem had. The Conventional agroecosystem, add manure, synthetic fertilization, pesticides and fungicides. Pesticides and fungicides are known to affect the microbial population rapidly, which may be the reason why there is less in the results obtained. In addition, another practice that they carry out is weeding. In Natural Farm, they only weed in the first growth stage of the crop. On the other hand, in the Conventional Farm, they try to keep the soil without weeds. This practice could be affecting microorganisms. According to Massenssini et al. (2014), the soil microbial community structure might change depending on the crop species. Studies have shown that the relationships of weeds and crops with the soil microbiota may be different. Weeds seem to show higher dependence on interactions with soil microorganisms. The structure of the soil microbial community is responsive to competition between plants. In general, the competition promotes changes in the soil microbial community structure, making it different from that found when plants are grown in monoculture. Furthermore, weeds tend to have positive feedback interactions with soil microorganisms, while crops may present neutral or negative feedback interactions.

Table 3 Biological properties in both agro ecosystem

Agroecosystem	Number of colony forming units/g dry soil		Total microbial biomass (μg/g)
	Total culturable fungi	Total culturable bacteria	
Conventional	6.92×10^{1a}	3.15×10^{3A}	0.16^{α}
Natural	1.71×10^{3b}	1.10×10^{4B}	0.22^{β}

a, A, α significance difference p> 0.05

CONCLUSION

The difference between both farms is by using fertilizers and pesticides. The Natural Farm is not adding any amendments for 20 years. Furthermore, Conventional Farm use more manure than chemical fertilizers. Pesticides affect the survival of soil microorganisms more severely than other practices carried out by the farm. The diversity of plant roots helps to maintain soil microorganism diversity and abundance.

Interdisciplinary soil research is necessary to better understand the biological properties of soil. To maintain the sustainability of the production it is necessary to maintain the population of soil microorganisms. Further research is needed to understand the correlation with chemical and physical properties. As well as to begin to understand the function that each group of bacteria and fungi has, its relationship with other living organism in the soil.

The production system influences the diversity of arthropods and microorganisms in an agricultural ecosystem. Therefore, if a system cannot conserve or increase agricultural land biodiversity, it will be more unstable and poor health of the soil ecosystem.

ACKNOWLEDGEMENTS

I would like to express my gratitude to Nakamura farm as well as the people of the NPO Tagayasu, who gave me the opportunity to take the samples from their farms.

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