Evaluation of Soil Health Indicators in Different Land Uses*

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Abstract: Soil health plays an important role in environmental sustainability and food security, but measuring soil health is still uncertain. An evaluation of soil health indicators was conducted using soils from five land uses: forest land, grassland, farmland in corn, farmland in soybean and urban construction land. With the exception of the construction site all of the soils were taken from Agronomy Research Center, Purdue University, West Lafayette, Indiana, USA. The following indicators of soil health were selected and analyzed in the laboratory: bulk density, field moisture content, pH, total carbon and nitrogen, carbon and nitrogen mineralization rates and soil enzyme activities (fluorescein diacetate, ß-glucosidase, arylamidase, acid phosphatase, and arylsulfatase). The experimental data showed that the selected indicators of soil health are sensitive, and all were more favorable in the forest and grassland than in soybean and corn cropland. The least favorable values were in the soil from the construction site. It is clear that land use can influence soil health and these indicators are sensitive to cropping practices.

Keywords: soil health, indicator, soil enzymes, evaluation

1 Introduction

It is well known that soil is a critically important component of the earth ecosystem, functioning not only in the production of food and fiber but also in the maintenance of local, regional and worldwide environmental quality. A recent call for development of a soil health index was stimulated by the perception that human health and welfare is associated with the quality and health of soils (Haberern, 1992). However, how to measure and assess soil health is still uncertain because of complicated physical, chemical and biological soil attributes and multiple functions. So this paper tries to develop some useful indicators for soil health by studying different land use systems.

2 Materials and methods

Soils were collected from five kinds of land uses: forest land, grassland, farmland in corn, farmland in soybean and urban construction land. With the exception of the construction site all of the soils were from the A horizon(0 cm—7.5 cm) of Aquic Argiudolls taken from Agronomy Research Center, Purdue University, West Lafayette, Indiana, USA, on Sep. 21—22, 2001. For each land use, about thirty individual cores (7cm dia.) were collected randomly and composited into three replicates of bulk soils respectively in three plots (20 m×10 m), and three cylinder cores were also taken for bulk density and field moisture measurement. The following indicators to assessing soil health were selected and analyzed in the laboratory: bulk density, field moisture content, pH, total carbon and nitrogen, carbon and nitrogen mineralization rates and soil enzyme activities including Fluorescein diacetate(FDA), ß-glucosidase, Arylamidase, Acid phosphatase, and Arylsulfatase.

Soil was air dried, weighed and crushed to pass a screen (2mm) to homogenize the samples and remove stones. Field moisture content and pH were measured according to routine soil testing procedures.

* This project was funded by 2001 International Higher Education Loan Program (I-HELP) "Food Security and Environmental sustainability" and Guangdong Provincial Natural Science Foundation(980148)

Bulk density was calculated from the oven-dried soil weight and coring device volume. Soil for subsequent analyses was stored at ambient conditions. A subsample was ground to a fine powder and analyzed for total C and N with dry combustion. Two subsamples of soil were wetted to the field moisture of soils, placed into a 1-L canning jar, along with vials containing 10 mL of 1 M KOH to trap evolved CO_2 and water to maintain humidity, and incubated at 25℃±1℃ for 24d to determine C mineralization. Alkali traps were replaced at 3d and 10d. Evolved CO_2 was calculated by titrating alkali with 0.1M HCl. Net N mineralization was determined from the difference in inorganic N concentration between 0 and 24 d of incubation (Franzluebbers and Arshad, 1996). Inorganic N was determined from the filtered extract of a 10 g subsample of oven-dried and sieved (<2mm) soil shaken with 20 mL of 2M KCl for 1hr using autoanalyzer techniques (Lachat Flow Injection Analysis System) (Bundy and Meisinger, 1994). Enzyme assay procedures were adapted from the methods outlined in book of《Methods for assessing Soil Quality》(SSSA Special Publication Number 49).

3 Results and Discussion

3.1 The difference of pH, field moisture content and bulk density between soils from five land use systems

From Table 1, it showed that the soils had different pH values in different land use system. The pH of forest soils was lowest, indicating forest soil was more acid than that of other soils. Soil and land use practices can have a significant effect on pH in relatively short period. Because the five soils originated from same soil types and under similar natural environment in same area, there was no big difference between pH values (6.0—7.0) of five sampled soils. However, the parameters of pH are easily measured in the field and laboratory, and can provide valuable information for assessing the soil condition for plant growth and nutrient cycling, biological activity, soil health and environment quality. So soil pH is still a good indicator of soil health change.

Table 1 pH, field moisture content and bulk density for soils of five land use systems

Items	pH	Field moisture(%)	Bulk density(g/cm^3)
Farmland in soybean	6.9	19.8	1.19
Farmland in corn	6.7	19.9	1.35
Grass land	6.4	26.6	1.15
Forest land	6.1	27.0	0.99
Construction land (urban soil)	6.6	7.9	—

Soil is major reservoir for water. Soil water content is a basic soil parameter and a quantitative evaluation of it is needed for almost every aspect of soil and related sciences from those dealing with soil organisms and plant growth to environmental concerns (Birl Lowery and M.A.Arshad *et al.*, 1996). So soil field moisture content was selected and measured, the analysis data showed that the field moisture contents of five sampled soils had a significant difference by different land uses. The soils of grass and forest land had relatively high field water moisture (27% or so) in mass basis, but the water content of soils taken from construction land was very low, only 7.9% (Table 1). So soil field water content can be also used as an indicator for soil health.

Soil bulk density is a very useful parameter. It varies with structural condition of the soil and altered by cultivation, compressing by animals and agricultural machinery. Generally, Good soils have a relatively bulk density. From our experimental data, the lowest bulk density was found in forest soils, and soils in farmlands had relatively high bulk density (Table 1). This indicates that soil bulk density is a good feature to assess soil health.

3.2 The changes and differences of total carbon and nitrogen, carbon and nitrogen mineralization of soils under different land use systems

Soil total carbon/nitrogen is a source of and a sink for plant nutrients in soils and is important in maintaining soil properties (Gregorich *et al.*, 1993). In this study, the contents of total carbon and total nitrogen of soils varied from high to low with different land practices in following order: Forest land > Grass land > Farmland in soybean > Farmland in corn > Construction land. The contents of total carbon and total nitrogen can reach 5.53% and 0.44% in forest soil respectively, but they are only 1.11% and 0.07% in the urban soils respectively (Table 2). This shows that total carbon and total nitrogen are significant for soil health and environmental sustainability.

Carbon and nitrogen mineralization rates are also useful indicators to identify soil quality or soil health. They depend on the land use pattern and management, annual climatic variation, microbial activity and inherent properties. For cumulative carbon mineralization and net nitrogen mineralization, the more favorable values can also be found in soils of grass, forest and soybean farmland. And they are very low in the soils under urban construction, only 1,970 CO_2-C mg/kg • 0—24d and 7.1 mg/kg • 0—24d respectively(Table 2). There was significant difference of the two indicators between different land use systems, this is to say, the two indicators are sensitive for soil health assessment.

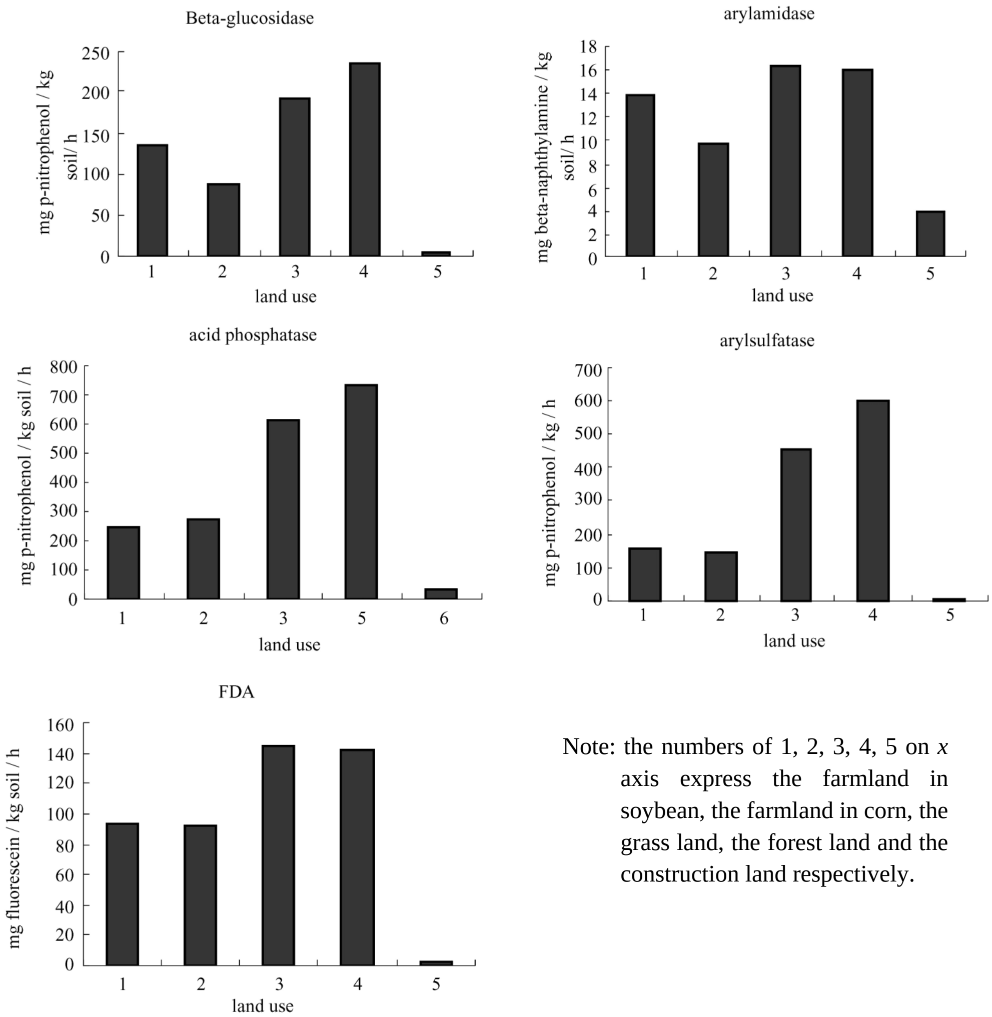
Table 2 Total carbon and nitrogen, carbon and nitrogen mineralization rates of soils taken from five land use systems

Items	Total Carbon (%)	Total Nitrogen (%)	Carbon mineralization (CO_2-C mg/kg 0—24d)	Net nitrogen mineralization (mg/kg 0—24d)
Farmland in soybean	2.11	0.18	3, 620	27.2
Farmland in corn	1.94	0.16	2, 929.3	15.3
Grass land	3.30	0.27	4, 172	47.1
Forest land	5.53	0.44	3, 132	61.4
Construction land (urban soil)	1.11	0.07	1, 970	7.1

3.3 The changes and differences of selected five soil enzymes under the different land use systems

It is well known that all biochemical reactions are catalyzed by enzymes, which are proteins with catalytic properties owing to their power of specific activation. Enzymes in soils are primarily produced by the microbial biomass, plant and animal residues. So measuring the enzyme activities is good way to identify soil biological and ecological status. In this study, five soil enzymes were selected, including β-glucosidase, arylamidase, acid phosphatase, arylsulfatase and fluorescein diacetate. β- Glucosidase is an important enzymes in C cycle(Eivazi & Tabatabai, 1988), and the hydrolysis products of β- Glucosidase are believed to be important energy sources for microorganisms(Tabatabai, 1994). Arylamidase is a kind of enzyme which involved in the N cycle and N mineralization. It is widely distributed in soils, plants, yeast and fungi. Phosphatases are also important in the P cycle because they provide P for plant uptake by releasing PO_4, and acid phosphatase can provides a potential index for a soil to mineralize organic P. Arysulfatase is the most widely studied soil sulfatase and is thought to play an important role in the hydrolysis of ester sulfatase, which comprises 40% to 70% of total S in many soils (Tabatabai, 1994). The hydrolysis of fluorescein diacetate has potential to broadly represent soil enzyme activity (Schnurer & Rosswall, 1982) and accumulated biological effects because FDA is hydrolyzed by a number of different enzymes, such protease, lipase and esterases (Rotman & Paperaster, 1966) and its hydrolysis has been found among a wide array of the primary decomposers, bacteria and fungi (Lundgren, 1981).

Based on our experimental data about enzyme activities, it is found that the activities of five selected soil enzymes are quite different between different land use practices (Figure 1). The activities of enzymes can be divided into three levels: (1) high activities of soil enzymes in the forest land and grass lands; (2) middle level activities of soil enzymes in the farmlands of soybean and corn plantation; (3) very low activities of soil enzymes in the construction land. This showed that soil enzyme activities reflect the effects of land uses and management.



Note: the numbers of 1, 2, 3, 4, 5 on *x* axis express the farmland in soybean, the farmland in corn, the grass land, the forest land and the construction land respectively.

Fig. 1 Activities of five selected soil enzymes under different land uses and management

4 Conclusion

From this study, we can conclude: (1) most of selected indicators or parameters to identify soil health status are sensitive, especially total carbon and nitrogen, carbon and nitrogen mineralization, soil enzyme activities. (2) above indicators selected were more favorable in the forest and grass land than in soybean and corn cropland. The least favorable values were in the soil from the construction site. (3) Farming or cropping and construction land use systems can decrease most of the selected indicators for soil health. It is clear that land use can influence soil health.

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