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Notes

Biological variables as soil quality indicators: Effect of sampling time and ability to classify soils by their suitability

Silvia Benintende*, María Benintende, María Sterren, Mariano Saluzzio, Pedro Barbagelata

Facultad de Ciencias Agropecuarias, UNER, Ruta 11 km 10, CP: 3100, Oro Verde, Entre Ríos, Argentina

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ABSTRACT

Soil biological variables are considered good soil quality indicators due to their high sensitivity and ability to reflect soil management effects. However, they frequently show high temporal variability. Our objectives were: (a) to analyze temporal stability and seasonal effect on biological variables, (b) to choose between autumn and spring to sample for soil biological variables, and (c) to determine biological variables able to discriminate among selected soil subgroups. Areas with minimal human disturbance were sampled in three soil orders (Mollisol, Vertisol and Alfisol) during two and a half years, each autumn and spring. Microbial biomass C and N (MBC, MBN), basal respiration (Resp), metabolic quotient (qCO_2), potential of N mineralization (PNM-AI), soil organic C (TOC) and total soil N (TON) were measured in three composite soil samples collected from homogeneous areas at 0–15 cm depth. For the studied soils, selected soil biological variables presented different levels depending on the time of sampling, spring or autumn. Hence, the importance of pointing out the time of sampling to report results of these variables in this kind of studies is remarked. In general, biological variables presented higher stability when we sampled soils in autumn compared to spring. Because of this, we used autumn soil samples to determine the best soil biological variables to discriminate among selected subgroups of soils. The separation of soil subgroups by means of discriminant analysis using just TOC and TON was scrutinized, considering that these soil variables are routinely measured in soil test laboratories. Nonetheless they were not able to discriminate properly among soil subgroups because they showed high error rates classifying the samples in the correct subgroups. In contrast, the variables PMN-AI, MBC, and MBN adequately discriminated the five soil subgroups. From the biological variables, PMN-AI and MBC were the best ones to characterize (discriminate) among the five soil subgroups. Particularly, PMN-AI was able to separate soils by their suitability for agricultural purposes.

1. Introduction

Attributes able to reflect soil production ability and their environmental function need to meet certain prerequisites to be considered as good soil quality indicators. Among those prerequisites, Doran and Zeiss (2000) stated as a desirable characteristic that the variable show a significant variation with time as a result of soil management practices modifications. Furthermore, they should be sensitive enough to detect long-term changes in soil quality produced by resources (soil) use and management, but not so sensitive as to be influenced by short-term weather patterns.

Soil biological indicators are often assumed to be good soil quality indicators due to their high sensitivity and ability to reflect soil management effects (Marinari et al., 2006; Benintende et al., 2008; Kaschuk et al., 2011). However, biological properties frequently show high temporal variability (Tscherko and Kandeler, 1999; Paz-Ferreiro et al., 2013). Paz-Ferreiro et al. (2011) reported the effect of the mean average daily temperature during the week prior to sampling was a significant factor explaining the variation of microbial biomass C, labile C, basal respiration and net N mineralization values. They concluded that, in general, temperature, rather than soil humidity, drives the variations in some biochemical properties that are, at least, partly dependent on abiotic factors. Despite variations among sampling dates, Marinari et al. (2006) reported that both microbial biomass content and activity of an organically

* Corresponding author. Tel.: +54 3434975075.
E-mail addresses: silviab@fca.uner.edu.ar (S. Benintende), crisben@fca.uner.edu.ar (M. Benintende), msterren@fca.uner.edu.ar (M. Sterren), marianosaluzzio@arnet.com.ar (M. Saluzzio), barbagelata.pedro@inta.gob.ar (P. Barbagelata).

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Table 1
Upper layer characteristics of each soil subgroup: Aquic Argiudoll, Vertic Argiudoll, Argiudolic Pelludert, Argic Pelludert, and Vertic Ocracualf.

Soils	"A" horizon depth (cm)	Clay content [g (100 g)$^{-1}$]	Moisture equivalent [g (100 g)$^{-1}$]	CEC[a] (cmol$_c$ kg^{-1})	pH in water (1:2.5)
Aquic Argiudoll	17	27.6	26.9	23.8	5.7
Vertic Argiudoll	21	35.4	33.6	38.4	6.1
Argiudolic Pelludert	24	36.8	35.7	36.2	6.6
Argic Pelludert	16	40.5	41.2	39.8	7.3
Vertic Ocracualf	12	29.9	32.0	31.0	6.1

[a] CEC: cation exchange capacity.

managed field were always higher than conventionally managed field. Similarly, Giacometti et al. (2013) found that microbial-related parameters fluctuated over time, but their seasonality did not hamper the identification of fertilization-induced effects.

Even though there are many studies on temporal variability of soil quality indicators, most of them have been conducted in temperate regions. Furthermore, many of these experiments had been performed on fields were the main evaluated effects were those caused by crop residues inputs during the growing season (Giacometti et al., 2013; Monokrousos et al., 2008). Although there are fewer papers on other climate areas, Izquierdo et al. (2003), working in tropical climate with dry winters, found that biological variables trends were governed by rainfall distribution.

For land use planning, attributes able to reflect soil suitability for agricultural purposes would be useful.

Few studies have been conducted evaluating biological variables in different soil types with this goal. Jin et al. (2013), who studied microbial C and N mineralization in grassland soils (Alfisol, Molisoll and Vertisol) during a period of 112 days, found that mineralization was lowest in the Alfisol and highest in the Vertisol. Also, soil type was the primary controller determining the relative contribution of litter-C to total soil C mineralized. Since they assumed that differences in N mineralization were likely due to different sized soil N pools in each soil type, with the Vertisol soils having a significantly larger total N pool compared to Mollisol and Alfisol, we believe that C and N mineralization may be useful to discriminate by soil type.

In this research, we analyzed temporal variability of biological parameters in a region of humid subtropical climate with no distinctive dry season. Moreover, substrate availability is almost constant throughout the year mainly due to the fact that temperature does not drop below freezing. Among those variables which show minimum temporal variations we evaluated their capacity to classify soils by their agricultural suitability. Accordingly, our objectives were: (a) to analyze temporal stability and seasonal effect on soil biological variables in a subtropical region, (b) to choose between autumn and spring to sample for soil biological variables, and (c) to determine soil biological variables able to discriminate among selected soil subgroups.

2. Materials and methods

2.1. Study area

The study was performed in Entre Ríos province, Argentina (31.7° S and 58.5° W). The climate of the area is classified as Cfa (humid subtropical) according to Köppen. The average annual temperature is16.6 °C (24.9 °C in January and 12.0 °C in July) and the average annual rainfall is 1000 mm, 73% of which precipitate from October to April.

Selected areas were sampled in three soil orders (Mollisol, Vertisol and Alfisol) where human disturbance was minimal (native grassland or areas under fence) during the course of two and half years, each autumn and spring. Within the Mollisols, two subgroups were selected: Aquic Arguidoll (AA) and Vertic Argiudoll (VA). These soils are the most suitable for agricultural production in the region (Soil Survey Staff, 2010; Tasi and Bedendo, 2008).

Within the Vertisols (Typic Hapludert according to Soil Survey Staff, 2010), two series were selected: one, Argic Pelludert (AP), with characteristics of tipic Verisols; and the other, Argiudolic Pelludert (AudP), which have a surface layer with characteristics of a mollic epipedon. Both soils, particularly AP, have physical and chemical limitations for agricultural use, related to the high content and nature of dominant clays (expandable type), and the water regime.

Alfisols have similar limitations to those described for Vertisols. These limitations are worsened by little or no slope of the landscape in which these soils were developed. A Vertic Ocracualf subgroup (VO) was selected (Soil Survey Staff, 2010). Upper layer characteristics of each soil subgroup are shown in Table 1.

Three composite soil samples were collected from homogeneous areas of approximately 0.5 ha, at 0–15 cm depth, from each soil subgroup. Sampling time was in autumn and spring, throughout 2.5 years. Soil sampling locations were geo-referenced to repeat sampling points. The general guidance described by ISO 10381-6 (1993), for collection, handling, and storage of soil samples, was followed.

2.2. Microbiological and chemical analysis

Each sample was handled according to the variable to be measured. Biological variables were measured in samples on field-moist conditions and chemical variables, on air-dried soil.

2.2.1. Variables measured on field-moist samples

Microbial biomass C (MBC) and microbial biomass N (MBN) were determined by chloroform fumigation extraction method (ISO 14240-2, 1997). Carbon and N contents were estimated with a kc of 0.35 and a kn of 0.54, respectively (Voroney et al., 2008).

Basal respiration (Resp) was determined by CO_2-C flux in a 7 days incubation period (Isermayer, 1952; described in Alef and Nannipieri, 1995). The metabolic quotient (qCO$_2$, [μgC-CO_2 (μg of MBC h)$^{-1}$]), which represents the quantity of CO_2 breathed per microbial mass unit, was calculated. Potential of N mineralization was measured on 5 g of soil incubated during seven-days in anaerobic conditions (PNM-AI) (Waring and Bremner, 1964).

Soil water content was measured and expressed as the ratio of water content to moisture equivalent (water content expressed as a percentage of the dry weight that a soil can retain against a centrifugal force one thousand times the force of gravity) of each soil (H/Hequiv.).

2.2.2. Variables measured on air-dried samples

Soil organic C (TOC) was determined by Walkley and Black, and total soil N (TON) by Kjeldahl (Jackson, 1982).

In addition, the following relations were calculated: MBC/TOC and MBN/TON are C and N proportions of the soil organic matter contained in the microbial biomass. PNM-AI/TON represents the proportion of the total N mineralized during the anaerobic incubation.