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The adoption of no-till instead of reduced tillage does not improve some soil quality parameters in Argentinean Pampas

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ABSTRACT

No-till (NT) has been recognized worldwide as a more suitable system than tillage for enhancing soil quality. However, several concerns remain about its conservative nature, especially when it is performed either without cover crops or appropriate rotation schedules, and when it is accompanied by the usage of high amounts of agrochemicals. In this paper, we study some soil quality parameters when NT is adopted instead of reduced tillage, as well as the relevance of soil physical and chemical properties to explain the impact of management systems on soil macrofauna. We compared NT and reduced tillage (RT) systems, using natural grasslands (GR) as reference. We hypothesised that (1) soil quality will decline in both agricultural systems compared to the grassland but this declination will be less in no-till than in reduced tillage, and that (2) the changes in macrofauna community could be explained by changes in physical and chemical soil properties. Soil cover, organic matter, pH, moisture content, bulk density and mechanical resistance were assessed as indicators of soil physical and chemical quality. Soil macrofauna abundance and composition was determined by the TSBF method. We rejected our first hypotheses since from the assessed parameters only soil moisture content and spider abundance were favoured in NT compared to RT. Changes caused by both systems in the macrofauna composition (especially in soil inhabitants) were mainly explained by soil physical and chemical attributes. The ordination of sites according to canonical correspondence analyses clearly shows the influence of the management systems in the relationship between macrofauna assemblages and soil physical and chemical parameters; especially in the upper 30 cm of soil. GR had both a better soil physical and chemical quality and a higher abundance of the main macrofauna taxa (earthworms, beetles and ants) compared to agricultural systems. NT and RT were similar, sharing low earthworm and ant abundance and high potworm abundance. Our results show that adopting NT instead of RT does not favour assessed soil quality parameters. Thus, NT is questioned as a system which enhances soil quality, at least in the way it is performed by most farmers from Argentine Pampa.

1. Introduction

No-till has been recognized worldwide as a conservation farming practice, especially when practiced together with soil cover and crop rotations (FAO, 2008). In that case, no-till has been considered an effective practice to control soil erosion and runoff, increase water infiltration, enhance soil organic matter concentration, increase soil biological activity, and save energy (Lal, 2007).

However, there still are several concerns about these advantages of no-till. Some of them are: What happens if no-till is not conducted together with soil cover and crop rotation? To which extent can soil fauna engineering replace soil tillage to avoid soil compaction as a consequence of heavy machinery traffic? What are the consequences of the large increase in glyphosate usage? Some researchers have previously dealt with some of these issues. Paul et al. (2013) tested the interaction between two of the main principles of conservation agriculture – minimum tillage and crop residue management – and found that tillage and residue management alone did not influence soil carbon content. Other authors agree with the need of cover crop presence in no-till management to enhance soil quality (Aquino et al., 2008; Blanchart et al., 2006; Brévault et al., 2007; Ding et al., 2006; Sainju et al.,

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2002). Regarding the consequences of no-till on soil structure, compaction of the topsoil under no-till systems has been described in several studies in the Pampas region. Díaz-Zorita et al. (2002) mention higher bulk density values in no-till compared to tillage systems. Moreover, lower crop yields have been attributed to higher bulk density values. In other regions, Filipovic et al. (2006), Franzluebbers et al. (1995) and Thomas et al. (2007) have also found higher soil bulk density values in no-till than in tilled systems. Regarding the possible impact of glyphosate on soil fauna, studies are still not conclusive. Casabé et al. (2007) did not find a negative effect on survival rate of *Eisenia fetida* but a negative effect on hatchability and viability of cocoons (at a concentration of 1440 g a.i.ha^{-1}). Buch et al. (2013) found no lethal effect but avoidance behaviour in two earthworm species (*Pontoscolex corethrurus* and *Eisenia andrei*, at a concentration of 47 mg a.i. kg^{-1}). However, glyphosate effect on Argentinean native earthworm species has not been assessed.

No-till has been widely promoted in Argentina by agronomists and agrifood companies and then widely adopted by most farmers. This technique is applied not only across all the Pampean region (the main agricultural region of Argentina) but also in regions previously not dedicated to agriculture, since no-till practices have allowed to extend agricultural boundaries. Nowadays, about 27 million ha are cropped under no-till, this system being applied in 78.5% of the cropped surface (AAPRESID, 2012), which emphasizes the need for deep soil quality assessment. Moreover, in most cases the no-till system has been restricted to the use of genetically modified crops, no-till-seeders and a chemical fallow during the winter season. Few cover crops and appropriate rotation schedules have been applied. No-till has also been accompanied by a huge increase in the use of some agrochemicals, mainly of glyphosate. In the period 1991–1992, 1 million l of glyphosate were sprayed while 20 years later the use of this herbicide reached 200 million l (Camino and Aparicio, 2010). There are also several studies which have linked soil physical, chemical and biological degradation with no-till practices performed in the study region (Arolfo et al., 2010; Bedano et al., 2006; Domínguez et al., 2010; Parra et al., 2011). Several aspects can be evaluated to analyse whether continuous no-till management is actually better for soil quality than other systems with tillage. Soil physical and chemical properties have always been considered as suitable indicators of soil quality (Cluzeau et al., 2012; Doran and Parkin, 1994). However, biological indicators have the potential to provide early warning because they capture subtle changes in soil quality as a result of their integrative nature that simultaneously reflect changes in physical, chemical and biological characteristics of the soil (Barrios, 2007). Within soil biota, the soil macrofauna (invertebrates with body diameter greater than 2 mm) has been highlighted as a useful indicator of soil quality. The assessment of macrofauna community provides evidence of the diversity and intensity of physical and chemical ecosystem engineering operated by invertebrates themselves and subsequent associated microbial activities, which contribute significantly to the production and delivery of soil ecosystem services in many ways (Lavelle et al., 2006; Velasquez et al., 2007). Therefore, the aims of this paper are to study whether assessed soil quality parameters are promoted by no-till system and the relevance of soil physical and chemical properties in explaining the impact of management systems on macrofauna. Thus, we compared no-till systems with reduced tillage systems, using natural grasslands as references. We hypothesise that (1) soil quality parameters will decline in both agricultural systems compared to the grassland but that decline will be less in no-till than in reduced tillage; (2) the changes in macrofauna community could be explained by changes in physical and chemical soil properties.

2. Materials and methods

2.1. Site description

The study was conducted in the south of Córdoba province, Argentina (32°44′50″S, 63°54′48″W and 32°49′55″S, 63°45′05″W). Soil is a coarse loamy, illitic, thermic Typic Haplustoll (Soil Survey Staff, 2010). The climate is sub humid temperate with a marked dry season in winter; mean annual rainfall is 695 mm and mean annual temperature is 16 °C. Annual rainfall in the two sampled years was 744 mm and 614 mm.

2.2. Management description

Three systems were studied: two farming systems, no-tillage (NT) and reduced tillage (RT), and natural grassland as reference; each one with two replicates. The agricultural sampling sites were at least 100 ha in area and they were managed with similar agricultural practices for at least 8 years before sampling. They have the same Soil Series (according to Soil Taxonomy classifications) and they were also selected by having similar geomorphological characteristics in terms of slope (1–3%) and elevation (290–340 m a.s.l.). It can also be assumed that until 1900 all the sites had the same land-use history: they were natural grasslands. In 1900, land tenure was divided and a mixed production system of cattle rising and agriculture was applied in most farms (La Calle, 1977). Approximately since 1930 continuous agriculture under conventional tillage was spread in the region. Agrochemicals applied in all the sites during the sampled years were urea and phosphate (fertilizers); glyphosate and atrazine (herbicides) and chlorpyrifos (insecticide). In RT sites subtiller, disk harrow and roller were used. A soybean-corn crop rotation was applied in all the sites at least 5 years prior to sampling.

A third system was included in the study: natural grassland (GR), to be used as a reference. For that, two sites of about 2 ha were sampled. These natural sites had the same Soil Series and geomorphological characteristics as the managed sites, but they have been undisturbed and covered with natural pastures during the last 50 years. The plant community was dominated by *Stipa* sp. Plant cover was 100% and the litter layer was approximately 1 cm thick. These sites were not managed; they only had occasional cattle grazing.

2.3. Soil quality assessment

Soil sampling was conducted twice, in two consecutive springs. In each sampling time and in each field five sampling points were defined every 20 m along a transect with random starting point. In each sampling point we sampled all soil attributes. To assess soil macrofauna, a soil monolith of 25 × 25 × 30 cm was delimited, extracted and then separated into four layers: litter, 0–10 cm, 10–20 cm, and 20–30 cm in depth, according to the TSBF method (Anderson and Ingram, 1993). Altogether, 180 soil samples and 60 litter samples were collected and gently moved to the laboratory (3 systems × 2 fields × 5 monoliths × 4 layers × 2 years). We used the same frame of 25 × 25 cm to estimate the soil cover, measured as the percentage of soil covered by litter or crop residues. Next to each monolith, mechanical resistance was also measured with a hand penetrometer up to 30 cm depth (Bradford, 1986). Finally, 120 undisturbed soil cores (0–10 cm and 10–20 cm) were extracted to measure bulk density and moisture content.

In the laboratory, immediately after sampling, undisturbed soil cores sampled were weighed first to obtain moist weights, and then oven-dried up to a constant weight at 105 °C. Soil moisture percentage (gravimetric method) and soil bulk density were then