Acta Oecologica 92 (2018) 102–116

Contents lists available at ScienceDirect

Acta Oecologica

journal homepage: www.elsevier.com/locate/actoec

Soil macrofauna diversity as a key element for building sustainable agriculture in Argentine Pampas

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ARTICLE INFO

Keywords:
Macroarthropods
Earthworms
Extensive organic farming
No till
Crop rotation
Sustainability

ABSTRACT

The agricultural activity in the Argentine Pampas, characterized by an important trend towards no-till soybean monocropping, has completely transformed the original Pampas landscape into a monotonous scenario with a continuous succession of farms of very low crop diversity. This process has led to soil physical, chemical and biological degradation in those systems. The increase of crop rotation rates in no-till and reduced tillage systems has been proposed as an alternative with reduced negative impact on soils in the context of conventional agriculture. On the other hand, extensive organic farming is also suggested as an alternative to high-input agriculture systems. In this article, we aim to explore how different variations of farming practices and systems impact soil macrofauna, along an edaphoclimatic gradient in the Pampas region. We studied the following systems: natural grassland (Gr) as indicator of the original community, extensive organic farming (Org), conventional agriculture with no-tillage and three crop rotation levels (Nt-R1, Nt-R2 and Nt-R3), and reduced tillage with two levels of crop rotation (Til and Til-R). We assessed soil macrofauna, with emphasis on earthworm, beetle and ant communities; and soil physical and chemical properties. Macrofaunal taxa composition was significantly affected by both management systems and edaphoclimatic conditions. The Gr community had pronounced differences from all the agricultural systems. The earthworm community from Gr had distinctive features from those of most agricultural systems, with Org and Nt-R3 being the most similar to Gr in native and exotic earthworm species, respectively. The beetle community in Org was the most different one, and the communities from the other systems did not show a pattern related to management. Ant community composition was not determined by management systems, but it was affected by edaphoclimatic conditions. All the studied macrofauna groups had a significant co-variation with soil physical and chemical properties, showing that both the characteristics of each soil relative to the geographic location and the effect of management on abiotic soil attributes have an important effect on soil macrofauna. This study confirms that biodiversity is being lost in Pampas soils, which implies a possible threat to the soil capacity to perform the processes that sustain soil functioning and hence plant productivity. Further considerations about the sustainability of the current agricultural model applied in the Argentine Pampas are needed.

1. Introduction

Soils are non-renewable resources, meaning that their loss and degradation are not recoverable within a human lifespan. However, soils of all around the world are being exploited, mostly neglecting this essential feature. Important soil threats have been described but the extent, severity, and consequences of soil degradation remain poorly documented (Brevik et al., 2015).

The main region devoted to agricultural land use in Argentina is the Pampas region; however, in the last years, agricultural boundaries have been moving to other regions where soils are less developed and more susceptible to degradation. Cereal and oilseed production covered 37.4 Mha. in the 2015/2016 crop season, with 68.2% of that area being cropped with soybean (*Glycine max*) and 23% with maize (*Zea mays*), meaning that 91.2% of the land sown with cereal and oilseeds was cultivated with only two crops. Most crop production in Argentina follows a production model initiated after the “green revolution”, in the 70s. That model was then reinforced with the incorporation of transgenic crops, most of them with resistance to herbicides, and with the widespread use of a synthetic package of fertilizers, herbicides,

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https://doi.org/10.1016/j.actao.2018.08.012
Received 17 November 2017; Received in revised form 22 June 2018; Accepted 30 August 2018

insecticides and fungicides in the region. Therefore, agricultural activity has completely reshaped the Pampas landscape, generating a monotonous scenario with a continuous succession of farms cropped using similar conventional practices and with very low crop diversity, typically with absence of timberline, partly because many tree species are susceptible to herbicides used in annual cropping.

Previous research in the area has warned about the loss of biodiversity, especially of soil biodiversity, associated with that agricultural model (Bedano et al., 2016; Bedano and Domínguez, 2016; Domínguez et al., 2010, 2014; Domínguez and Bedano, 2016). There is growing concern about this situation, given that soil biodiversity is thought as one of the resources that require the greatest attention, since the soil capacity to sustain crops ultimately relies on soil biology. Actually, soil biology sustains or regulates many of the soil functions that are needed to keep resilient soils, those able to sustain ecosystem services in time and withstand to perturbation whether anthropogenic or not (Tittonell, 2016).

Soil biota includes an enormous diversity of organisms and addressing them as a whole would pose an arduous challenge. However, some groups of organisms, such as soil macrofauna, can be assessed as indirect indicators of the whole soil community as well as direct indicators of soil functioning. Soil macrofauna includes invertebrates with body diameter greater than 2 mm, inhabiting surface litter or digging galleries in the soil (Lavelle and Spain, 2003). Macrofauna comprises organisms belonging to two functional groups: ecosystem engineers and litter transformers. The former directly or indirectly modulate the availability of resources to other species by causing physical state changes in biotic and abiotic materials, and in so doing, they modify, maintain, and create habitats (Jones et al., 1994). Earthworms, termites, ants and some beetle larvae are the most important examples (Lavelle et al., 2006, 2007; 2016; Stork and Eggleton, 1992). In the Pampas region, earthworms are by far the most important ecosystem engineers, strongly linked to processes like soil structure formation and nutrient cycling. Numerous litter transformers, like isopods, millipedes, many beetles, larval insects, and some earthworm and enchytraeid species, are important in litter decomposition through comminution of organic residues, facilitating and enhancing decomposing process mediated by bacteria and fungi (Lavelle and Spain, 2003). Furthermore, a diverse community of predators dwell in litter, acting as regulators of soil invertebrate populations and ecosystem processes (Moya-Laraño, 2011).

While there is a wide consensus about the role of soil fauna in soil functioning and therefore in achieving sustainable agriculture production, in Argentina these organisms are rarely considered by the most important actors in deciding which agricultural models and practices are used: international companies involved in the agricultural businesses, the governmental agricultural agencies and farmers. Aware of this situation, farmers have proposed different approaches based on different agricultural paradigms that intend to promote soil biodiversity conservation in the Pampas region.

One of the approaches is organic agriculture, which is based on ecological and biological processes and involves soil biodiversity conservation as an inherent goal (IFOAM, 2012). Organic agriculture is not merely limited to farming without using chemical inputs (Jiménez, 2007). Rather, it implies understanding the farm as an organism, in which all the components, living or not, interact to create a coherent, self-regulating and stable whole; organic farming implies a degree of awareness of the functioning of, and inter-relationships (between animals, plants, and the environment) within the farm system (Jiménez, 2007). However, extensive organic farming in Argentina often lacks this holistic approach and practices related to improve agroecosystem biodiversity are not applied evenly. Mixed farming with alternation of crop and livestock is generally adopted; however, cover crops, green manure, intercropping, agroforestry, and management practices in the environment surrounding the agricultural plots, such as the use of windbreaks, shelterbelts, and living fences, are very scarcely used in extensive organic farms in the Pampas region. A wide variety in the tillage system applied for weed controlling is also observed. Therefore, in many cases, the main measure in favour of biodiversity conservation is the non-use of synthetic agrochemicals and the inclusion of pasture in the crop rotation, usually every 3–4 years.

There is still controversy in the scientific community regarding the benefits of organic farming to soil organisms. Several studies show that organic farming favours them compared to conventional systems (e.g. Bengtsson et al., 2005; Hole et al., 2005; Mäder et al., 2002) with earthworms seeming to be the group most consistently benefited (Bettiol et al., 2002; Crittenden and de Goede, 2016; Domínguez et al., 2014; Domínguez and Bedano, 2016; Siegrist et al., 1998; Suthar, 2009). However, Flohre et al. (2011) found that the effects of organic farming on soil biota are greatly influenced by the landscape context. In a recent meta-analysis, Tuck et al. (2014) observed a lack of positive effects on decomposers, which are mostly soil fauna, although they remarked that organic farming effects on soil organisms are ambiguous and in general understudied. Some studies have also found neutral or even negative effects. Specific practices, such as the use of manure, green manure, fertilization, different tillage intensities, and different pesticides, are very variable and hinder identification of the specific aspects of organic farming that produce positive effects. Therefore, research articles usually find different results because they assessed systems that vary in specific practices. Nonetheless, the bias towards the study of organic farming systems adopted in Europe and, to some extent, in USA, has enormous proportions. Latin American countries, especially Argentina, lack deep research in organic agriculture and its effect on soil biology.

On the other hand, following the general principles of conventional agriculture, which involves a wide use of machinery, transgenic crops and synthetic agrochemicals, several schemes with different levels of crop rotation and tillage intensities are being used by Argentinean farmers. Reducing tillage intensity and enhancing crop diversity, with higher crop rotation or with the use of cover crops, have been recognized as practices with a strong positive effect on soil biology (e.g. Blanchart et al., 2006; Brevault et al., 2007; de Aquino et al., 2008; House and Parmelee, 1985; Lavelle et al., 2001). Moreover, those practices have been linked to a general improvement of soil physical and chemical properties, such as organic matter content, aggregation, and nitrogen content (Caviglia and Andrade, 2010; Lal et al., 2007). The improvement of those soil habitat characteristics has a great importance in soil biology as well. Thus, the positive effect of increasing crop diversity and reducing tillage intensity has been proven to have several beneficial effects on ecosystem processes; however, studies addressing this issue in an applied agronomic context are very scarce (Bender et al., 2016). Thus, it is interesting to assess if soil biota conservation is improved when crop rotation intensity is increased and if that improvement is then translated into higher yields.

Therefore, we aimed to study how different variations in farming practices and systems, belonging to different agricultural paradigms, impact on soil macrofauna along an edaphoclimatic gradient in the Pampas region. Since agricultural practices which preserve soil biodiversity while maintaining crop production are intended, we were not interested in comparing different land uses, i.e. forests or pastures versus monocultures, but in comparing changes in specific management practices in the agricultural land use. We are aware that those practices present subtle differences in crop rotations or in tillage intensity and therefore we do not expect to find the kind of major differences in soil macrofauna expected, for example, when comparing different and contrasting land uses. However, considering the sensitivity of many of the macrofauna taxa to changes in soil, litter and microenvironmental conditions, produced by changes in land management, we expected