Agricultural Systems 167 (2018) 103–112

Contents lists available at ScienceDirect

Agricultural Systems

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

Industrial agriculture and agroecological transition systems: A comparative analysis of productivity results, organic matter and glyphosate in soil

Aparicio Virginia[a,c,*], Martín Zamora[b], Agustín Barbera[b], Mauricio Castro-Franco[c], Marisa Domenech[b], Eduardo De Gerónimo[a,c], José Luis Costa[a]

[a] *Instituto Nacional de Tecnología Agropecuaria INTA, EEA Balcarce. Ruta 226. Km 73.5, Balcarce, Argentina*
[b] *Instituto Nacional de Tecnología Agropecuaria INTA, CEI Barrow. Ruta 3 Km 488, 7500, Argentina*
[c] *Consejo Nacional de Investigaciones Científicas y Técnicas CONICET, Av. Rivadavia 1917, Buenos Aires C1033AAJ, Argentina*

ARTICLE INFO

Keywords:
Agroecology
Soil physics
Pesticides
Chromatography
Gross margin

ABSTRACT

The system of industrial agriculture (IA), often implemented on a large scale and with high dependence on the supplies use, is reducing the soil organic matter (SOM) and increasing the glyphosate presence in the environment. An alternative approach to IA is agroecologywhich takes greater advantage of natural processes and beneficial on-farm interactions in order to reduce off-farm input use and to improve the efficiency of farming systems. In this study, a transition agroecological system (AT) is the alternative of the IA. Our objectives were: (i) to compare the agronomic productivity between AT and IA systems, (ii) to determine the effect of management practices on soil quality indicators such as soil organic matter content (SOM), soil bulk density, change in the weighted mean diameter (CMWD) and glyphosate and aminomethyl phosphonic acid (AMPA) concentration and (iii) to compare the economic results through a multi-temporal economic analysis between AT and IA systems. The soil sampling was carried out per soil-specific zones, delimited from apparent soil electrical conductivity (ECa) and elevation. Samples were taken at 0 to 2, 2 to 5, 5 to 10, 10 to 20, 20 to 30 and 30 to 40 cm of depth to determine the SOM content, the glyphosate concentration and main glyphosate metabolite, AMPA. Besides, the bulk density (δ_a) and CWMD were determined. The δ_a was lower in AT with respect to IA, both under no tillage (NT). No significant differences were found for CWMD between AT and IA systems, although a tendency to a lower value in AT system was observed. If we consider the percentage of organic matter as carbon matter per hectare, this means that in 6.5 years increase 540 kg ha^{-1} at 0 to 40 cm depth. The SOM content increased from 4,9 to 5,6% in AT with respect to IA. The content of glyphosate + AMPA at the first 40 cm was 0.06 kg ha^{-1} in the AT and 0.84 kg ha^{-1} in the IA system. In the AT system, the gross margin accumulated during 6.5 years, increased 244% with respect to IA. These results suggest that the AT system proposed could be applicable in extensive productions with temperate climates without interfering with the livelihood of the agricultural producers and it allows an improvement in soil conditions. It is important to carry out further studies in order to confirm the benefits of the AT system in other edaphic-climatic conditions, integrating productive, economic and environmental aspects.

1. Introduction

Society needs to assure stability in the availability, accessibility and healthy food at a regional and global scale (Bommarco et al., 2018). However, conventional agro productive systems are not solving that, because they are generating a considerable environmental pollution (Dumont and Baret, 2017; Francis et al., 2003; Gliessman, 2005, 2014). This, added to climate extreme events, population growth, policies disputes, social inequity, poor governance, the functioning of the global trade system, biofuels production, financial speculation and poverty, are threatened the global food security for next decades (Bommarco et al., 2018; Stephens et al., 2018).

The Argentine Pampas and South America in general are one of the most important agricultural zones of the world (Choumert and Phélinas, 2015; FAOSTAT, 2015; Ferraro and Benzi, 2015). In these zones, conventional system of industrial agriculture (IA) have been predominant since 90´s, contributing to generate an environmental degradation focuses on: i.- Increasing soil degradation rate which manifests itself mainly in structure loss and compaction (Costa et al., 2015; Aparicio and Costa, 2007; Fabrizzi et al., 2003; Ferreras et al.,

---

[*] Corresponding author at: Instituto Nacional de Tecnología Agropecuaria INTA, EEA Balcarce. Ruta 226. Km 73.5, Balcarce, Argentina.
E-mail address: aparicio.virginia@inta.gob.ar (A. Virginia).

https://doi.org/10.1016/j.agsy.2018.09.005
Received 8 November 2017; Received in revised form 12 September 2018; Accepted 12 September 2018

2000) and a reduction in the content of organic carbon (Domínguez et al., 2010). Soils play an important role in global climate processes through the regulation of emissions of carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4). According to a technical report from the "World Soil Resource State "(FAO, 2015), on a global scale, soils are the largest terrestrial reservoir of carbon and therefore have a greater influence on the concentration of carbon dioxide (CO_2) in the atmosphere. The Intergovernmental Panel on Climate Change (IPCC) estimated the accumulated soil organic carbon (SOC) in the first meter of the soil at 1.502 billion tons. Current global estimates derived from the Harmonized Soil Database of the World () suggest that approximately 1.417 billion tons of SOC are stored in the first meter of soil and about 716 billion tons of SOC in the 30 cm superiors. Globally the primary driver of SOC loss is the change in territory use. A meta-analysis conducted in 2014 and based on 119 publications showed that storage of SOC was reduced by 98% of places with an average of 52% in temperate regions (Argentina is a country with temperate regions). The global loss of SOC stored since 1850 is estimated at around 66 ± 12 billion tons. This decrease in soil organic carbon (SOC) contributes to the increase of CO_2 in the atmosphere. Carbon (C) accumulates in the atmosphere at a rate of 3,5 µg C year-1 (Pg = 1015 g), while phytocenosis stores C at approximately 550 Pg (Houghton et al., 2007); ii.- Excessive use of agrochemical, mainly glyphosate (Aparicio et al., 2013; Peruzzo et al., 2008; Primost et al., 2017; Rampoldi et al., 2011; Soracco et al., 2018; Castro Berman et al., 2018). The main metabolic pathway of glyphosate is its microbial degradation to aminomethylphosphonic acid (AMPA), which is more persistent in soils than glyphosate (Bento et al., 2016). The World Health Organization concluded that there is evidence to classify glyphosate as 'probably carcinogenic to humans' (Group 2A; WHO, 2015), and the experts on pesticide residues in food and the environment at a meeting of the FAO concluded that glyphosate together with AMPA should be considered as residues toxicological interest. For the purpose of estimating the dietary intake and to allow comparison of the calculated intakes with Acceptable Daily Intake it is preferable to express the residues in terms of glyphosate (glyphosate = 1.5 × AMPA; FAO report, 2005); iii.- Increasing pesticides and nutrients concentration on water (Etchegoyen et al., 2017; Ronco et al., 2016; Lupi et al., 2015; De Gerónimo et al., 2014; Peruzzo et al., 2008) and iv.- Displacement of rural community to urban/periurban areas (Fernández and de los Ríos Carmenado, 2010; Phélinas and Choumert, 2017).

In the next decades, if this IA system is consolidated, ecosystem services would be irreversible damaged (Phélinas and Choumert, 2017). Also, a key factor which has determined the expansion of the IA system is the lack of alternative systems which reduce the environmental impact being socially just and economically viable (Gliessman, 2014). In this context, it would be necessary to design and validate alternative agro productive systems which mitigate harmful effects of IA systems (Altieri, 2018; Bonaudo et al., 2014; Francis et al., 2003; Gliessman, 2014).

In this study, a transition agroecological system (AT) as alternative of the IA conventional system predominant. This AT system is based on: (i) to generate and validate agroecological management practices and (ii) to generate and/or validate productive, environmental and economics metrics which monitor the impact of these practices, at field scale.

Agroecology takes greater advantage of natural processes and beneficial on-farm interactions in order to reduce off-farm input use and to improve the efficiency of farming systems (Altieri, 2018; Reijntjes et al., 1992). Technologies emphasized tend to enhance the functional biodiversity of agroecosystems as well as the conservation of existing on-farm resources. Promoted technologies such as cover crops, green manures, intercropping, agroforestry and crop–livestock mixtures, and pest integrate management and nutrient balance (Altieri, 2002; Altieri, 2018; Bonaudo et al., 2014; Steenwerth and Belina, 2008). It has been widely reported that these agroecological practices not only mitigate environmental degradation caused by AI system, but also contribute to economic and social viability of agro productive systems (Gliessman, 2014).

The aim of this study was to evaluate quantitatively an alternative agroecological system using productive, environmental and economic variables. The objectives were: (i) to compare the agronomic productivity between AT and IA systems, (ii) to determine the effect of management practices on soil quality indicators such as soil organic matter content (SOM), soil bulk density, change in the weighted mean diameter (CMWD) and glyphosate and AMPA concentration and (iii) to compare the economic results through a multi-temporal economic analysis between AT and IA systems. These results would imply a clear understanding of an alternative agroecological system, which benefits can be quantified to be implemented by farmers, scientists and technicians.

2. Materials and methods

2.1. Experimental site

The experimental site was a 16 ha agricultural field located in the southeastern Pampas of Argentina (38°19′S, 60°15′W, Datum WGS84) (Fig. 1). This experimental site was selected because it represents the landscape position and spatial variability of soil depth usually found in the southeastern Pampas of Argentina. The soils are classified as Subgroups Typic Argiudoll and Petrocalcic Argiudoll; Family fine, illitic, thermic (Domenech et al., 2017; Soil Survey Staff, 2014). In the experimental field, the mean annual temperature is 14.8 °C and has a frost-free period that extends from October to March. It has a humid and subhumid hydric regime (Thornthwaite, 1948). The mean annual precipitation is about 756 mm. The lowest rains are recorded between June and August; while the heaviest rains occur between October and March (Costa et al., 2015).

2.2. Cropping management systems

In January 2011, the experimental field was divided into two plots of eight (8) hectares each. In one of them, the IA system was followed while in the other one, an extensive agroecological crop system (AT) was started, integrating agriculture and cattle breeding, focusing on biodiversity, the equilibrium and nutrients cycling and the progressive reduction in the use of pesticides.

Crops rotation and sequence, in the case of IA, corresponds to a typical sequence for Tres Arroyos area, while in the AT agroecology principles were used, in agreement with an interdisciplinary team of professionals, increasing the number of species per year (Table 1). The management of each plot allows us to see the contribution of external supplies in each system: IA and AT (Table 2).

2.3. Delimitation of soil-specific zones

Apparent soil electrical conductivity (ECa) and elevation were used as auxiliary information to delimitate soil-specific zones within the experimental site (Fig. 1).

ECa measurements were collected on September 9th, 2016 using a Veris® 3100 soil electrical conductivity sensor (Veris Technologies Inc., Salina, KS, USA). With this sensor, the system records ECa in mS m^{-1} by electrical resistivity at a shallow depth (0 to 30 cm, ECa 0-30 cm) and deep depth (0 to 90, ECa 0-90 cm) (Castro Franco et al., 2015). ECa measurements were made along parallel transects approximately 20 m apart on the surface of the experimental site. Latitude, longitude, ECa 0-30 cm and ECa 0-90 cm data were recorded in an ASCII text file and transferred to GIS software.

Elevation was measured simultaneously with ECa, using an advance differential GPS Surveying instrument GPS Trimble®R3 (Trimble Navigation Limited, CA, USA). Elevation data were post-processed with