

## Response of soil microbial communities to agroecological versus conventional systems of extensive agriculture



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### ABSTRACT

World population growth has led to a rise in resource demands imposed on agricultural systems, generating an increased global use of natural resources. However, agroecology proposes self-regulation in order to achieve a sustainable agricultural balance. Therefore, considering the rapid responses of microbial communities to small changes in soil use, the objective of this study was to assess the response of soil microbial communities to agroecological vs. conventional systems of extensive agriculture. Soil sampling was carried out in 2016 and 2017 with three different treatments using the sequence soybean/maize (*Glycine max* L./*Zea mays* L.) as the main crop: Agroecological (AE), conventional with cover crops (CC) and conventional without cover crops (control). Species used as cover crops were wheat (*Triticum aestivum*), vetch (*Vicia sativa* L.), oat (*Avena sativa* L.) and radish (*Raphanus sativus* L.). Agroecological treatment showed the lowest total nitrogen ( $0.18 \text{ mg N g}^{-1}$ ) and organic carbon ( $1.99 \text{ mg C g}^{-1}$ ) content of soil, and CC treatment showed the highest value of fluorescein diacetate hydrolysis, with values 63.2% and 12.1% higher than AE and the control, respectively. However, AE treatment also produced the highest F:B ratio (44.8) and the lowest metabolic quotient (1.14), which indicates an improvement in metabolic efficiency and soil quality. No significant differences were recorded in the abundance of fungal and bacterial communities between treatments. Our results suggest that agroecological management is characterised by fungal dominance in soil microbial communities and a higher microbial metabolic efficiency compared to conventional management. These results demonstrate more efficient use of carbon substrates in agroecological systems, which could counteract the negative effect of the lack of synthetic fertilisation and reduced-tillage in the long term. The findings demonstrate that sustainable agricultural tools with adequate management can be effectively used to preserve soil quality.

### 1. Introduction

In recent years, research studies of major agricultural regions of the world have focused on diversification and sustainable management of agricultural systems, in order to restore systems which have been misused and their resources over-exploited (Massawe et al., 2016; Kanter et al., 2016; Zeweld et al., 2017). In this sense, world population growth has led to a rise in resource demands imposed on agricultural systems, generating a greater global use of natural resources and a

significant decline in ecosystem services (Gianinazzi et al., 2010). High-intensity agriculture has mainly focused on productivity, instead of integrating natural resource management into food production security; monocultures and increased use of synthetic inputs, such as chemical fertilisers and pesticides, have reduced soil fertility (Foley et al., 2005). Therefore, there is no doubt that an alternative agricultural development paradigm is required that encourages more durable, greener, more resilient forms of agriculture that favour biodiversity and are socially just.

Abbreviations:  $q\text{CO}_2$ , metabolic quotient; TN, total nitrogen; eP, extractable phosphorus; SOC, soil organic carbon; AP, acid phosphatase; FDA, fluorescein diacetate; MBC, microbial biomass carbon; 18S, fungal rDNA copies; 16S, bacterial rDNA copies; F:B, fungal:bacterial ratio; C:N, carbon:nitrogen ratio

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Given the high economic and environmental costs of the conventional agricultural system and future predictions of climate change, agroecology may represent the theoretic basis that could promote the equity and sustainability of agroecosystems. Conventional agriculture is based in transgenic crops developed for pest control using a single control mechanism (pesticide) which has frequently failed to control insect pests, pathogens and weeds (Altieri and Nicholls, 2000). Moreover, transgenic crops use tends to accelerate the evolution of resistant plagues (Tabashnik and Carrière, 2017), thus, agroecology involves biodiversification as a primary technique for inducing self-regulation in order to achieve a sustainable balance. Agroecology represents a scientific, methodological, and technological basis for a new “agrarian revolution” worldwide (Ferguson and Morales, 2010), since agroecology-based production systems are resilient, energetically efficient, biodiverse, socially just, and provide the basis for an energy, productive and food sovereignty strategy (Altieri et al., 2012). Hence, the study of the effect of agroecological management on natural resources in comparison with conventional management is extremely useful.

Since sustainability of agricultural systems is based on conservative practices which encompass the entire productive chain within an efficient resource use framework (Ferreira et al., 2011), microbiological processes occurring in the soil constitute the basis on which agroecological farming is sustained (Faria and Franco, 2002). This is because soil microbial communities develop a fundamental role in nutrient cycling and organic matter decomposition and, considering their interactions with crops, the study of microbiology provides an accurate means of analysing different agricultural management systems (Burton et al., 2010). Thus, the ability of microbial communities to respond rapidly to the changes in land use (Singh, 2015) can be employed to compare the effects of agroecological and conventional management. Since agroecological practices include an integration of several agricultural tools, such as cattle dung, reduced-tillage and crop diversification (Altieri et al., 2012), it would be expected that changes in microbial dynamics compared to conventional management would be observed. Therefore, considering that the higher diversity of microbes in ecosystems could establish a functional equilibrium which may enable sustainability to be preserved (Seneviratne, 2012), it is important to generate knowledge about the effect of agroecology on soil microbial communities.

Since agroecological systems use agricultural techniques to compensate for the lack of synthetic inputs, strategies such as integrated livestock-crop systems and reduced-tillage are commonly used by agroecological farmers (Toffolini et al., 2017). However, loss of soil quality caused by reduced-tillage compared to no-tillage and uncoupling of the nitrogen cycle from the carbon cycle caused by consumption of plant residues by cattle has been widely reported (Peigné et al., 2007; Favardin and Peyraud, 2010). Therefore, it is also necessary to take into account the negative aspects when studying the impact of agroecology on edaphic microbiology. Overall, the objectives of this study are: 1) to compare the response of soil microbial community structure and functionality to an agroecological system and a conventional agricultural system including a cover crop mixture; 2) to evaluate soil chemical parameters with both agricultural management systems evaluated; and 3) to study the relationships between the response of soil microbial functionality and chemical parameters with both agricultural management systems evaluated. We hypothesised that agroecological agriculture generates an increase in the structure and functionality of soil microbial communities, which is related to a greater microbial metabolic efficiency and macronutrient availability.

## 2. Material and methods

### 2.1. Field experiment

The study was carried out at the Pergamino Experimental Station of the National Institute of Agricultural Technology (INTA) (33°51'S,

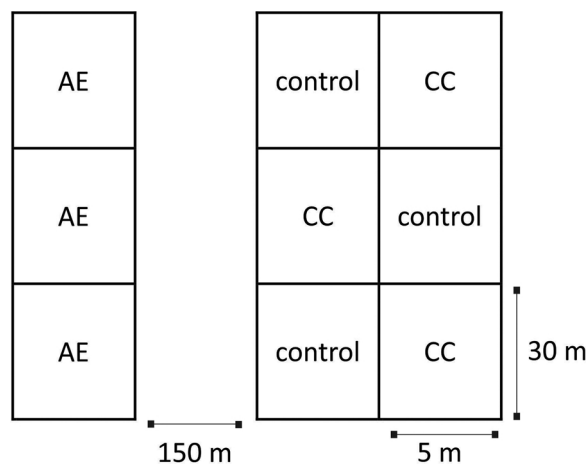


Fig. 1. Representative scheme of the field trial with the three treatments: agroecological management (AE), conventional management with cover crops (CC) and conventional management without cover crops (control).

60°40'W), Buenos Aires province, Argentina, in 2016 and 2017. Two long-term field trials set up in 2006 at the experimental station were evaluated, an agroecological trial and a conventional trial. Even though both trials were physically separated from each other (1500 m) to ensure that agroecological treatment was not exposed to agrochemicals, they were considered as a single trial for the purpose of statistical design and data analysis. The climate in this site is temperate humid, with mean annual temperature of 16.5 °C and rainfall occurring mostly in autumn and spring, with a mean annual rainfall of 971 mm for the 1910–2010 period (Agroclimatological Network Database, INTA; <http://climayagua.inta.gob.ar/>). The soil at the study site is predominantly Typic Argiudoll (USDA Soil Taxonomy) of the Pergamino series with a silt loam A horizon without eroded phase (< 0.3% slope). The experimental design was based on a one-way factorial design with three replications. The experiment consisted of three treatments with three replicates of each, totaling nine plots (Fig. 1). The treatments were: 1) Agroecological management (AE), 2) Conventional management with cover crops (CC), 3) Conventional management without cover crops (control). Agroecological plots were managed without the use of external synthetic inputs, such as herbicides, pesticides, mineral fertilisation or genetically modified crops. The plots were sown with soybean/maize (*Glycine max* L./*Zea mays* L.) sequence as main crops, in rotation with triticale (*Triticosecale*) and vetch (*Vicia sativa* L.) as cover crops, with crops sown by a reduced-tillage method. The plots included the presence of cattle in order to provide the addition of cattle dung to the soil. Weed control was performed using mechanical methods, such as chisel-ploughing and killing cover crops by disc harrowing which incorporated the vegetable residues into the soil. Conventional plots (including CC treatment and the control treatment) were managed with the application of herbicides, mineral fertilisers, and pesticides, and the use of genetically modified crops. The plots were also sown with soybean/maize sequence as main crops, with both crops being sown using a no-tillage method. Maize was fertilised at sowing with calcium superphosphate (150 kg ha<sup>-1</sup>) and between V5-V6 with 32 kg N ha<sup>-1</sup>. The species used as cover crops in CC treatment were: oat (*Avena sativa* L.), vetch (*Vicia sativa* L.) and radish (*Raphanus sativus* L.), which were sown as a mixture of species (oat-radish-vetch). In CC treatment, cover crops were killed using 3–4 l ha<sup>-1</sup> of glyphosate (48% active ingredient), and their residue left on the surface without tilling into the soil.

### 2.2. Soil sampling

Soil sampling was performed at soybean and maize harvest in March 2016 and 2017, according to a previous study (Restovich et al., 2012).

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