



Land use shapes the resistance of the soil microbial community and the C cycling response to drought in a semi-arid area

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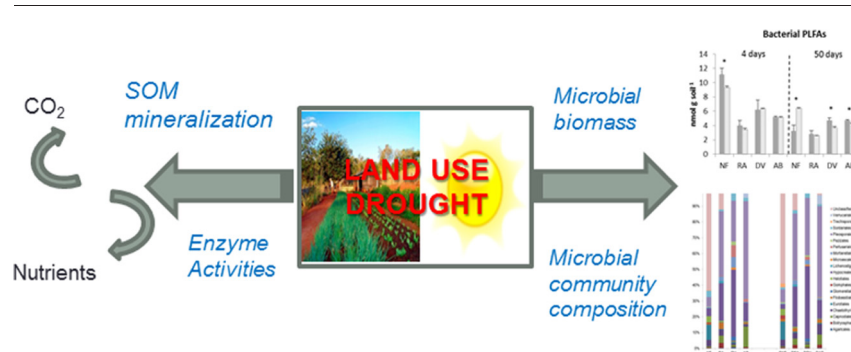
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HIGHLIGHTS

- The drought resistance of the soil microbial community is shaped by the land use.
- Land use had a greater impact on the soil microbial community structure than drought.
- The microbial community of the forest soil was the most resilient to drought.
- Microbiome was more drought-resistant in rainfed soils than in irrigated ones.

GRAPHICAL ABSTRACT



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ABSTRACT

The aim of this study was to understand the responses of the microbial community of soil under different land uses to drought in a semi-arid Mediterranean area. In a laboratory incubation, soil samples from different land uses (natural forest, drip-irrigated orchard, rain-fed almond tree cultivation and abandoned area) were maintained at 20% and 60% of the WHC. The microbial biomass and potential enzyme activities were determined after four and fifty days of soil incubation. The diversity and composition of the microbial community were studied after 50 days of incubation. The total mineralisation of soil organic C (SOC), as well as, the mineralisation of fresh organic matter (FOM) and the “priming effect” were analysed after addition of ¹³C-enriched plant tissue. Both land use and drought had significant effects in the soil microbial community, but the effect of land use was stronger than that of drought. The PLFA content (microbial biomass) of the forests soil was greater under drought. After 50 days of soil incubation, the microbial biomass and most of potential enzyme activities of the almond tree and abandoned soil samples were not significantly affected by drought contrary to those in orchard soil. The total and FOM mineralisation were on average lower in soil under drought than under optimal moisture for all land uses. However, the responses of the priming effect to drought were dependent on the land use. Overall, we conclude that the resistance to drought of the soil microbial community from an agroecosystem having a semi-arid climate is strongly influenced by the previous land use.

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1. Introduction

The Mediterranean agroecosystems in the South-East of Spain are among the most productive in Europe, and agriculture is a key economic activity in this area (Grindlay et al., 2011). The productivity of

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Mediterranean agroecosystems is water-limited due to the low precipitation and the high evapotranspiration rates. Thus, soils in Mediterranean agroecosystems are vulnerable to the impacts of climate change, particularly because longer and extreme drought periods are predicted by climate-change models (Iglesias et al., 2011; Thomas, 2008). Indeed, it has been reported that extreme drought periods can decrease the C stocks in terrestrial ecosystems (Reichstein et al., 2013). In agroecosystems, soil management and moisture affect crop productivity which, in turn, influences the soil organic C (SOC) concentration (Collins et al., 2000). Indeed, there has been a decline in the SOC concentration of Spanish Mediterranean croplands during the 20th Century, due to the historical change of land uses, management practices and climate (Aguilera et al., 2018).

Several studies have indicated that the conversion of grassland or semi-natural soils to agricultural soils may affect soil microbial communities (de Vries et al., 2012; French et al., 2017) and the ecosystem services that they support: i.e., carbon (C) cycling, nutrient transformation, soil fertility, plant growth, etc. (Bardgett et al., 2008; Schmidt et al., 2011). Among the ecosystem services that are mediated by microbes, those related to C cycle are fundamental because they can determine CO₂ fluxes to atmosphere and climate feedbacks. The soil priming effect (PE) is a critical component of the C cycle that consists on the change in soil organic matter (SOM) mineralisation after the input of fresh organic matter (FOM) (Blagodatskaya et al., 2007). PE has received increased attention to the understanding of global C cycle and nutrient mobilization in soil. This microbially-driven soil phenomenon has been postulated as a major determinant of the capacity of soils to function as sources or sinks of atmospheric C (Bradford, 2017). However, the influences of land use and drought on PE are scarcely understood. Thus, a deeper knowledge of this phenomenon would permit us to better predict C fluxes in soils with different management legacy and subjected to the forecasted climate change.

Due to the soil organic matter (SOM) content is a limiting factor for plant and microbial growth in semi-arid agroecosystems (Bastida et al., 2006; Hernandez et al., 2014), agricultural practices that help to enhance the SOM content can promote their sustainability. Furthermore, practices that enhance the SOC content may also increase soil microbial diversity (Thiele-Bruhn et al., 2012). Indeed, there is evidence that the diversity of soil microbial community confers stability to stress and disturbance (Bastida et al., 2017b; Bononi et al., 2018). However, information about the effects of organic management in soil microbial community is contrasting. Bowles et al. (2014) observed that differences in organic management of agroecosystems influenced the soil nutrient content and enzyme activities, but did not impact the composition of microbial communities. Schlatter et al. (2017) observed that bio-solids can have a strong influence on soil fungal communities. Brennan and Acosta-Martinez (2017) found that the cover cropping frequency in organic vegetable agroecosystems is a major driving force of the soil microbial community. Particularly, it was evidenced that C inputs from frequent cover cropping are the primary driver of changes in the soil food web and soil health in organic vegetable production systems.

Besides organic matter, water management (i.e. irrigation) is another factor that can influence the biomass, activity and composition of the soil microbial communities (Bastida et al., 2017c), as well as soil respiration (Starke et al., 2017). Limited water availability may reduce SOC levels through the diminished formation of organo-mineral complexes, as a consequence of the alteration of the microbial biomass and its activity (Canarini et al., 2016) and/or the microbial community composition (Bastida et al., 2017a). In this sense, several studies have found that reduced soil water contents promote the abundance of fungi and Gram+ bacteria (Barnard et al., 2015; de Vries and Shade, 2013; Fuchslueger et al., 2014; Manzoni et al., 2012). However, other studies did not find consistent impacts of drought on the composition of microbial communities (Canarini et al., 2016; Rousk et al., 2013).

Despite the predictions of climate change and the agronomic importance of Mediterranean agroecosystems, there is limited information about how land use influences the responses of soil microbial communities to drought. Here, we aim to evaluate if the resistance of the soil microbial community against drought depends or not on the previous land use. It is known that distinct land use can alter the SOM concentration and the soil microbial community, and that these changes may strongly influence the soil functionality (Acosta-Martinez et al., 2008; Bastida et al., 2017c; Francaviglia et al., 2017; French et al., 2017). We hypothesize that the long-term legacies of land use will shape the responses of the soil microbial community to induced drought under laboratory conditions in terms of its biomass, composition, activity and C-cycle. Particularly, we hypothesize that: i) the high OM content of the natural forest soil provides it with a superior capacity of water retention, which confers a resilience to the microbial community exposed to the induced drought; and ii) the microbial community of rain-fed cultivated and abandoned soils is adapted to natural drought conditions and will be more resistant to induced drought than that of irrigated soils in terms of biomass, activity and composition.

In this study, the responses to induced drought of the microbial community of soils subjected to different land uses will be evaluated by a suite of approaches that include microbial biomass (phospholipid fatty acids, PLFAs); potential enzyme activities related to the C, N and P cycles; community composition (16S rRNA and ITS sequencing); and OM mineralisation through isotopic approaches.

2. Material and methods

2.1. Field area and experimental design

The soil plots were located on a farm in Moratalla (Murcia Region, SE Spain), which has geographic coordinates of 38° 12' 51.27" N; 1° 52' 49.86" W and an elevation of 529 m.a.s.l. The studied soil had a sandy clay loam texture and was classified as a Haplic Calcisol (IUSS, 2015). The area had a semi-arid climate with a mean annual rainfall of <300 mm and a mean annual temperature of 18 °C.

The field area (1.4 ha) included four land uses and the short distance between them minimised soil and microclimatic variability. The four different land uses were: 1) a natural ancient forest plot dominated by *Pinus halepensis* (natural forest-NF); 2) a transformed-into agricultural plot cultivated for about 65 years with *Prunus dulcis* (almond) under rain-fed conditions (rain-fed almond-RA), this plot had not been fertilised in the last six years and had been subjected to two light operations of tillage each year; 3) a drip-irrigated organic plot farmed with a vegetable rotation (tomato, aubergine, cucumber and pepper) for five years (drip-irrigated vegetables-DV). This plot had been fertilised with horse manure and subjected to drip irrigation three times per week; and 4) a soil that was abandoned from agricultural use 40 years ago (abandoned-AB). The plots were established in triplicates (n = 3) with 100 m² per plot. Chemical, biochemical and microbial data of the selected soils were presented in Table S1 (Supporting information).

In May 2016, six subsamples from each plot were randomly collected to a depth of 15 cm and mixed to form one composite sample per plot. In order to study the influence of drought on the microbial community of these soils subjected to different land use, an incubation experiment was performed under controlled laboratory conditions. A total of 48 incubation microcosms were prepared in plastic containers without cover, each with 200 g of soil. A total of 12 microcosms were prepared per land use treatment. All microcosms were pre-incubated in an incubation chamber at an optimal water-holding capacity (WHC) of 60%, achieved by adding deionized water, for 15 days at 25 °C and in the dark. Once the soil samples had adapted to this optimal water content, 24 microcosms [4 land use treatments (NF, RA, DV, AB) × 3 replicates × 2 independent incubation times] were maintained at 60% WHC during the following incubation (well-watered samples). A soil water content of 50–60% WHC is agreed to be the better optimal

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