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Effect of land abandonment on soil organic carbon fractions along a Mediterranean precipitation gradient

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ABSTRACT

Land abandonment has been the main land use change in rural Mediterranean areas over the last decades. The secondary succession following land abandonment is strongly affected by precipitation, which in turn determines the change of soil organic carbon (SOC) and other soil properties. However, SOC consists of different fractions with contrasting resistance to decomposition that are differently affected by land abandonment. The aim of this study is assessing the evolution of different carbon fractions after land abandonment along a West–East precipitation gradient in southern Spain (Gaucín (GAU): 1080.5 mm y^{-1}–Almogía: 650 mm y^{-1}–Gérgal (GER): 350 mm y^{-1}). In each site, samples from a chronosequence of land abandonment were size fractionated, yielding three fractions with increasing degrees of carbon stability (coarse, intermediate, fine). Following land abandonment, there was a transitional grassland state in GAU and ALM that promoted a quick SOC gain of 0.87 and 0.42 kg m^{-2}, respectively. The majority of this gain, i.e. 79.2% in GAU and 71.4% in ALM, occurred in the most stable fractions. SOC was rapidly stabilised due to the presence of litter with a low C:N ratio. The colonisation of grasslands, in GAU and ALM, or croplands, in GER, by woody vegetation triggered SOC accumulation of 0.07, 0.78 and 0.74 kg m^{-2}. However, in GAU there was at the same time a SOC loss in the most stable fractions (0.23 kg m^{-2}). In ALM and GER a reverse trend was observed: SOC accumulated in the intermediate and fine fractions. SOC accumulation in the coarse fraction was related to the low quality of the litter from woody vegetation, that had a higher C:N ratio than litter from grasslands. The largest effect of precipitation was found in the fine fraction, whereas SOC in the coarse fraction was mostly controlled by land abandonment and related factors, such as vegetation, litter quality and soil conditions.

1. Introduction

Land abandonment has been one of the most important land use changes in rural areas of the Mediterranean basin during the last decades (Nunes et al., 2010). Between 1961 and 2011, 24.5% of the acreage under annual and permanent crops in southern Europe has been abandoned (127,450 km^2) and 17.0% (35,200 km^2) in Spain (FAO, 2013). This phenomenon has been attributed to a complex of socio-economic factors such as globalization as well as specific policies. For instances, the European Union and the local governments reduced the subsidies for extensive farming and increased the ones for cropland reforestation.

Recently abandoned lands have properties that differ from the ones in natural areas as a result of legacy from previous cultivation (Compton and Boone, 2000; Hooker and Compton, 2003). After land abandonment, colonisation by natural vegetation begins and the soil properties gradually change until they reach similar values to undisturbed areas (Bonet, 2004). In Mediterranean environments, secondary succession usually starts with grassland colonisation that persists for variable time until woody vegetation takes over (Cuesta et al., 2012; Rey Benayas, 2005). Precipitation is the limiting factor for this process, since in semiarid lands establishment of woody plants has been reported to be slow and grasses can remain for a long time (Bonet and Pausas, 2004). Since vegetation is the main driver of the changes in the soil chemical properties, the evolution of soil characteristics will differ depending on the rainfall regime.

Soil organic carbon (SOC) is strongly affected by land abandonment and secondary succession (Gabarrón-Galeote et al., 2015; Novara et al., 2014). However, the rate of recovery depends to a great extent on precipitation and on the way it affects vegetation cover evolution (Guo and Gifford, 2002; Jackson et al., 2002; Poeplau et al., 2011). In wet environments, the colonisation of abandoned lands by grasslands provokes rapid SOC recovery (Poeplau et al., 2011). In semiarid and arid

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Mediterranean areas, on the contrary, soil properties have been reported to recover slowly after abandonment, due to the seasonality of the grassland cover (Ruiz-Sinoga and Martínez-Murillo, 2009) and the slow colonisation of woody species (Rey Benayas, 2005).

SOC content is probably not the most sensitive parameter to react after abandonment, as it is a mixture of different pools with contrasting resistance to decomposition and thus residence time in the soil (DeGryze et al., 2004; Six et al., 2002; von Lützow et al., 2006): i) non-protected soil organic carbon, easily decomposable and with short turnover time (1–10 years). This pool consists of free particulate organic matter (POM) mainly composed of unprotected plant residues, seeds and microbial debris, such as fungal hyphae and spores; ii) physically protected SOC pool by occlusion in stable microaggregates, with intermediate turnover time (10–100 years); iii) chemically protected pool by organo-mineral association with silt and clay particles, and with a turnover time of 10–100 years; and iv) biochemically recalcitrant SOC pool with a turnover time > 100 years. Free POM, due to its labile nature, is believed to be more sensitive and respond rapidly to land use changes and other external disturbances (Cambardella and Elliott, 1993; Guidi et al., 2014), but it can be easily processed by a microorganism and then become physically or chemically protected, or it can remain as free POM (Condron et al., 2010). Knowing the degree of protection of the SOC added or depleted upon land conversion, as expressed in SOC fractions, is thus crucial since it leads to a better understanding of SOC dynamic than the study of the overall SOC. Thus, there is a strong need for studies about the influence of land use changes on SOC fractions representing SOC pool with different stability, taking in account the effect of precipitation and colonising vegetation. This is especially the case in Mediterranean areas where C stocks are supposed to be highly affected by climate change (Rodeghiero et al., 2011).

The present study aims to assess the evolution of different carbon fractions after land abandonment along a Mediterranean precipitation gradient. It is limited to the first 10 cm of soils since they are the most affected by land use changes (DeGryze et al., 2004) and, in general, the relative importance of climate decreases with depth (Albaladejo et al., 2013). Moreover, soils are known to be very shallow in the area (Ruiz-Sinoga et al., 2010). The specific objectives are: i) to determine the net effect of land abandonment on the different soil organic carbon fractions; ii) to assess the relation between vegetation evolution and SOC fractions; and iii) to determine the relative importance of the factors affecting the SOC fraction dynamics.

2. Material and methods

2.1. Study sites

The study was conducted along a precipitation gradient in the South of Spain (Fig. 1), from the Strait of Gibraltar (mean precipitation > 1100 mm y^{-1}) to the Cape of Gata (mean precipitation < 200 mm y^{-1}). The climate is Mediterranean, with cool winters and hot summers that coincide with a severe drought. Three sites were selected with markedly different mean annual precipitation: Gaucín (GAU), Almogía (ALM) and Gérgal (GER; Table 1). These three sites have a similar annual precipitation distribution, are located in the same biogeographical province, have a common potential vegetation consisting of *Quercus* spp., have a similar land use history and are on non-calcareous metamorphic micaschist parent material (Gabarrón-Galeote et al., 2015). Unfortunately, all abandoned fields on micaschists in GAU and ALM were originally almond and olive groves. As land use history explains a large part of the total SOC variability (Schulp and Veldkamp, 2008), we preferred to restrict the study to abandoned cereal fields for all sites, even if this meant that the fields in GAU and ALM had to be found in the neighbouring lithological unit i.e. unconsolidated marls and clays with allochthonous blocks of sandstones. In GAU, texture is silt-loam, with 20.3%, 69.5% and 10.2% of sand, silt and clay, respectively. Vegetation is mainly cereal crops and citrus tree plantations,

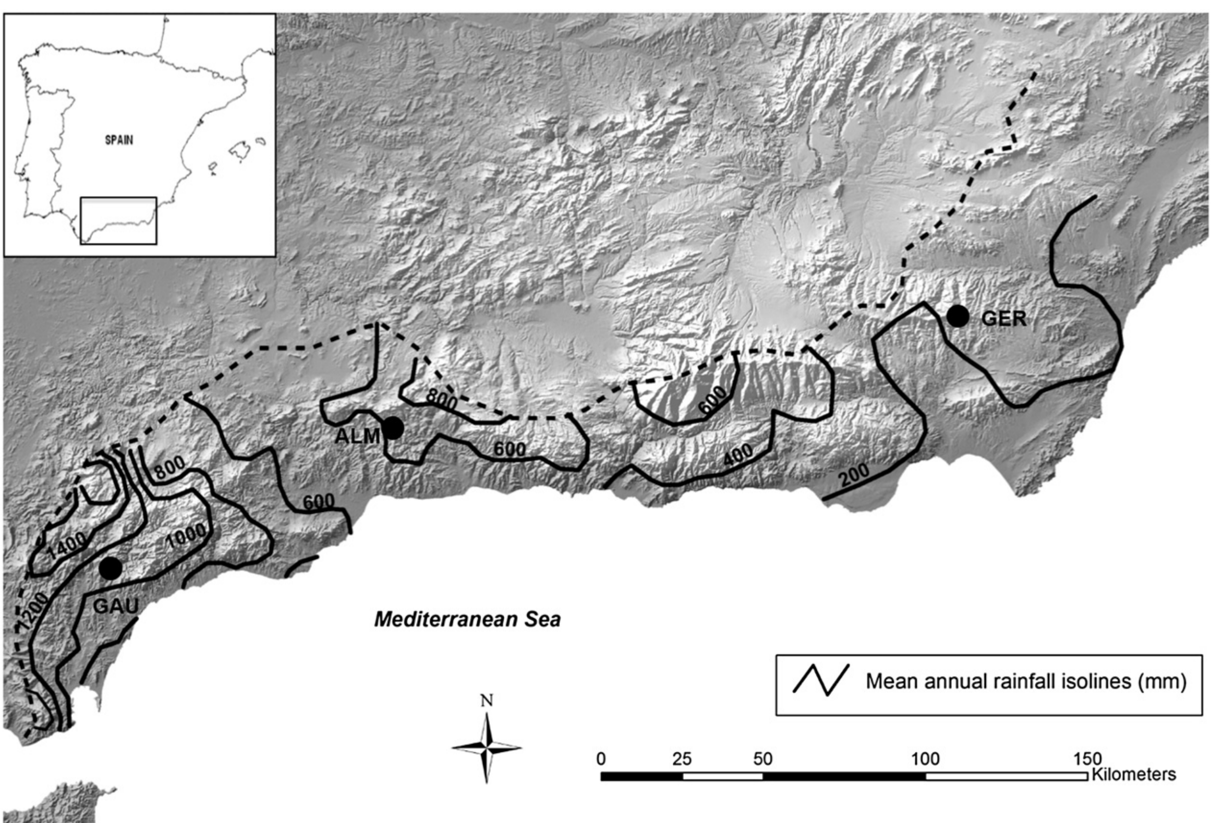

Fig. 1. Precipitation gradient and location of study sites. GAU: Gaucín (1085 mm); ALM: Almogía (650 mm); GER: Gérgal (350 mm).