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Net ecosystem CO_2 exchange in an irrigated olive orchard of SE Spain: Influence of weed cover

Sonia Chamizo[a,*], Penélope Serrano-Ortiz[b,c], Ana López-Ballesteros[d,c], Enrique P. Sánchez-Cañete[e,c], José Luis Vicente-Vicente[f], Andrew S. Kowalski[a,c]

[a] Departamento de Física Aplicada, Universidad de Granada, 18071 Granada, Spain
[b] Departamento de Ecología, Universidad de Granada, 18071 Granada, Spain
[c] Instituto Interuniversitario de Investigación del Sistema Tierra en Andalucía, Centro Andaluz de Medio Ambiente (IISTA–CEAMA), 18071 Granada, Spain
[d] Estación Experimental de Zonas Áridas (EEZA–CSIC), 04120 Almería, Spain
[e] Biosphere 2, University of Arizona, 85623 AZ, USA
[f] Departamento de Biología Animal, Biología Vegetal y Ecología, Universidad de Jaén, 23071 Jaén, Spain

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ABSTRACT

No-till management and the establishment of plant cover have been implemented in olive crops in recent years in order to prevent soil erosion and increase soil organic carbon. However, the effect of these conservation practices on the net CO_2 exchange at the ecosystem scale has not been explored so far. In this study, we analyze the influence of resident vegetation cover (hereafter weeds) on the net ecosystem CO_2 exchange (NEE) in an irrigated olive orchard located in Jaén (SE Spain) by using the eddy covariance technique. NEE was measured in the olive orchard under two treatments, one with weed cover in the alleys from autumn to spring, and another where weed growth was avoided by the application of a glyphosate herbicide. Our study demonstrates that the presence of weeds in the alleys increased carbon assimilation in the weed-cover treatment during the weed growing period (from December to April). However, the net ecosystem CO_2 uptake decreased in the weed-cover treatment during late spring (May and June), after weeds were cut and left on the soil, compared to the weed-free treatment, probably due to an increase in soil respiration. On an annual basis, weed removal decreased net carbon uptake by 50% compared to the weed-cover treatment. The annual NEE was $-140\,g\,C\,m^{-2}\,y^{-1}$ in the weed-cover treatment and $-70\,g\,C\,m^{-2}\,y^{-1}$ in the weed-free treatment. In summary, our study demonstrates that, during the first year of differential treatment, maintenance of weed cover in olive groves has a positive effect on CO_2 uptake and enhances the capacity of the agro-system to act as a net CO_2 sink.

1. Introduction

Soil cultivation and anthropogenic climate change have caused a great impact on the global soil carbon (C) cycle over the last century. Inadequate management of agricultural land has led to accelerated rates of soil erosion and has exposed trapped C to decomposition, accelerating mineralization of soil organic carbon (SOC; Lal, 2004). As a consequence, these practices have modified gains and losses of soil C, altering the natural C balance and increasing greenhouse gas emissions (Aguilera et al., 2015; Amundson et al., 2015). Some estimates point to global SOC losses by agricultural erosion of $404\,Tg\,C\,y^{-1}$ (Doetterl et al., 2012) and to global C releases to the atmosphere associated with erosion that range from 0.8 to $1.2\,Gt\,C\,y^{-1}$ (Lal, 2003). These C emissions are equivalent to 12% of global C emissions by fossil fuels and industry (9.80 Gt C in 2014; Le Quéré et al., 2015). Therefore, the application of sustainable practices aimed to increase C sequestration in agriculture has become a relevant subject of interest. This can be especially important in Spain, where SOC contents lower than 1% are frequent, mostly in southern areas and agricultural soils (Rodríguez Martín et al., 2016).

Olive trees (*Olea europaea L.*) are one of the most important crops in the Mediterranean basin, where they cover around 9.5 Mha and account for 98% of the world's olive cultivation area (Repullo-Ruibérriz de Torres et al., 2012). The largest area dedicated to this crop is found in Spain, where it occupies 2.6 Mha and represents 72% of world's olive production (data for 2013–2014; IOOC, 2015). Around 60% (1.5 Mha) of the olive cultivation in Spain is located in Andalusia (southern Iberian

* Corresponding author.
E-mail address: schamizo@ugr.es (S. Chamizo).

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Peninsula; MAGRAMA, 2012). Thus, olive groves represent an important agricultural system in this region due to its environmental, social and economic benefits. However, olive groves are subject to several environmental problems due to inadequate conventional soil-management practices such as intensive tillage and overgrazing, which have caused high runoff and erosion rates, high soil and SOC losses, and the loss of soil fertility (Álvarez et al., 2007; Francia Martínez et al., 2006; Martinez-Mena et al., 2008; Gómez et al., 2009). In order to mitigate these problems, research has been carried out in recent decades to improve soil management practices, and prevent the mineralization of organic matter and the loss of soil structure and fertility (FAO, 2004).

One of the most widespread conservation practices applied in olive-grove plantations has been the maintenance of spontaneous resident vegetation cover (hereafter "weeds") in the alleys from autumn to spring (Marquez-Garcia et al., 2013; Nieto et al., 2013). Weed covers, in addition to protecting the soil against erosion, offer a number of well-known benefits for soil properties: improvement of soil physicochemical properties (Ramos et al., 2010); increases in the interception and storage of rainfall water, as well as in soil water content and water availability in deep soil (Celano et al., 2011; Palese et al., 2014); increases in atmospheric C fixation and SOC content, thereby improving soil structure and fertility (Hernández et al., 2005; Castro et al., 2008; Gómez et al., 2009; Repullo-Ruibérriz de Torres et al., 2012; Marquez-Garcia et al., 2013; Soriano et al., 2014; Herencia, 2015); and increased biodiversity (Plaza-Bonilla et al., 2015). In this regard, some estimates point to SOC increases between 44% and 85% in topsoil (0–15 cm) in olive groves after 100 years of cover crop management (Nieto et al., 2013), and preliminary estimations suggest an increase in soil C sequestration of around 1 ton C ha^{-1} y^{-1} in olive orchards under Mediterranean conditions due to the adoption of plant covers (Vicente-Vicente et al., 2016). Thus, agricultural systems can function as C sinks if adequate management practices are applied.

Although numerous studies have examined the effect of weed cover on soil properties and SOC content, little research has been focused on their effect on soil CO_2 fluxes or how they affect the ecosystem C balance in olive orchards. Indeed, few studies have reported information on CO_2 fluxes from olive groves or quantified the ecosystem C uptake accounting for total CO_2 inputs and outputs (see Testi et al., 2008; Nardino et al., 2013). So far, most CO_2 exchange measurements have been conducted at the tree (Villalobos et al., 2012; Pérez-Priego et al., 2010) and soil levels (Bertolla et al., 2014) by using chambers, and soil CO_2 emissions have been also estimated via modelling approaches (Nieto et al., 2010). In the absence of weed cover, net ecosystem CO_2 exchange (NEE) from olive groves will result from the balance between CO_2 inputs by tree photosynthesis and CO_2 outputs by aboveground autotrophic respiration (olive leaves, trunks and branches), belowground autotrophic respiration (olive roots) and heterotrophic soil respiration. However, in the presence of weeds, it is

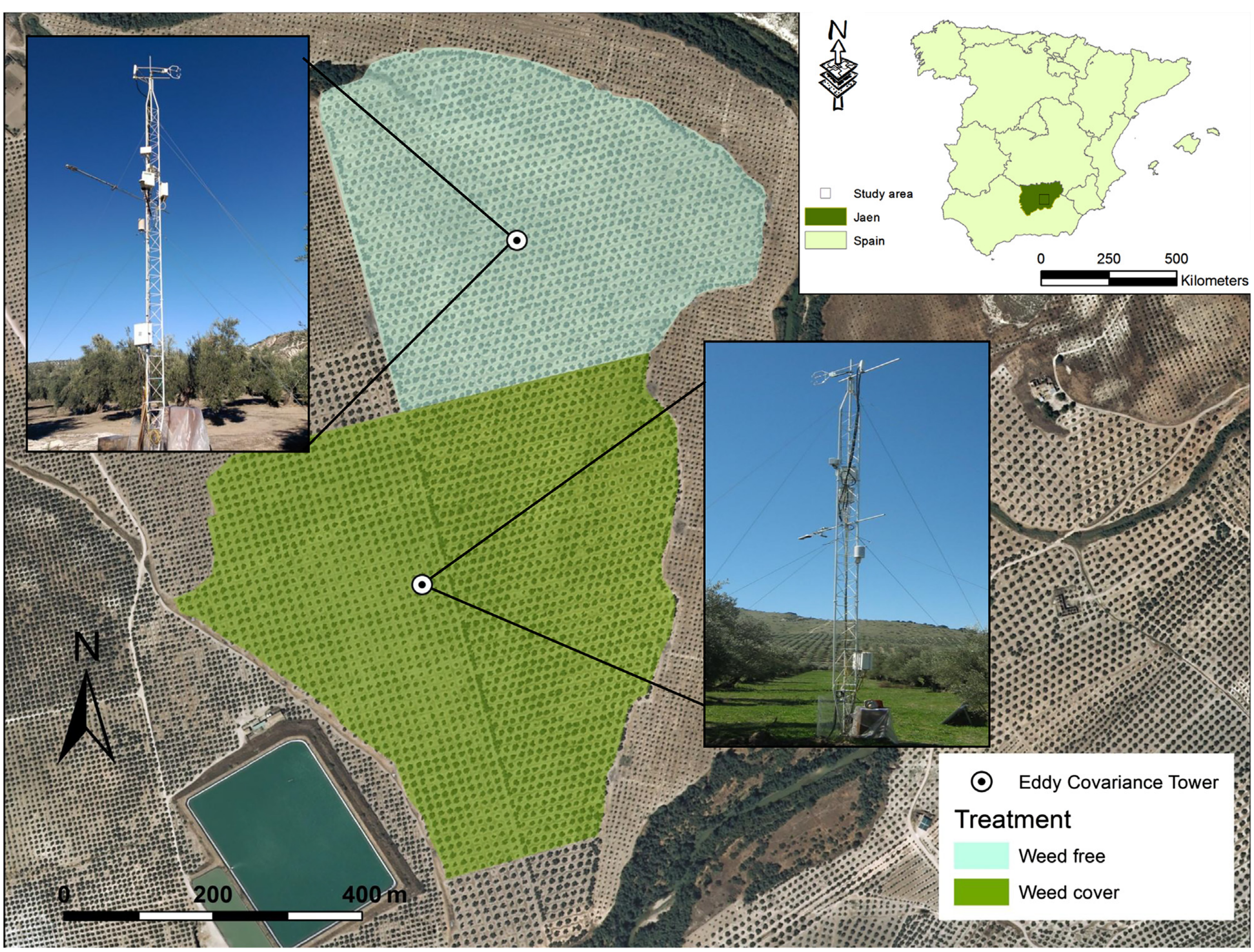

Fig. 1. Location of the olive orchard and picture of the eddy tower installed at each treatment considered at this site: maintenance of spontaneous weeds (weed cover) and weed removal by application of an herbicide (weed free). Points indicate the location of the eddy covariance towers. The colored area indicates the fetch for each treatment.