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The impact of agricultural management on selected soil properties in citrus orchards in Eastern Spain: A comparison between conventional and organic citrus orchards with drip and flood irrigation

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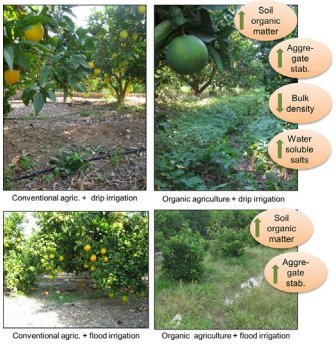
HIGHLIGHTS

- Agricultural management with irrigation type has influences on soil parameters.
- Aggregate stability and the amount of SOM were higher under organic farming.
- Organic soils with drip irrigation were more favorable for bulk density and nutrients.

GRAPHICAL ABSTRACT



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ABSTRACT

The agricultural management of citrus orchards is changing from flood irrigated managed orchards to drip irrigated organic managed orchards. Eastern Spain is the oldest and largest European producer of citrus, and is representative of the environmental changes triggered by innovations in orchard management. In order to determine the impact of land management on different soil quality parameters, twelve citrus orchards sites were selected with different land and irrigation management techniques. Soil samples were taken at two depths, 0–2 cm and 5–10 cm for studying soil quality parameters under the different treatments. Half of the studied orchards were organically managed and the other six were conventionally managed, and for each of these six study sites three fields were flood irrigated plots and the other three drip irrigated systems. The outcome of the studied parameters was that soil organic matter (SOM) and aggregate stability were higher for organic farms. Bulk density and pH were only significantly different for organic farms when drip irrigation was applied in comparison with flooded plots. C/N ratio did not vary significantly for the four treatments. Although there are some points of discussion, this research shows that a combination of different management decisions leads to improvement of a couple of soil quality parameters. Organic management practices were found to be beneficial for soil quality, compared to conventional management for soils with comparable textures and applied irrigation water.

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1. Introduction

Soils provide a variety of important ecosystem services, such as food production (Tilman et al., 2002), buffering and filtering of ground water (Keesstra et al., 2012), soil carbon storage and climate mitigation (De Vries et al., 2012; Montanarella, 2015; Keesstra et al., 2016a, 2016b). Therefore, it is important to preserve or even improve the quality of soils after millennia of abuse of soil resources resulting in declining ecosystem services. To maintain or improve soil quality transdisciplinary approaches are needed, incorporating input from different science fields such as soil science, ecology, hydrology, and geomorphology in combination with management expertise (Brevik et al., 2015).

Currently, a transition in agricultural soil management of citrus orchards is occurring all over the world as a consequence of the increasing use of drip irrigation. The area of Valencia is representative of this change due to private, national and European policies that subsidise the development of highly mechanized, drip-irrigated, chemically and computer-managed orchards. However also socioeconomic changes played a role. Valencia is the region that produces two thirds of the Spanish oranges and it is the oldest and the largest European producer of citrus. Conventional managed orchards with flood irrigation (currently <50%) changed to drip-irrigation over the last 30 years. The ageing of the farmer population, or farmers that cannot take care of the flood irrigation system, the low prices for oranges, and the need for agricultural mechanization to be more competitive, all have their impact on land and irrigation management. Due to changes in irrigation type, differences in soil quality are expected to occur, which consequently also will affect the soil moisture regime. Drip irrigation moistens only 20% of the soil, but continuously throughout the growing season. Meanwhile flood irrigation moistens all soil every 15–30 days in summer in three to six controlled flooding events. The soil wetting patterns resulting from of the two irrigation methods are different, and also the use of chemicals is different as the drip irrigation is more regular at low dose (once per day, usually for 30 to 120 min), in contrast to the higher short fluxes under controlled floods. Consequently, SOM content and the bulk density should change as a result of the changed spatio-temporal distribution of soil moisture (Cassel Sharmasarkar et al., 2001; Wang et al., 2006).

Another fast change in the citrus agriculture in the world is the development of organic farming strategies to supply a high quality product to the markets of developed countries. Organic farming is more than a fashion and is well established. Right now, 3% of the Valencia citrus production is under organic farming rules, and no-tillage, reduction of pesticide application, use of machinery to weed, and mulching with chipped pruned branches is widespread among non-organic farmers to avoid expenses, labour and to increase subsidies.

Research has been conducted to compare organically managed farms and conventional farms (Marriott and Wander, 2006; Gómez et al., 2009; Cerdà et al., 2016; Keesstra et al., 2016a, 2016b; Prosdocimi et al., 2016) as well as for different irrigation systems (drip versus flood irrigation) (e.g. Swietlik, 1992; Nelson et al., 2011). However, the combined effect of organic or conventional farming in combination with different irrigation types is not studied yet.

Soriano et al. (2014) studied the shift from conventional to organically managed orchards in olive groves. Their conclusion was that some soil properties, such as texture, pH, C/N ratio, cation exchange capacity (CEC) and exchangeable potassium were equal in conventional and organically managed systems. However, organic C and N, saturated hydraulic conductivity and available water-holding capacity (AWC) of the soil improved in olive groves under organic farming strategies. Glover et al. (2000) made a comparison between conventional, organic and integrated systems (a combination of both systems) in apple orchards and applied a soil quality index. Some chemical, biological and physical soil properties were shown to be of higher quality in organic systems if compared to conventional. Also, Bulluck et al. (2002) found higher crop yields for organic farming systems in the second year of harvest of vegetables. Soybean yields were found to be similar for organic and conventional farms (Liebhardt et al., 1989). However, a long-term experiment by Mäder et al. (2002) showed a 20% decrease of crop yield for organic practices over a period of 21 years, for fields with crop rotation. Van Leeuwen et al. (2015) found no improvement in chemical and physical parameters for organic farms in comparison with conventional farms. Still organic farming is recommended due to a decrease in energy consumption and fertilizer utilization (Mäder et al., 2002) as well as by the improvement of biological parameters (Van Leeuwen et al., 2015). Soil organic matter (SOM) is another important indicator of soil quality, which is correlated with the degree of soil aggregation (Marriott and Wander, 2006). Marriott and Wander (2006) also found an increase of total and labile SOM concentrations in surface soils at organic farms in comparison to conventionally managed farms. However, there is still an ongoing debate about the question whether organic farming management is enhancing the carbon storage in the soil (Gattinger et al., 2012; Leifeld et al., 2013).

Another key issue is whether drip irrigation will affect soil quality. Studies have been focusing on the differences of drip and flood irrigated practices in agroecosystems (Swietlik, 1992; Nelson et al., 2011). Various studies found positive responses of different crop and soil types to drip irrigation, with no reduction or even a higher crop yields due to drip irrigation in comparison with flood irrigation (Swietlik, 1992; Cassel Sharmasarkar et al., 2001; Wang et al., 2006; Nelson et al., 2011). Furthermore, flood irrigation does not saturate the soil fully due to the sudden application of a large amount of water. The irrigated water will partly be lost to the groundwater due to preferential flow in macro pores making it unavailable to crops. In general, flood irrigation is recharging aquifers, but this is not of profit for the farmers where the irrigation takes place, although others will be benefit of the increased groundwater downstream (Zhang et al., 2014). This is not the case with drip irrigation (Cassel Sharmasarkar et al., 2001), where the watering takes place daily, while the saturation of the soil and the flow in macro-pores is avoided. Another advantage of drip-applied water systems compared to flood irrigation is that it has been found to be water saving as less water is evaporated (Uckoo et al., 2005; Deng et al., 2006). Bryla et al. (2005) showed that young peach trees grew taller and had higher yields under drip irrigation. Geleta et al. (1994) stated that total nitrogen (N_t) and nitrate (NO_3^-) losses were reduced when drip irrigation was applied. Although much attention has been paid to effects of irrigation in the context of water management, relatively little is known about how they affect soil quality.

The combined effects of management (organic or chemical) and irrigation (drip or flooding) are not yet studied in combination, and little is known about the effect on soil quality in citrus orchards. Therefore, the objective of this research is to get a better understanding of managing citrus orchards in relation to the chosen soil quality parameters, irrigation systems and the presumable benefits of a better soil quality under organic agriculture. Our hypothesis is that out of the four different managed orchard types the organically managed orchards with a drip irrigation system have the highest score on the studied soil quality parameters. For conventional orchard with flood irrigation we expect the opposite. We think that the research findings can contribute to an improved management of citrus orchard on Mediterranean type of soils under Mediterranean climatic conditions.

2. Materials and methods

2.1. Study site

The research area is located in Eastern Spain, in the province of Valencia (39°04′46″N, 0°25′44″W and 38°58′16″N, 0°35′06″W). The area has a Mediterranean climate, which implies an annual rainfall ranging from 498 to 715 mm $year^{-1}$ and 3 to 5 months of summer drought, with an average annual temperature of 14.2 °C. Frost is unusual in this area. The actual evapotranspiration for mature orange trees has been

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