SOIL Discuss., 2, 1–27, 2015
www.soil-discuss.net/2/1/2015/
doi:10.5194/soild-2-1-2015
© Author(s) 2015. CC Attribution 3.0 License.

SOIL Discussions Open Access

This discussion paper is/has been under review for the journal SOIL. Please refer to the corresponding final paper in SOIL if available.

Effect of land management on soil properties in flood irrigated citrus orchards in Eastern Spain

A. Morugán-Coronado[1,2], F. García-Orenes[2], and A. Cerdà[1]

[1]SEDER (Soil Erosion and Degradation Research Group), Departament de Geografia, Universitat de València, Blasco Ibáñez, 28, 46010 València, Spain
[2]GEA (Environmental Soil Science Group), Agrochemistry and environmental, University Miguel Hernández, 03202-Elche, Alicante, Spain

Received: 2 December 2014 – Accepted: 10 December 2014 – Published: 5 January 2015

Correspondence to: A. Morugán-Coronado (amorugan@umh.es)

Published by Copernicus Publications on behalf of the European Geosciences Union.

SOILD
2, 1–27, 2015

Effect of land management on soil properties

A. Morugán-Coronado et al.

Abstract

Agricultural land management greatly affects soil properties. Microbial soil communities are the most sensitive and rapid indicators of perturbations in land use and soil enzyme activities are sensitive biological indicators of the effects of soil management practices. Citrus orchards frequently have degraded soils and this paper evaluates how land management in citrus orchards can improve soil quality. A field experiment was performed in an orchard of orange trees (*Citrus Sinensis*) in the Alcoleja Experimental Station (Eastern Spain) with clay-loam agricultural soils to assess the long-term effects of herbicides with inorganic fertilizers (H), intensive ploughing and inorganic fertilizers (P) and organic farming (O) on the soil microbial properties, and to study the relationship between them. Nine soil samples were taken from each agricultural management plot. In all the samples the basal soil respiration, soil microbial biomass carbon, water holding capacity, electrical conductivity, soil organic matter, total nitrogen, available phosphorus, available potassium, aggregate stability, cation exchange capacity, pH, texture, macronutrients (Na, Ca and Mg), micronutrients (Fe, Mn, Zn and Cu), calcium carbonate equivalent, calcium carbonate content of limestone and enzimatic activities (urease, dehydrogenase, β-glucosidase and acid phosphatase) were determined. The results showed a substantial level of differentiation in the microbial properties, which were highly associated with soil organic matter content. The management practices including herbicides and intensive ploughing had similar results on microbial soil properties. O management contributed to an increase in the soil biology quality, aggregate stability and organic matter content.

1 Introduction

The land management in agricultural areas has an important influence in microbial soil properties (García-Orenes et al., 2013). Unsuitable land management can lead to a loss in soil fertility and a reduction in the abundance and diversity of soil microorgan-

SOILD

2, 1–27, 2015

CC BY

isms. However, ecological practices and some organic amendments can promote the activities of soil microbial communities and increase biodiversity (García-Orenes et al., 2010). Mulches and catch/cover crops are often seen as one of the best strategies to improve the biological activity of soils (Martir-Torres et al., 2013; Maul et al., 2014), and they are very efficient at reducing soil losses in agriculture land (Giménez Morera et al., 2010), on road embankments (Lee et al., 2013) and on fire affected rangelands (Fernández et al., 2012).

The Mediterranean Belt is suffering from an intense degradation of its soils due to the millennia old land use (Zornoza et al., 2007), the use and abuse of the soil system due to non-sustainable management, land abandonment in the 1950s and 60s, and now as a consequence of the intensification of agricultural management (Cerdà et al., 2010).

The land uses determine the fate of the soil properties and quality and they are time and spatially dynamic (Zhao et al., 2013). Soil erosion due to non-sustainable land management changes in land use and agriculture system evolution is the main reason for land degradation in many regions of the world, especially in semiarid areas (Cerdà et al., 2009a; Barbera et al., 2013; Jones et al., 2014). Land degradation processes are also linked to reduction in soil fertility and damage to the abundance and diversity of soil microorganisms (Caravaca et al., 2002) and plants (Raizada and Juyal, 2012). Soil erosion and soil biological activity decline are seen as the main cause of agricultural land degradation in Eastern Spain (García-Orenes et al., 2009; Cerdà and Doerr, 2007).

Soil organic matter (SOM) improves a soil's chemical and physical properties, promoting biological activity and maintaining environmental quality (Brevik, 2009), and this is why organic fertilisers, such as manure, waste water and sewage sludge, promote the activities of soil microbial communities (Morugán-Coronado et al., 2011; Balota et al., 2013; Macci et al., 2013). Plants and microorganisms are key players within the soil ecosystem and are responsible for many important soil cycling processes, such as C mobilization and N mineralization (Zak et al., 2003). On the other hand, land use influences soil microbial processes by changing the quantity and quality of plant residues entering the soil and their spatial distribution, through changes in nutrients and inputs (García-Orenes et al., 2009, 2012; Blagodatskaya et al., 2011).

Within agricultural lands, the Mediterranean Belt is characterised by the depletion of SOM after millennia of ploughing and burning. In the 20th century, the arrival of herbicides, chemical fertilizers, fungicides and insecticides (biocides in general) drastically modified the function and structure of microbial communities, altering the terrestrial ecosystems, which has important implications for soil quality (Sofo et al., 2012; Imfeld and Vuilleumier, 2012). Soil quality is the "foundation" of the sustainable development of terrestrial ecosystems as the soil can act as a source or as a sink of carbon or pesticides (Paz-Ferreiro and Fu, 2013; Vasconcellos et al., 2013).

The traditional flood irrigated orchards and gardens are a very special component of Mediterranean landscapes. They are characterised by a recurrent controlled flood that allows vegetables and trees to grow during the typical Mediterranean drought. This is a man-made landscape, where the crops are not originally from the Mediterranean, the weeds are also foreigners (invasive or imported), and soils are the result of agricultural practices over millennia. The traditional flood irrigation garden systems changed their crop from vegetables to citrus during the 20th century. Most of them moved to chemical fertilization and herbicide use in the last five decades, although in the past ploughing was the most popular management. Since the 1990s, some farmers have moved to organic farming (3 % of farmers). Meanwhile, the chemical farmers that plough the land (5 %) are typically the oldest ones as they maintain the tradition of tillage, and 92 % of farmers use herbicides. Herbicides arrived in the region in the 1980s and they were the most popular management after the 1990s, which is also connected to increased use of drip-irrigation (Cerdà et al., 2009a).

Although the traditional flood irrigated gardens are widespread in the Mediterranean type agroecosystems, and they are also found in other semiarid and arid ecosystems, there is not information about the impact of the above-mentioned changes in land management on soil quality and biological activity. This is why we are applying an integrated

SOILD
2, 1–27, 2015

CC BY

approach by measuring the microbiological characteristics of the soil, the enzymatic activities and the soil physicochemical properties. This will allow an understanding of the impact of the land management on the soil system.

The main goal of this study is to determine the impact of land management change (from ploughing to herbicides and to organic farming) on soil microbial and biochemical properties in citrus orchards under flood-irrigation in Eastern Spain.

2 Materials and methods

2.1 Study site

This research was conducted at the Alcoleja Experimental Station located in L'Alcúdia de Crespins municipality, 60 km from coastal land, in the Eastern Iberian Peninsula, southwest of the Valencia province (UTM: 709191X, 4316356Y; Zone 30), at 156 m a.s.l. The climate is typically Mediterranean with a mean annual precipitation of 500 mm and a mean annual temperature of 16 °C. The soil is a Xerorthent (Soil Survey Staff, 2010). The texture of soil is clay-loam, consisting of 20 % clay, 40 % silt, and 40 % sand.

2.2 Experimental design

The three plots studied at the Alcoleja Experimental Station have been planted with citrus (*Citrus Sinensis*) the last 30 years. The planting pattern is 7 × 4 m this is the usual pattern for citrus in this agricultural area. The orchards have been flood-irrigated with fresh water from the Sants River, which is a spring of the Macizo del Caroig aquifer. The spring supplies the discharge for the irrigation and is 2 km from the experimental station. No pollution, no sources of OM and no wastewater is mixed with the high quality water coming from the spring. The orchards are flooded every 20 days in summer and no irrigation takes place in winter. The irrigation schedule is based on the farmer's experience. Three different agricultural managements were established in the

CC BY

experimental station 30 years ago: (H) Herbicides with inorganic fertilizers applied before irrigation (Glyphosate (*N*-(phosphonomethyl)glycine) 4 times per year; NPK 15 %, 1 Mg ha^{-1} per year), (P) ploughing 5 days after the irrigation and inorganic fertilizers applied before the flooding (NPK 15 %, 1 Mg ha^{-1} per year) during 30 years and (O) organic farming were established 8 years ago (chipped pruned branches and weeds, manure from sheep and goats, 20 Mg ha^{-1}: 0.07 % N, 0.03 % P_2O_5, and 0.09 % K_2O applied once per year, in winter, after the harvest of the oranges, usually in January).

2.3 Soil sampling

In July 2013, nine soil samples from individual trees were collected in a randomised design from every agricultural management: herbicide with inorganic fertilizers (H), ploughing with inorganic fertilizers (P) and O with manure, weeds and chipped pruned branches (O). The soil samples were taken from the 0–5 cm and were collected from three farms that are neighbours, and the distance between the individual sampling points was less than 10 meters. Field-moist soil samples were sieved at 2 mm and stored at environmental temperature to conduct the physicochemical analysis. Soil sample aliquots were sieved between 0.25–4 mm to determine the percentage of stable aggregates. Also an aliquot of every soil sample was kept cool (4 °C) to carry out the microbiological analysis.

Vegetation cover was determined as the percentage of soil covered by plants (Cerdà et al., 2007). The plant recolonization was calculated at the 9 sampling points for each treatment by means of a 50 × 50 cm square frame, and vegetation cover was measured at 100 points (each 5 × 5 cm) by a pin.

2.4 Soil physicochemical, microbiological and biochemical analyses

Soil pH and electrical conductivity (EC) were measured with a 1 : 5 (w / v) aqueous solution. The basal soil respiration (BSR) was measured using a multiple sensor respirometer (Micro-Oxymax, Columbus, OH, USA). Soil organic matter (SOM) was determined

SOILD
2, 1–27, 2015

by Walkley and Black (1934), available Na, K, Mg and Ca were extracted with 1N ammonium acetate (Knudsen et al., 1982) and Fe, Cu, Zn and Mn were extracted with DTPA (Lindsay and Norvell, 1978) and measured by atomic absorption and emission spectrophotometry. The reason for the inclusion of Na in the study is because the research is focused mainly on potential soil degradation and Na is related to sodicity processes, which lead to the loss of soil structure due to clay dispersion. Cation exchange capacity (CEC) was measured by the method described by Roig et al. (1980). Microbial biomass carbon (Cmic) was extracted using the chloroform fumigation and extraction procedure (Vance et al., 1987). Soluble carbon from the soil solution was extracted through potassium dichromate digestion, following the Jenkinson and Powlsow method (1976). Aggregate stability (AS) was measured using the method of Roldán et al. (1994); this method examines the proportion of aggregates that remain stable after a soil sample (sieved between 0.25–4 mm) is subjected to an artificial rainfall of known energy ($270\,\mathrm{J\,m^{-2}}$). Total nitrogen (Nk) was determined by the Kjeldahl method (Bremmer and Mulvaney, 1982). Available phosphorus was determined by the Burriel-Hernando method (Díez, 1982). Water holding capacity (WHC) was assayed by the method of Forster (1995). Calcium carbonate equivalent (CCE) and calcium carbonate content of limestone ($CaCO_3$) were measured by Porta et al. (1986). Urease activity (EC 3.5.1.5) was assayed according to the method of Tabatabai (1994), using urea as the substrate. Dehydrogenase activity was determined according to García et al. (1997). Phosphatase (EC 3.1.3.1) and β-glucosidase (EC 3.2.1.21) activities were determined using p-nitrophenyl phosphate disodium (PNPP, 0.115 M) and p-nitrophenyl-β-D-glucopyranoside (PNG, 0.05 M) as substrates, respectively. The assay is based on the release and detection of p-nitrophenol (PNP) according to Tabatabai (1994).

2.5 Statistical analyses

The fitting of the data to a normal distribution for all soil properties was checked with the Kolmogorov-Smirnov test at $p < 0.05$. To compare the effect of agricultural man-

CC BY

agement, an ANOVA test was done. We tested significance between treatments for each soil to observe changes over treatments. The separation of means was carried out according to the average post-hoc Tukey test $p < 0.05$, assuming equal variance. Pearson's correlation coefficients (R) were calculated to quantify the linear relationship between parameters. All soil properties from all samples were subjected to principal components analysis (PCA) to elucidate major variation patterns in terms of the three treatments of study. To perform correlation-based PCA ($p \leq 0.05$), the data was normalized in order to have the same (= 1) variance for the samples along all species axes. Alexakis (2011) concluded that principal component analysis proves a successful tool for the interpretation of results. All statistical analysis was performed with the SPSS program (Statistical Program for the Social Sciences 18.0).

3 Results

3.1 Physicochemical parameters

Table 1 shows the vegetation cover, texture, pH, EC, CCE, WHC, $CaCO_3$, CEC, macronutrients (Na, Ca and Mg) and micronutrients (Fe, Mn, Zn and Cu). The maximum vegetation cover was observed in the O plot (42.2 %) with less cover in the other agricultural managements (H: 1.2 % and P: 1.1 %), the main weeds species observed at organic farming management were *Brachypodium retusum* (pers.) Beauv. and *Cistus albidus* L. (Table 1). The ploughed soil (P) had the highest clay content, and the highest values of WHC and $CaCO_3$ in comparison to the herbicide (H) and organic farming (O) land managements (Table 1). The pH level in the plots ranged from 7.9 in O plot to 8.3 in P plot. In the O plot, soils showed a statistically significantly higher content of salts (EC) and a slight decrease in pH was observed compared with the other agricultural managements studied (Table 1). The lowest value of CEC was found in H plot and the highest value of CEC was found in O plot (Table 1).

CC BY

The H plot did not show a great improvement in the fertility parameters (Table 1 and Fig. 1). The percentage of sand in this plot (H) was higher than the other agricultural managements (Table 1).

Figure 1 shows the content of the main nutrients parameters studied (N, P and K) in the three different agricultural management soils. This information shows that the soil under O management had a higher content of these elements important for soil fertility. The H plot was the one that had the lowest values in SOM, N, P and K content. Furthermore, O plot showed the highest content in SOM reaching almost 8 % against the low content of the other agricultural managements studied, which reached 2 %. Agricultural management with O increased the N content five times compared to the other management plots. Available P and available K obtained their maximum in the O plot and this agricultural management had statistical differences with the other farming practices (H and P), P plot had the lowest values for these two soil parameters.

Figure 1 also shows the percent aggregate stability at each plot. The O management obtained the highest level of AS which seems to be related with the organic matter content.

3.2 Microbial biomass carbon, basal respiration and enzymatic characterization of the soil

Soils under O management had higher levels of Cmic and BSR than P and H plots (Fig. 2a and b). The microbial biomass carbon is considered the most active and living part of OM and is composed of microorganisms that participate in different processes in the soil.

Enzymatic activities (dehydrogenase, urease, phosphatase and β-glucosidase) were measured in the three types of agricultural management (Fig. 2c, d, e and f). Significant differences were found between the organic management and the other management systems for all enzymatic activities studied, with phosphatase highest in the soil under O when compared to the H and P plots. The dehydrogenase enzyme activity (Fig. 2c) in the soil reflects the total oxidative activity of the microbes, and its concentration was

CC BY

high in O plot indicating that the activity of the microbial community increases with agriculturally sustainable management.

We have not recovered data about the productivity of harvest in the different agricultural managements because the objective of this study was evaluate effects on soil properties not in crop productivity. However, we observed and stimated that there had not been important differences of yield between treatments in the last five years.

3.3 Bivariate correlation coefficients

Table 2 shows the correlation coefficients between the most important physicochemical and biochemical properties studied in all agricultural treatments of this research. Vegetation cover had strong correlation coefficients with BSR, SOM, AS, Nk, AP, K and CEC. On the other hand, pH was negatively correlated with the soil fertility parameters (SOM, Nk, AP, K, CEC), microbiological activity (BSR, Cmic and enzimes), AS and vegetation cover. Referring to fertility properties, SOM shows a strong correlation with AS, Nk, AP, K, CEC, phosphatase and vegetation cover. Nk was strongly correlated with AS, K, SOM, CEC, phosphatase and vegetation cover. AP showed strong correlations with K, AS, Nk, SOM, CEC and vegetation cover, and available K showed strong correlation coefficients with AS, Nk, SOM, AP, CEC and vegetation cover. CEC had strong positive correlation coefficients with vegetation cover, AS and fertility properties (Nk, SOM, AP and K). Aggregate stability had strong correlation coefficients with vegetation cover and soil fertility parameters (SOM, Nk, AP, K, CEC). BSR and Cmic did not show strong correlations with the other parameters studied, although it should be noted that a relationship was observed between BSR and SOM, CEC and vegetation cover. No strong correlation coefficients were found between enzymatic activities and any soil properties studied. We only founded positive correlation between phosphatase and AS, Nk, SOM, AP, K and CEC.

SOILD
2, 1–27, 2015

CC BY

3.3.1 PCA

With the PCA performed on the soil physical, chemical, and biochemical properties 69 % of the total variation could be explained by the first three principal components. Figure 3 shows the soil property clusters analyzed through principal components analysis, performed with the different agricultural managements studied. The first principal component (PC) explained 40 % of the variation and it separates the O soil samples from those of the other agricultural managements (P and H). The second component explained 20 % of the variance and separates the soil samples from H and P management while, the third component explained 9 % of the variation. The first component was determined by vegetation, CEC, SOM, Nk, AS, BSR, acid phosphatase, available P, Ca and K. The second component was correlated with Sand, relation C / N and extractable Fe. The third component was associated with urease (Table 3). In Fig. 3 it is shown that the analysis has clearly clustered the soils by type of agricultural management received, and the majority of fertility and microbiological activity properties analyzed are closely associated with soils under O management.

4 Discussion

A combination of high throughput approaches along with physical, chemical, and microbiological methods were used to investigate three different agricultural practices in citrus orchards under flood irrigation. This research approach provides insight into how key fertility parameters and microbiological activity respond to the different agricultural managements, how the O management (weeds, manure, and no chemical fertilization) improved most soil properties, and how inorganic fertilisation drastically changed soil microbial activity. These hypotheses were supported by the results obtained. First, SOM is responsible for microbiological processes and organic compound turnover. Indeed, in agricultural soils that are intensively managed, microbial activity tends to change quicker in response to organic management than community compo-

SOILD
2, 1–27, 2015

sition (Burger and Jackson, 2003). Secondly, distinct enzyme activities indicated that O increased the association of enzyme activity with fertility properties (Piotrowska and Wilczewski, 2012; Bowles et al., 2014). Enzymatic activities may be considered as biochemical indicators of soil quality, mainly based on OM content and related biological and biochemical parameters (García-Ruiz et al., 2008).

In our study all the enzymes studied are closely related with SOM and biological parameters such as Cmic and BSR, as indicated by their correlation coefficients shown in Table 2. These results are consistent with other studies that showed high correlations between different enzymatic activities and the microbial response (Acosta-Martinez et al., 2008; Bonanomi et al., 2011). The high level of enzymatic activities observed in the organic management plot indicates that this soil is biologically and biochemically more active than the other agricultural managements, it is also able to process labile organic components and to protect more stable organic fractions (Emran et al., 2012; Gispert et al., 2013) as shown by the high SOM of this treatment. The phosphatase activity that has been reported in the literature usually shows a negative correlation with the high presence of available phosphorus (Allison et al., 2007). In contrast, in this work we found high phosphatase activity in O plot even with a high presence of available P. This behaviour could be due to the great correlation between the enzyme and the SOM (Table 2), suggesting that soil SOM has been more important than P availability in regulating investment in phosphatase in this soil (Bowles et al., 2014). The decrease of the enzymatic activities in H soil could be explained by the low levels of SOM, nutrients and also microbiological activity found. In P soil, this decrease is worsened by tillage management and could be modified by the potential of soil enzyme-mediated substrate catalysis (Kalender et al., 1996).

Furthermore, it was clearly observed in our survey that O improved the microbial biomass carbon and basal soil respiration; the quantity and quality of SOM and nitrogen inputs are the overriding controls on soil microbial biomass carbon (Fierer at al., 2009, Kallenbach and Grandy, 2011). Thus, different agricultural amendments (e.g. manure, leguminous cover crops, and composted materials) can stimulate Cmic differ-

SOILD
2, 1–27, 2015

ently through increases in OM (Marriot and Wander, 2006; Smukler et al., 2008). In contrast, García-Orenes et al. (2010) already detected low basal soil respiration quotients in agricultural soils with null inputs of OM under rainfed conditions in the rangelands and agriculture lands of the mountainous areas of Eastern Spain. The success of manure additions in the citrus orchards in recovering SOM, vegetation cover, and microbiological activity, must also be due to the fact that there was high soil water content as a consequence of the irrigation (Sorensen et al., 2013). The contribution of the irrigation to improving soil microbial biomass has been mainly studied on soil treated with wastewater (Chaerun et al., 2011; Prado et al., 2011; Morugán-Coronado et al., 2011) and all of these studies confirm improvements as water and OM are key factors for healthy soil development (Morugán-Coronado et al., 2013). Soil moisture tends to have a positive influence on soil quality due to its contribution to the improvement of soil microbial activity when there are improvements in the SOM (de Oliveira et al., 2014; Oo et al., 2014).

SOM additions from organic farming help stabilize soil from runoff losses and protect the soil surface from erosion increasing infiltration and water holding capacity (Apezteguía et al., 2009). There is also an increase in biological activity as insects such as ants are more common (Cerdà et al., 2009b). Moreover, the increase in SOM can lead to greater soil aggregation, which increases pore space and further promotes infiltration (Williams and Petticrew, 2009; Larsen et al., 2014). Additionally, SOM is the major aggregate agent and provides structure in temperate soils (Mataix-Solera et al., 2011). The importance of soil aggregation and OM is true in both agricultural and rangeland soils (Brevik and Fenton, 2012). The low SOM observed in the herbicide plot and the corresponding decrease in microbial activity affects the soil's physicochemical properties, as well as the productivity of agricultural ecosystems (De Grood et al., 2005). The aggregation of soil (AS) and SOM observed in plots H and P were lower than AS in O plot, ploughing and the herbicide application facilitates decomposition of SOM due to the disruption of aggregate-embedded organic matter (Tisdall and Oades, 1982). Intensive tillage can be a major cause of erosion due to disruption of the soil

SOILD
2, 1–27, 2015

surface and removal of protective cover that would be effective in reducing runoff and soil loss (Kok et al., 2009). Organic farming systems and sustainable agricultural management systems use organic inputs, leaving residue on the fields that cover at least 30 % of the soil surface, and this conservation practice has been shown to reduce soil erosion (Brevick, 2009) and increase SOM in agricultural soils (Brevik, 2009).

In comparison with conventional tillage, organic farming has potential benefits in encouraging soil structure formation (Pulleman et al., 2003), and enhancing soil microbiology (Mäder et al., 2002; Oehl et al., 2004) such as has been shown in the Alcoleja research site. Organic farming avoids the inputs of inorganic fertilizers and their consequences (Tu et al., 2006), offers organic C inputs to soil, and has been used to successfully reduce soil erosion (Bilalis et al., 2003; Jordan, 2004). It is also effective in preserving soil moisture and buffering severe changes in soil temperature (Brevick, 2009), which can be important in Mediterranean soils to improve biological activity.

5 Conclusions

The main conclusion of the research carried out at the L'Alcoleja experimental station is that on traditional flood-irrigated citrus orchards, the organic farming strategy (manure, no tillage, high vegetation cover) contributed to better soil conditions, including high biological activity, increased enzymatic activities, more organic matter and more stable aggregates. Meanwhile, the chemical (herbicide treated) and ploughing managements resulted in low vegetation cover, low aggregate stability and low microbial biomass.

The implication of this work potentially entails environmental positive applications in soil agricultural management (soil protection, residue crop reuse and stop soil degradation). Hence, the present research represents a further step towards a more sustainable and crop production in Mediterranean agricultural soil.

Acknowledgements. Eric Brevik kindly reviewed and improved the original manuscript. The research projects GL2008-02879/BTE, LEDDRA 243857 and RECARE supported this research.

CC BY

References

Acosta-Martinez, V., Acosta-Mercado, D., Somajor-Ramirez, D., and Cruz-Rodriguez, L.: Microbial community and enzymatic activities under different management in semiarid soils, Appl. Soil Ecol, 38, 249–260, 2008.

Alexakis, D.: Diagnosis of stream sediment quality and assessment of toxic element contamination sources in East Attica, Greece, Environ. Earth Sci., 63, 1369–1383, doi:10.1007/s12665-010-0807-9, 2011.

Allison, V. J., Condron, L. M., Peltzer, D. A., Richardson, S. J., and Turner, B. I.: Changes in enzyme activities and soil microbial community composition along carbon and nutrient gradients at the Franz Josef chronosequence, New Zeland, Soil Biol. Biochem., 39, 1770–1781, 2007.

Apezteguía, H. P., Izaurralde, R. C., and Sereno, R.: Simulation study of soil organic matter dynamics as affected by land use and agricultural practices in semiarid Cordoba, Argentina, Soil Till. Res., 102, 101–108, 2009.

Balota, E. L., Yada, I. F., Amaral, H., Nakatani, A. S., Dick, R. P., and Coyne, M. S.: Long-term land use influences soil microbial biomass p and s, phosphatase and arylsulfatase activities, and mineralization in a brazilian oxisol, Land Degrad. Dev., 25, 397–406, doi:10.1002/ldr.2242, 2013.

Barbera, V., Poma, I., Gristina, L., Novara, A., and Egli, M.: Long-term cropping systems and tillage management effects on soil organic carbon stock and steady state level of C sequestration rates in a semiarid environment, Land Degrad. Dev., 23, 82–91, doi:10.1002/ldr.1055, 2013.

Bilalis, D., Sidiras, N., Economou, G., and Vakali, C.: Effect of different levels of wheat straw soil surface coverage on weed flora in Vicia faba crops, J. Agron. Crop Sci., 189, 223–241, 2003.

Blagodatskaya, E., Yuyukina, T., Blagodatsky, S., and Kuzyakov, Y.: Turnover of soil organic matter and of microbial biomass under C3-C4 vegetation change: Consideration of 13C fractionation and preferential substrate utilization, Soil Biol. Biochem., 43, 159–166, 2011.

Bonanomi, G., D'Ascoli, R., Antignani, V., Capodilupo, M., Cozzolino, L., Marzaioli, R., Puopolo, G., Rutigliano, F. A., Scelza, R., and Scotti, R.: Assessing soil quality under intensive cultivation and tree orchards in Southern Italy, Appl. Soil Ecol., 47, 184–194, 2011.

SOILD
2, 1–27, 2015

Effect of land management on soil properties

A. Morugán-Coronado et al.

Bowles, T. M., Acosta-Martínez, V., Calderón, F., and Jackson, L. E.: Soil enzyme activities, microbial communities, and carbon and nitrogen availability in organic agroecosystems across an intensively-managed agricultural landscape, Soil Biol. Biochem., 68, 252–262, 2014.

Bremmer, J. M. and Mulvaney, C. S.: Nitrogen total, in: Methods of Soil Analysis, Part 2, Chemical and Microbiological Properties, edited by: Page, A. L., Miller, R. H., and Keeney, D. R., ASA, Madison, 595–624, 1982.

Brevik, E. C.: Soil Health and Productivity, in: Soils, Plant Growth and Crop Production, edited by: Verheye, W., Encyclopedia of Life Support Systems (EOLSS), Developed under the Auspices of the UNESCO, EOLSS Publishers, Oxford, UK, available at: http://www.eolss.net/Sample-Chapters/C10/E1-05A-04-00.pdf, 2009.

Brevik, E. C. and Fenton, T. E.: Long-term Effects of Compaction on Soil Properties Along the Mormon Trail, South-Central Iowa, USA, Soil Horizons, 53, 37–42, doi:10.2136/sh12-03-0011, 2012.

Burger, M. and Jackson, L. E.: Microbial immobilization of ammonium and nitrate in relation to ammonification and nitrification rates in organic and conventional cropping systems, Soil Biol. Biochem., 35, 29–36, 2003.

Caravaca, F., Masciandaro, G., and Ceccanti, B.: Land use in relation to soil chemical and biochemical properties in a semiarid Mediterranean environment, Soil Till. Res., 68, 23–30, 2002.

Cerdà, A. and Doerr, S. H.: Soil wettability, runoff and erodibility of major dry-Mediterranean land use types on calcareous soils, Hydrol. Process., 21, 2325–2336, doi:10.1016/j.catena.2008.03.010, 2007.

Cerdà, A., Flanagan, D. C., le Bissonnais, Y., and Boardman, J.: Soil erosion and agriculture Soil Till. Res., 106, 107–108, doi:10.1016/j.still.2009.10.006, 2009a.

Cerdà, A., Hooke, J. Romero-Diaz, A., Montanarella, L., and Lavee, H.: Soil erosion on Mediterranean Type Ecosystems, Land Degrad. Dev., 21, 71–217, doi:10.1002/ldr.968, 2010.

Cerdà, A., Jurgensen, M. F., and Bodí, M. B.: Effects of ants on water and soil losses from organically-managed citrus orchards in eastern Spain, Biologia, 3, 527–531, doi:10.2478/s11756-009-0114-7, 2009b.

Chaerun, S. K., Pangesti, N. P., Toyota, K., and Whitman, W. B.: Changes in microbial functional diversity and activity in paddy soils irrigated with industrial wastewaters in Bandung, West Java Province, Indonesia, Water Air Soil Poll., 217, 491–502, 2011.

SOILD

2, 1–27, 2015

Title Page
Abstract | Introduction
Conclusions | References
Tables | Figures
◀| |▶
◀ ▶
Back | Close
Full Screen / Esc
Printer-friendly Version
Interactive Discussion

cc BY

De Grood, S. H., Classens, V. P., and Scow, K. M.: Microbial community composition on native and drastically disturbed serpentine soils, Soil Biol. Biochem., 37, 1427–1435, 2005.
de Oliveira, S. M., de Lacerda, N. B., Blum, S. Ch., Escobar M. E. O., and de Oliveira, T. S.: Organic carbon and nitrogen stocks in soil of northeastern Brazil converted to irrigation agriculture, Land Degrad. Dev., doi:10.1002/ldr.2264, online first, 2014.
Díez, J. A.: Consideraciones sobre la utilización de la técnica extractiva de Burriel – Hernando para la evaluación de fósforo asimilable en suelos, An. Edafol Agrobiol., 41, 1345–1353, 1982.
Emran, M., Gispert, M., and Pardini, G.: Comparing measurement methods of carbon dioxide in a soil sequence under land use and cover change in North Eastern Spain, Geoderma, 170, 176–185, 2012.
Fernández, C., Vega, J. A., Jiménez, E., Vieira, D. C. S., Merino, A., Ferreiro, A., and Fonturbel, T.: Seeding and mulching + seeding effects on post-fire runoff, soil erosion and species diversity in Galicia (NW Spain), Land Degrad. Dev., 23, 150–156, doi:10.1002/ldr.1064, 2012.
Fierer, N., Strickland, M. S., Liptzin, D., Bradford, M. A., and Cleveland, C. C.: Global patterns in belowground communities, Ecol. Lett., 12, 1238–1249, 2009.
Forster, J. C.: Soil physical analysis, in: Methods in Applied Soil Microbiol. Biochem., edited by: Alef, K. and Nannipieri, P., Academic Press Inc., San Diego, CA, 1995.
García, C., Hernández, M. T., and Costa, F.: Potential use of dehydrogenase activity as an index of microbial activity in degraded soils, Commun. Soil Sci. Plant Nutr., 28, 123–134, 1997.
García-Orenes, F., Cerdá, A., Mataix-Solera, J., Guerrero, C., and Bodí, M. B.: Effects of agricultural management on surface soil properties and soil-water losses in eastern Spain, Soil Till. Res., 106, 117–123, 2009.
García-Orenes, F., Guerrero, C., Roldán, A., Mataix-Solera, J., Cerdá, A., Campoy, M., Zornoza, R., Barcenas, G., and Caravaca, F.: Soil microbial biomass and activity under different agricultural management systems in a semiarid Mediterranean agroecosystem, Soil Till. Res., 109, 110–115, 2010.
García-Orenes, F., Roldán, A., Mataix-Solera, J., Cerdà, A., and Campoy, M.: Soil structural stability and erosion rates influenced by agricultural management practices in a semiarid Mediterranean agroecosystem, Soil Use Manag., 28, 571–579, 2012.
García-Orenes, F., Morugán-Coronado, A., Zornoza, R., and Scow, K.: Changes in Soil Microbial Community Structure Influenced by Agricultural Management Practices in a Mediterranean Agro-Ecosystem, PLoS ONE 8, e80522, 2013.

SOILD
2, 1–27, 2015

CC BY

García-Ruiz, R., Ochoa, V., Hinojosa, B., and Carreira, J. A.: Sustainability of enzyme activities of the monitoring of soil quality improvement in organic agricultural systems, Soil Biol. Biochem., 40, 2137–2135, 2008.
Giménez Morera, A., Ruiz-Sinoga, J. D., and Cerdà, A.: The impact of cotton geotextiles on soil and water losses in Mediterranean rainfed agricultural land, Land Degrad. Dev., 21, 210–217, doi:10.1002/ldr.971, 2010.
Gispert, M., Emran, M., Pardini, G., Doni, S., and Ceccanti, B.: The impact of land management and abandonment on soil enzymatic activity, glomalin and aggregate stability, Geoderma, 202–203, 51–61, 2013.
Imfeld, G. and Vuilleumier, S.: Measuring the effects of pesticides on bacterial communities in soil: a critical review, Eur. J Soil Biol., 49, 22–30, 2012.
Jenkinson, D. S. and Powlson, D. S.: The effects of biocidal treatments on metabolism in soil-I. Fumigation with chloroform, Soil Biol. Biochem., 8, 209–213, 1976.
Jones, N., de Graaff, J., Duarte, F., Rodrigo, I., and Poortinga, A.: Farming systems in two less favoured areas in Portugal: their development from 1989 to 2009 and the implication for sustainable land management, Land Degrad. Dev., 25, 29-44, doi:10.1002/ldr.2257, 2014.
Jordan, C. F.: Organic farming and agroforestry: Alleycropping for mulch production for organic farms of southeastern United States, Agroforestry Systems, 61/62, 79–90, 2004.
Kalender, E., Kampichler, C., and Horak, O.: Influence of heavy metals on the functional diversity of soil microbial communities, Biol Fertil. Soils., 23, 299–306, 1996.
Kallenbach, C. and Grandy, A. S.: Controls over soil microbial biomass responses to carbon amendments in agricultural systems: a meta-analysis, Agric. Ecosyst. Environ., 144, 241–252, 2011.
Knudsen, D., Peterson, G. A., and Pratt, P. F.: Lithium, sodium and potassium, A.S.A. – S.S.S.A, Methods of soil analysis, Madison, WI, 2, 225–246, 1982.
Kok, H., Papendick, R. I., and Saxton, K. E.: STEEP: impact of long-term conservation farming research and education in Pacific northwest wheatlands, J. Soil Water Cons., 64, 253–264, 2009.
Larsen, E., Grossman, J., Edgell, J., Hoyt, G., Osmond, D., and Hu, S.: Soil Biological properties, soil losses and corn yield in long-term organic and conventional farming systems, Soil Till. Res., 139, 37–45, 2014.
Lee, J. W., Park, C. M., and Rhee, H.: Revegetation of decomposed granite roadcuts in Korea: Developing Digger, evaluating cost effectiveness, and determining dimension of drilling

CC BY

holes, revegetation species, and mulching treatment, Land Degrad. Dev., 24, 591–604, doi:10.1002/ldr.2248, 2013.
Lindsay, W. L. and Norvell, W. A.: Development of a DTPA soil test for zinc, iron, manganese, and copper, Soil Sci. Soc. Am. J., 42, 421–428, 1978.
Macci, C., Doni, S., Peruzzi, E., Mennone, C., and Masciandaro, G.: Biostimulation of soil microbial activity through organic fertilizer and almond tree association, Land Degrad. Dev., doi:10.1002/ldr.2234, online first, 2013.
Mäder, P., Fliebach, A., Dubois, D., Gunst, L., Fried, P., and Niggli, U.: Soil fertility and biodiversity in organic farming, Science, 296, 1694–1697, 2002.
Marriott, E. E. and Wander, M.: Qualitative and quantitative differences in particulate organic matter fractions in organic and conventional farming systems, Soil Biol. Biochem., 38, 1527–1536, 2006.
Martir-Torres, M. C. and Bruns, M. A.: Comparative diversity and abundance of ammonia monooxygenase genes in mulched and vegetated soils, Soil Biol. Biochem., 57, 758–768, 2013.
Mataix-Solera, J., García-Irles, L., Morugán, A., Doerr, S. H., García-Orenes, F., Arcenegui, V., and Atanassova, I.: Soil water repellency patterns of a former wastewater disposal field with calcareous soil and effects of remediation approaches, Geoderma, 165, 78–83, doi:10.1016/j.geoderma.2011.07.006, 2011.
Maul, J. E., Buyer, J. S., Lehman, R. M., Culman, S., Blackwood, C. B., Roberts, D. P., Roberts, D. P., Zasada, I. A., and Teasdale, J. R.: Microbial community structure and abundance in the rhizosphere and bulk soil of a tomato cropping system that includes cover crops, Appl. Soil Ecol., 77, 42–50, 2014.
Morugán-Coronado, A., Arcenegui, V., García-Orenes, F., Mataix-Solera, J., and Mataix-Beneyto, J.: Application of soil quality indices to assess the status of agricultural soils irrigated with treated wastewaters, Solid Earth, 4, 119–127, doi:10.5194/se-4-119-2013, 2013.
Morugán-Coronado, A., García-Orenes, F., Mataix-Solera, J., Arcenegui, V., and Mataix-Beneyto, J.: Short-term effects of treated wastewater irrigation on Mediterranean calcareous soil, Soil Till. Res., 112, 18–26, 2011.
Oehl, F., Frossard, E., Fliessbach, A., Dubois, D., and Oberson, A.: Basal organic phosphorus mineralization in soils under different farming systems, Soil Biol. Biochem., 36, 667–675, 2004.

CC BY

Oo, A. N., Iwai, C. B., and Saenjan, P.: Soil properties and maize growth in saline and non saline soils using cassava-industrial waste compost with or without earthworms, Land Degrad. Dev., doi:10.1002/ldr.2208, online first, 2014.

Paz-Ferreiro, J. and Fu, S.: Biological indices for soil quality evaluation: perspectives and limitations, Land Degrad. Dev., doi:10.1002/ldr.2262, online first, 2013.

Piotrowska, A. and Wilczewski, E.: Effects of catch crops cultivated for Green manure and mineral nitrogen fertilization on soil enzyme activities and chemical properties, Geoderma, 189–190, 72–80, 2012.

Porta, J., López-Acevedo, M., and Rodriguez, R.: Técnicas y experimentos en edafología, Col-legi oficial d'enginyers agrònoms de Catalunya, Barcelona, Spain, 1986.

Prado, A. G., Evangelista, S. M., SouzaDe, J. R., Matos, J. G., Souza, M. A., Oliveira, D. A., and Airoldi, C.: Effect of the irrigation with residual wastewaters on microbial soil activity of the ornamental flowers (Dahlia pinnata) cultures monitored by isothermal calorimetry, J. Therm. Anal. Calorim., 106, 431–436, 2011.

Pulleman, M., Jongmans, A., Marinissen, J., and Bouma, J.: Effects of organic versus conventional arable farming on soil structure and organic matter dynamics in a marine loam in the Netherlands, Soil Use Manag., 19, 157–165, 2003.

Raizada, A. and Juyal, G. P.: Tree species diversity, species regeneration and biological productivity of seeded Acacia catechu Willd. In rehabilitated limestone mines in the North West Indian Himalayas, Land Degrad. Dev., 23, 167–174, doi:10.1002/ldr.1067, 2012.

Roig, A., Romero, M., Lax, A., and Fernández, F. G.: Estudio comparativo de métodos de determinación de capacidad de cambio catiónica en suelos calizos, An. Edafol. Agrobiol., 39, 2021–2032, 1980.

Roldán, A., García-Orenes, F., and Lax, A.: An incubation experiment to determinate factors involving aggregation changes in an arid soil receiving urban refuse, Soil Biol. Biochem., 26, 1699–1707, 1994.

Smukler, S. M., Jackson, L. E., Murphree, L., Yokota, R., Koike, S. T., and Smith, R. F.: Transition to large-scale organic vegetable production in the Salinas Valley, California, Agric. Ecosyst. Environ., 126, 168–188, 2008.

Sofo, A., Scopa, A., Dumontet, S., Mazzatura, A., and Pasquale, V.: Toxic effects of four sulphonylureas herbicides on soil microbial biomass, J. Environ. Sci. Health, 47, 653–659, 2012.

Soil Survey Staff, Keys to soil taxonomy, 11th Edn., USDANRCS, Washington DC, USA, 106–111, 2010.

SOILD

2, 1–27, 2015

CC BY

Sorensen, P. O., Germino, M. J., and Feris, K. P.: Microbial community responses to 17 years of altered precipitation are seasonally dependent and coupled to co-varying effects of water content on vegetation and soil C, Soil Biol. Biochem., 64, 155–163, 2013.

Tabatatai, M. A.: Enzymes, in: Methods of Soil Analysis, Part 2, edited by: Weaver, R. W., Angle, J. S., and Bottomley, P. S., Soil Sci. Soc. Am. J., Madison, 755–833, 1994.

Tisdall, J. M. and Oades, J. M.: Organic matter and water-stable aggregates in soils, Soil Sci. Soc. Am. J., 33, 141–163, 1982.

Tu, C., Ristaino, J. B., and Hu, S.: Soil microbial biomass and activity in organic tomato farming systems: Effects of organic inputs and straw mulching, Soil Biol. Biochem., 38, 247–255, 2006.

Vance, E. D., Brookes, P. C., and Jenkinson, D. S.: An extraction method for measuring soil microbial biomass C, Soil Biol. Biochem., 19, 703–707, 1987.

Vasconcellos, R. L. F., Bonfim, J. A., Baretta, D., and Cardoso, E. J. B. N.: Arbuscular mycorrhizal fungi and glomalin-related soil protein as potential indicators of soil quality in a recuperation gradient of the atlantic forest in brazil, Land Degrad. Dev., doi:10.1002/ldr.2228, online first, 2013.

Walkley, A. and Black, I. A.: An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method, Soil Sci., 37, 29–38, 1934.

Williams, N. D. and Petticrew, E. L.: Aggregate stability in organically and conventionally farmed soils, Soil Use Manag., 25, 284–292, 2009.

Zak, D. R., Holmes, W. E., White, D. C., Peacock, A. D., and Tilman, D.: Plant diversity, soil microbial communities, and ecosystem function: are there any links?, Ecology, 84, 2042–2050, 2003.

Zhao, G., Mu, X., Wen, Z., Wang, F., and Gao, P.: Soil erosion, conservation, and Eco-environment changes in the Loess Plateau of China, Land Degrad. Dev., 24, 499–510, doi:10.1002/ldr.2246, 2013.

Zornoza, R., Mataix-Solera, J., Guerrero, C., Arcenegui, V., and Mayoral, A. M.: Soil properties under natural forest in the Alicante Province of Spain, Geoderma, 142, 334–341, 2007.

CC BY

Table 1. Main soil characteristics and vegetation cover of different treatments (Herbicides with inorganic fertilizers (H), intensive ploughing and inorganic fertilizers (P) and organic farming (O)). Values are mean ± standard deviation.

	O*	H	P
Vegetation cover (%)	42.2 ± 8.9^{a}	1.3 ± 0.6^{b}	1.1 ± 0.6^{b}
Texture (% clay, silt, sand)**	$19^{a,b}$, 40^{a}, 39^{a}	17^{a}, 34^{b}, 48^{b}	23^{b}, 43^{a}, 34^{c}
pH (extract 1 : 5, w / v)	7.9 ± 0.15^{a}	8.2 ± 0.15^{b}	8.3 ± 0.07^{b}
EC (1 : 5, $\mu S\,cm^{-1}$)	244 ± 28^{a}	201 ± 44.4^{b}	175 ± 14.2^{b}
Carb (%)	48 ± 5.8^{a}	33 ± 4.4^{b}	46 ± 4.3^{a}
WHC (%)	$50 \pm 9.5^{a,b}$	44 ± 2.7^{a}	52 ± 2.3^{b}
$CaCO_3$ (%o)	147 ± 16.4^{a}	104 ± 18.7^{b}	157.8 ± 13.8^{a}
CEC ($cmol\,kg^{-1}$)	11.8 ± 2.8^{a}	6.7 ± 0.8^{b}	8.10 ± 2.0^{b}
Macronutrients ($g\,kg^{-1}$) Na, Ca, Mg	0.99^{a}, 3.27^{a}, 0.52^{a}	1.11^{a}, 2.70^{b}, 0.41^{b}	1.10^{a}, 2.90^{c}, 0.55^{a}
Micronutrients ($g\,kg^{-1}$) Fe, Mn, Zn, Cu	0.04^{a}, 0.01^{a}, bdl, bdl	0.04^{a}, 0.01^{b}, bdl, bdl	0.02^{b}, $0.01^{a,b}$, bdl, bdl

$n = 27$ * 0–5 cm depth. ** Sand: 2–0.02 mm, Silt: 0.02–0.002 mm, Clay: < 0.002 mm. bdl: below detection limit. Zn: 0.01 $g\,kg^{-1}$; Cu: 0.01 $g\,kg^{-1}$ EC: Electrical conductivity; WHC: Water holding capacity; Carb: calcium carbonate equivalent; $CaCO_3$: Calcium Carbonate Content of Limestone; CEC: Cation exchange capacity. (%o) parts per mil' symbol A one-way ANOVA ($P < 0.05$) were used to compare differences between managements. Letters above the bars indicate significant differences.

CC BY

Table 2. Correlation coefficients (R values) for relationships between physical, chemical and biochemical properties for all the managements.

	pH	EC	BSR	Cmic	AS	Nk	SOM	AP	K	CEC	β-Glucosidase	Urease	Phosphatase	Dehydrogenase	Vegetation cover
pH															
EC	−0.891***														
BSR	−0.418*	0.311^{ns}													
Cmic	−0.392*	0.414*	0.238^{ns}												
AS	−0.839***	0.619**	0.569*	0.363^{ns}											
Nk	−0.833***	0.587**	0.607**	0.403*	0.949***										
SOM	−0.878***	0.665***	0.642***	0.432*	0.950***	0.967***									
AP	−0.865***	0.686***	0.466*	0.595**	0.827***	0.875***	0.900***								
K	−0.838***	0.655***	0.298^{ns}	0.148^{ns}	0.779***	0.767***	0.773***	0.793***							
CEC	−0.725***	0.527**	0.631***	0.407**	0.845***	0.858***	0.887***	0.838***	0.686***						
β−Glucosidase	−0.259^{ns}	0.274^{ns}	0.246^{ns}	−0.247^{ns}	0.312^{ns}	0.260^{ns}	0.244^{ns}	0.084^{ns}	0.278^{ns}	0.351^{ns}					
Urease	−0.298^{ns}	0.169^{ns}	0.258^{ns}	0.046^{ns}	0.281^{ns}	0.307^{ns}	0.252^{ns}	0.191^{ns}	0.407*	0.261^{ns}	0.246^{ns}				
Phosphatase	−0.602**	0.332^{ns}	0.271^{ns}	0.242^{ns}	0.680***	0.775***	0.699***	0.712***	0.562**	0.629***	−0.009^{ns}	0.151^{ns}			
Dehydrogenase	−0.468*	0.359^{ns}	0.013^{ns}	0.133^{ns}	0.483*	0.436*	0.373^{ns}	0.310^{ns}	0.364^{ns}	0.184^{ns}	0.408*	0.307^{ns}	0.288^{ns}		
Vegetation cover	−0.851***	0.668***	0.682***	0.443*	0.930***	0.940***	0.971***	0.846***	0.750***	0.840***	0.259^{ns}	0.320^{ns}	0.600**	0.388*	

SOM: soil organic matter; Nk: total Nitrogen; AS: aggregate stability; Cmic: microbial biomass carbon; BSR: basal soil respiration; AP: available phosphorus; K: available Potassium; EC: Electrical conductivity; CEC: Cation exchange capacity. Significant correlation at: $p < 0.05$*; $p < 0.01$** and $p < 0.0001$***; ns: not significant correlation at $p > 0.05$.

SOILD
2, 1–27, 2015

cc BY

Table 3. Matrix of PCA obtained with all soil samples ($n = 27$). Numbers in bold indicate soil properties with highest in absolute value, indicating higher weight and dependence within that PC.

Variance explained	PC1 (40 %)	PC2 (20 %)	PC3 (9 %)
pH	−0.844	−0.435	−0.117
EC	0.660	0.505	−0.074
WHC	0.226	−0.476	0.108
BSR	**0.684**	−0.282	−0.182
Cmic	0.463	0.217	−0.456
AS	**0.949**	0.098	0.120
Nk	**0.969**	0.065	0.107
SOM	**0.963**	0.151	0.017
C/N	−0.183	**0.664**	−0.107
AP	**0.862**	0.374	−0.091
Na	−0.507	−0.058	0.277
K	**0.728**	0.392	0.307
Ca	**0.879**	−0.205	−0.097
Mg	0.404	−0.716	−0.216
Fe	0.164	**0.756**	−0.374
Cu	−0.687	0.198	0.119
Zn	0.400	0.482	0.190
Mn	0.531	−0.099	−0.228
CEC	**0.893**	−0.001	−0.068
Carb	0.625	−0.563	0.107
CCCL	0.477	−0.737	0.021
b−Glucosidase	0.328	−0.185	0.374
Urease	0.315	−0.087	**0.629**
Acid Phosphatase	**0.702**	0.088	0.101
Clay	−0.028	−0.674	0.596
Silt	0.403	−0.606	−0.554
Sand	−0.330	**0.870**	0.162
Dehydrogenase	0.387	0.255	0.570
Vegetation	**0.937**	0.180	0.032

SOILD
2, 1–27, 2015

Effect of land management on soil properties

A. Morugán-Coronado et al.

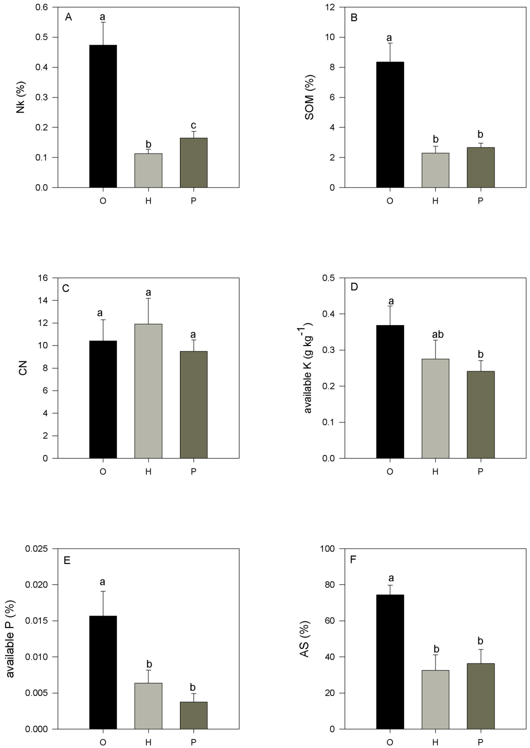

Figure 1. Mean values (± standard deviation) of nitrogen, soil organic matter (SOM), C/N relation, available potassium, available phosphorus, aggregate stability (AS) in soil. Different letters indicate significant differences ($P < 0.05$) between soil management – from black (organic farming-O), light gray (herbicide-H) to dark gray (ploughing-P) – for each treatment according to one-way ANOVA.

SOILD
2, 1–27, 2015

CC BY

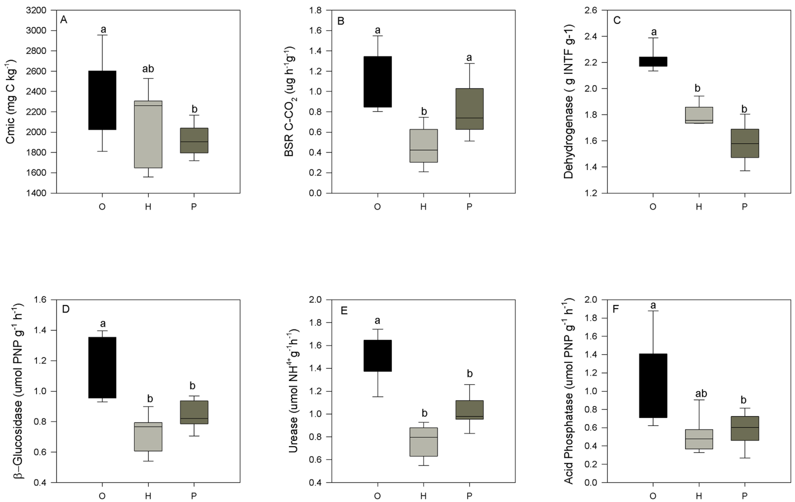

Figure 2. Mean values (±standard deviation) of Cmic, BSR, Dehydrogenase, β-Glucosidase, Urease and Acid phosphatase in soil. Different letters indicate significant differences ($P < 0.05$) between soil management – from black (organic farming-O), light gray (herbicide-H) to dark gray (ploughing-P) – for each treatment according to one-way ANOVA.

SOILD
2, 1–27, 2015

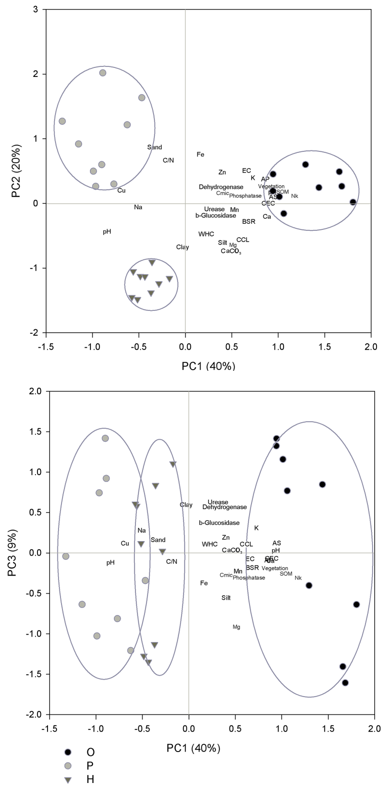

Figure 3. PCA factor scores from each agricultural management and loadings from soil properties in all management practices: Organic farming (O) (•), Ploughing (P) (•) and Herbicide (H), EC: Electrical conductivity; SOM: soil organic matter; N: total nitrogen; AP: Available phosphorus; CEC: Cation exchange capacity; WHC: water holding capacity; AS: aggregate stability; Cmic: microbial biomass Carbon; CCE: calcium carbonate equivalent; $CaCO_3$: Calcium carbonate content of limestone; BSR: basal soil respiration).

CC BY