Use of ecological agriculture as soil management system to improve soil properties and to mitigate greenhouse effect

Antonio Sánchez Navarro[A], Arantzazu Blanco Bernardeau[A], Purificación Marín Sanleandro[A], María José Delgado Iniesta[A], Juana Maria Gil Vázquez[A] and **Roque Ortiz Silla[A]**

Department of Agricultural Chemistry, Geology and Pedology, Faculty of Chemistry, University of Murcia, Murcia, Spain, Email, rortiz@um.es

Abstract
Over recent decades the quality of agricultural soils has suffered deterioration due to inappropriate agricultural management. This management has caused, among other negative effects, the increase in salinity, erosion and contamination, and the liberation to the atmosphere of great amounts of organic carbon due to a higher mineralization. As a result, there has been growing interest in so-called sustainable agriculture, which takes into account not only productivity, but also the quality of the soil and environmental protection. For this study two fertilisation trials were carried out. The first one was carried out according to the stipulations of European regulations on practices of organic agriculture, while the second one was conducted in accordance with conventional agricultural practices in the area. Over a three-year period, samples of the arable soil layer were taken in order to analyse the soil properties. The plot under organic agriculture techniques management showed better physical conditions for crop development, greater quantities of organic matter and nitrogen, greater cation exchange capacity and greater phosphorous availability than the conventionally managed plot. These results suggest that, although the trial period was only three years, the agronomic model based on organic agriculture has a permanent beneficial effect on soil properties and contributes soil function as C sink.

Key Words
Organic agriculture, fertilisation practices, soil quality, C sink.

Introduction
Soils represent the largest terrestrial stock of C, holding approximately 1,500 Pg (10^{15} g) C in the top metre and 2456 Pg at a depth of 2 m (FAO 2002) This carbon storage in soils makes of them one of the most important CO_2 deposits in our planet. Thus, agricultural practices which minimize organic matter mineralization or even increase OC contents will not only be relevant regarding the influence on soil properties, but also by the positive role in mitigating greenhouse effect .

Since the 1990's numerous studies have shown that agricultural activity whose only aim is to obtain higher profits has led to the progressive degradation of the natural environment and the subsequent loss of productive capacity. Soil degradation due to salinity is especially outstanding, as it affects 30 % of all agricultural use soils.

Mediterranean soils usually have low levels of organic matter. This reduction in organic matter leads to a deterioration of the soil physicochemical properties, and consequently to the loss of long-term productivity. Agronomic practices, such as type of crop, crop rotation and management of residues have a considerable bearing on the content of organic matter in the soil and especially on the fractions which are most sensitive to practice-induced changes. The growing interest in rational soil use implies the preservation of organic matter and its associated microflora. In this sense, plots under ecological farming methods management as opposed to conventional ones have shown to obtain higher levels of organic carbon (OC), total nitrogen (TN) and cation exchange capacity (CEC).

The present work has studied the evolution of several soil chemical parameters depending on the method of crop management employed over a period of three years. It aims to show the differences observed in soil management and to determine the measured parameters usefulness as indicators of soil quality as well as the soil carbon capacity given the pressing need to establish strategies of soil preservation and sustainable use. The properties/parameters selected for evaluation are those which may change according to the use and management over relatively short periods of time, and as such are suitable indicators of soil quality.

Methods

Location and experimental design

The experiment was carried out on a trial plot in southeast Spain (Figure 1), dedicated to green crops where a high-frequency local irrigation system was used In each subplot three blocks of replication were stablished, following a "complete random blocks" design.

Figure 1. Experimental location.

Three fertilization trials and three irrigation trials were carried out simultaneously. Regarding the fertilization trials, the first one (F1) consisted of an organic amendment (sheep manure) with a 1,7kg $m^{-2}\cdot$ $year^{-1}$ ratio; the second fertilization essay, used as control was made according to a conventional cropping system in the area, while the third fertilisation trial (F3) was a commercial organic amendment, suitable for ecological agriculture and made up with sheep manure and vegetable waste compost, which was applied, with a 0,7 kg/m^2year^1 ratio. Attending to the irrigation trials, three different doses were used: a deficitary dose (A), an optimal dose (B) and an excedentary dose(C). The treatment matrix is shown in Figure 2.

	F1	F2	F3	Replications	Total blocks
A	AF1	AF2	AF3	3	9
B	**BF1**	**BF2**	BF3	3	9
C	CF1	CF2	CF3	3	9
Replications	3	3	3	9	
Total blocks	9	9	9		**27**

Figure 2. Experimental design.

Arable layer samples (0-25 cm) were taken monthly during celery (APIO? – no será CEREAL) crop, being each sample a compound obtained in four different points of each plot. The samples were air dried and sifted to 2 mm for subsequent analysis in the laboratory. This paper describes only the evolution of soil properties in two treatments (BF1 and BF2), since these were the most different crop management system. Consequently, any existing difference in properties and evolution of soil between both fertilization essays would appear with more intensity.

General soil properties

The experiment was carried out on a soil with the profile *Ap1-Ap2-Bw-Ckm*, which meets the requirements to be classified as Palexeroll Petrocalcic (SSS 2006), Kastanozem Petrocalcic (FAO-ISRIC-IUSS, 2006). Soil had a loamy texture and OC content of A horizon was moderate. pH was basic (8,2), and no salinity problems were observed (EC in saturation extract lower tan 2 dS m^{-1}) it also had high concentrations of calcium carbonate (> 400 g/kg).

Chemical analyses

Organic Carbon (OC) was determined following the method of Anne modified by Duchafour (1970). Organic matter (OM) was calculated indirectly from the OC content, multiplying it by 1.72, the value expressed as OC in $g\cdot kg^{-1}$. Total nitrogen (TN) was determined by using the Kjeldahl's method as described by Duchafour (1970). Assimilable phosphorous (P) was determined by using the method of Watanabe and Olsen (1965) extracting P with 0.5M solution of $NaCO_3H$ and photocolorimetric determination of the amonic phosphomolybdate in a Philips PU 8625 UV/VIS spectrophotometer. Cation exchange capacity (CEC) and the Na, K and Mg exchangeable bases were determined by using Chapman's method (1965). Na, K and Mg were quantified by atomic absorption spectrometry, while the CEC was obtained by determining the ammoniac N with H_2SO_4 0.02 N using Bromocresol Green-Methyl Red as indicator.

1 – 6 August 2010, Brisbane, Australia. Published on DVD.

Statistical methods.
The data were statistically treated using the R software. When conditions of normality and homoscedasticity could be assumed, an ANOVA test was carried out to compare means; otherwise a non-parametric test of comparison of ranges was applied (Wilcoxon Test)

Results
As shown in Table 1 and Figure 3 and 4, content in Organic Carbon (OC), Total Nitrogen (TN), C/N ratio and Olsen Phosphorous (P) were significantly higher in treatment F1 than in the control plot F2. The increase of OC and P in F1 are related to the addition of organic matter, which stimulates microbian decomposition, and the positive action that humic compounds have on the availability of P, due to the contribution of organic phosphorous which when degraded by micro organisms in the soil, releases phosphate compounds (Tarafdar and Claasen 2005). Capriel (1991) and Mäder *et al*. (2002) reached the conclusion that CO content decreased less over time in plots under organic treatment than in conventional ones. Regarding the influence that ecological agriculture could have on soil as carbon sink, and in light of the results, use of manure amendments can be suggested to offset carbon emissions, especially in arable land, according to Article 3.3 and 3.4 of the Kyoto Protocol (Ogle *et al.* 2003; Smith and Powlson 2000). In this sense, these management practices imply an increase of 32% SOC in comparison with conventional agriculture (88,7 10^6 g CO_2/ha).

Table 1. Evolution of soil constituents and properties over 2005-2007.

Variables		2005	2006	2007	Mean	SD	N	P value
OC	F1	20,7	22,3	26,7	23,2	4,4	33	0,000***
	F2	17,8	17,8	16,8	17,5	1,6	33	
TN	F1	3,0	2,6	3,2	2,9	0,4	33	0.0116*
	F2	2,9	2,1	2,3	2,4	0,5	33	
C/N	F1	6,9	8,6	8,3	8,0	0,7	33	0.032*
	F2	6,1	8,5	7,3	7,3	0,8	33	
P	F1	44,3	50,8	41,0	45,4	4,1	33	0.00***
	F2	27,1	31.2	23,1	27,1	3,3	33	
CEC	F1	14,1	14,6	14,5	13,3	1,51	33	0,022*
	F2	11,8	13,3	12,2	12,5	1,6	33	
Na	F1	0,54	0,48	0,26	0,43	0,16	33	0,967
	F2	0,45	0,36	0,24	0,35	0,13	33	
K	F1	0,77	0,93	1,09	0,93	0,16	33	$1,11 \cdot 10^{-5}$***
	F2	0,56	0,45	0,29	0,44	0,14	33	
Mg	F1	0,96	0,88	0,82	0,89	0,07	33	$1,9 \cdot 10^{-7}$***
	F2	0,86	0,85	0,64	0,78	0,12	33	

CO, TN, Na, K, Mg (g/kg); P (mg/kg); CEC ($cmol_{(+)}$/kg)

The difference in N contents can be related to the decrease in F2, possibly due to leaching. It can be said, therefore, that the addition of sheep manure as organic amendment diminishes the loss of N (Hossain *et al.* 2003), but if N is applied in mineral form it is more likely to be lost to a greater of lesser extent depending on the soil characteristics.

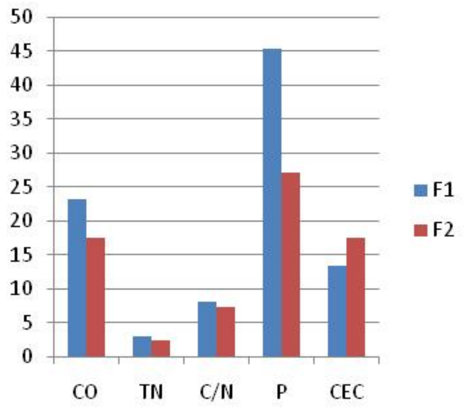

Figure 3. Average values of soil properties and constituents.

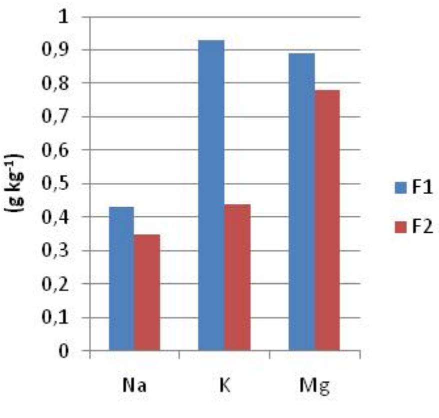

Figure 4. Exchangeable bases.

The low C/N ratio (less than 10 in all samples), lower than expected for calcareous mull humus, indicates that mineralisation of the organic matter prevails over humification, which gradually exhausts the soil N content unless it is periodically restored by applying additional sources. Cation exchange capacity (CEC) showed significant differences between treatments ($p<0.05$). These results confirm those obtained in other studies (Bending *et al*. 2004; Liu *et al*. 2006) which describe an improvement in the soil's CEC due to the addition of organic matter when compared to soils treated with conventional fertigation treatments. Contents of exchangeable sodium, magnesium and potassium are greater in the organically managed plot F1 than in the conventionally managed one F2, although differences found in Na contents between both treatments had no signification. These results confirm those obtained by Bulluck *et al*. (2002), and Morari *et al*. (2008) related with the improvements in the levels of nutrients linked to the addition of organic matter.

Conclusions

Considering the results, ecological agriculture is a soil and crop management system which increases the soil content in organic matter as well as certain nutrients such as nitrogen, phosphorous, magnesium and potassium compared to the plot treated with inorganic fertilisers. Changes were also observed in the soil properties, with an increase in the cation exchange capacity and the C/N ratio in the plot under manure treatment. Likewise, the results suggest that ecological agriculture practices increase soil carbon sequestration capacity.

References

Bending GD, Turner MK, Rayns F, Marx MC, Wood M (2004) Microbial and biochemical soil quality indicators and their potential for differentiating areas under contrasting agricultural management regimes. *Soil Biol. Biochem*. **36,** 1785–1792.

Bulluck LR, Brosius M, Evanylo GK, Ristaino JB (2002) Organic and synthetic fertility amendments influence soil microbial, physical and chemical properties on organic and conventional farms.*Applied Soil Ecology* **19**(2), 147-160.

Capriel P (1991) Vergleichende Bodenuntersuchungen von konventionell und alternativ bewirtschafteten Betriebsschlägen - 2. Mitteilungen. IV. Humuschemische Untersuchungen. *Landwirtschaftl. Jahrbuch* **68** (4), 427-430.

Chapman HD (1965) Cation exchange capacity. In "Methods of Soil Analysis" Part 2. (Ed CA Black). pp. 891-900 (Amer. Soc. Agronomy, Inc., Madison, Wis) .

Duchaufour P (1970) Pédologie. (Ed. Masson París)

FAO (2002) Captura de carbon en los suelos para un mejor manejo de la Tierra. In "Informe sobre recursos mundiales de suelos" nº 96. Roma.

FAO-ISRIC-IUSS Working Group WRB (2006) World reference base for soil resources 2006. In 'World Soil Resources Reports' No. 103 (FAO, Rome).

Hossain MF, Elahi SF, Khondaker M (2003) A comparison between ecological and conventional rice farming systems in Bangladesh. Diffuse Pollution Conference. Dublin

Liu B, Tu C, Hu S, Gumpertz M, Ristaino JB (2006) Effect of organic, sustainable, and conventional management strategies in grower fields on soil physical, chemical, and biological factors and the incidence of Southern blight. *Applied Soil Ecology* **37,** 202–214.

Mäder P, Fließbach A, Dubois D, Gunst L, Fried P, Niggli U (2002) Soil fertility and biodiversity in organic farming. *Science* **296,** 1694-1697.

Morari F; Lugato E; Giardini L (2008) Olsen phosphorus, exchangeable cations and salinity in two long-term experiments of north-eastern Italy and assessment of soil quality evolution. Agriculture, *Ecosystems and Environment* **124,** 85–96.

Ogle SM, Breidt FJ, Eve MD, Paustian K (2003) Uncertainty in estimating land use and management impacts on soil organic carbon storage for US agricultural lands between 1982 and 1997. In 'Global Change Biology' Vol. 9, pp. 1521–1542. doi:10.1046/j.1365-2486.2003.00683.x.

Smith P, Powlson DS (2000) Considering manure and carbon sequestration. *Science* **287**, 428–429

Soil Survey Staff (2006) Keys to Soil Taxonomy. 10th ed. USDA-Natural Resources Conservation Service, Washington, DC.

Tarafdar JC, Claasen N (2005) Preferential utilization of organic and inorganic sources of phosphorus by wheat plant. *Plant and Soil* **27,** 285–293

Watanabe FS, Olsen SR (1965) Test of ascorbic acid method for determinig phosphorus in water and $NaHCO_3$ extracts from soil. *Soil Sci. Soc. Am. Proc.* 677-678.