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Influence of intensive horticultural cultivation on soil salinity in Campo de Cartagena (Murcia)

Influencia del cultivo hortícola intensivo en la salinidad del suelo en el Campo de Cartagena (Murcia)
Influência da horticultura intensiva na salinidade do solo no Campo de Cartagena (Múrcia)

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ABSTRACT

The electrical conductivity (EC) and ionic composition of the soil solution of a Haplic Calcisol in Campo de Cartagena (Murcia, Spain) were studied *in situ* for four years in an experimental open-air vegetable plot, together with the relationship between these parameters, the quality of the irrigation water and the management of the plot. The results show that there were very significant fluctuations in these variables during the study period and that these fluctuations depended on the management of the plot and in particular on the irrigation water used. Therefore, for an adequate management of these agro-ecosystems, it is necessary to establish a network of experimental plots *in situ*, where sensitive indicators of soil degradation are monitored, in our case the EC and the ionic composition of the soil solution. Such indicators are capable of detecting these degradation processes and their relationship with the inappropriate management of this resource.

RESUMEN

Se han estudiado in situ *durante cuatro años, en una parcela experimental de hortalizas al aire libre, la conductividad eléctrica y la composición iónica de un Haplic Calcisol del Campo de Cartagena, así como la relación de éstas con la calidad del agua de riego empleada y con la gestión que se ha hecho del mismo. Los resultados demuestran que existen fluctuaciones muy importantes de estas variables durante el periodo de estudio y que dichas fluctuaciones dependen de la gestión de la parcela y, en particular, del agua de riego utilizada. Debido a ello, para una adecuada gestión de estos agroecosistemas, se precisa del establecimiento de una red de parcelas experimentales* in situ, *donde se lleve a cabo el seguimiento de indicadores sensibles de degradación edáfica, en nuestro caso la conductividad eléctrica (CE) y la composición iónica de la disolución del suelo, que sean capaces de detectar dichos procesos de degradación y su relación con la gestión inapropiada de este recurso.*

RESUMO

A condutividade elétrica e a composição iónica de um Haplic Calcisol no Campo de Cartagena (Múrcia, Espanha) foram estudadas in situ *durante quatro anos numa parcela experimental de hortícolas ao ar livre, bem como a relação entre estes parâmetros e a qualidade da água de rega utilizada e a gestão da parcela. Os resultados mostram que existem flutuações muito significativas destas variáveis durante o período de estudo e que estas flutuações dependem da gestão da parcela e, em particular, da água de rega utilizada. Assim, para uma gestão adequada destes agro-ecossistemas, é necessário estabelecer uma rede de parcelas experimentais* in situ, *onde são monitorizados indicadores sensíveis da degradação do solo, no nosso caso a condutividade elétrica (CE) e a composição iónica da solução do solo, que sejam capazes de detetar estes processos de degradação e a sua relação com a gestão inadequada deste recurso.*

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1. Introduction

After 40 years of exploitation of the Tajo-Segura aqueduct in Spain, there is evidence of the great structural changes that have occurred in the area of Campo de Cartagena (Murcia) as a result. However, there are few detailed studies that can verify the alterations suffered by the agroecosystem due to intensive agricultural management, and there are even fewer studies in the field where the evolution of edaphic properties and their relationship with the use, management, and type of soil are revealed. In this sense, after the papers published on this matter in the 1970s (Alías and Ortiz 1975, 1977a, 1977b, 1978), before the aqueduct came into operation, and those derived from the LUCDEME Project (Alías et al. 1992), no more recent ones have been found where the aforementioned problem is addressed.

The current scenario includes the serious environmental problems that have been occurring in Campo de Cartagena in recent years and, nearby, the situation of the Mar Menor, which stands out for its seriousness and media impact (Álvarez et al. 2005). Projects that evaluate the influence of intensive cultivation on each soil type need to be launched as a preliminary step in the design of integrated and sustainable management plans that take into account the characteristics of each soil and which are adapted to the soil diversity of the zone. The work carried out by Hernandez et al. (2005) and Hernández et al. (2010) demonstrates the alterations in the chemical properties of the soils in Campo de Cartagena caused by their inappropriate management during the cultivation of horticultural crops.

The starting hypothesis of this work considers that agriculture in general, and particularly intensive agriculture, causes changes in soil properties that can lead to accelerated degradation of this resource, and that these changes will be more or less relevant according to the type of soil (soil diversity) and the use and management of it.

Hence, the objective of this project is to study the evolution of the salinity and ionic composition of the soil solution of a Haplic Calcisol (IUSS Working Group WRB 2015) dedicated to the intensive cultivation of vegetables in the open air. The idea is to use these parameters as indicators of the rapid responses of the soil to its intensive management and thus to be able to evaluate the possible degradation that it can suffer as a result of this management.

KEY WORDS
Electrical conductivity, chemical indicators, chemical degradation, land uses.

PALABRAS CLAVE
Conductividad eléctrica, indicadores químicos, degradación química, usos del suelo.

PALAVRAS-CHAVE
Condutividade elétrica, indicadores químicos, degradação química, usos do solo.

2. Materials and Methods

The study was carried out in a plot dedicated to the cultivation of outdoor horticultural crops, in the municipality of Fuente Álamo (Murcia), with UTM coordinates X: 663,869.21; Y: 4,177,357.17. The selected plot is approximately 0.5 hectares in size and the soil is a Haplic Calcisol (IUSS Working Group WRB 2015), in which different horticultural species such as lettuce (*Lactuca sativa L.*), melon (*Cucumis melo L.*), spinach (*Spinacia oleracea L.*), and coriander (*Coriandrum sativum L.*) have been cultivated, alternating these crops with periods of fallow and/or the cultivation of cereals (*Avena sativa L.*) and legumes (*Vicia sativa L.*), which have been incorporated into the soil as a green fertilizer. The irrigation and fertilizer doses have been calculated specifically for each crop based on the effective nutrient extractions. The doses range between 2000 and 3000 m^3 ha^{-1} crop year, in the case of irrigation water, and, for NPK, between 125-100-90 for spinach or coriander and 170-125-200 for lettuce (kg ha^{-1} crop cycle).

Before the transplanting and after the harvest of the different vegetables, six samples of the arable layer (surface horizons, 0-25 cm) and six samples between 40-60 cm deep (subsurface horizons) were taken, distributed homogeneously throughout the plot, during the period 2016-2019. The soil samples were air dried and sieved at 2 mm. From them, the electrical conductivity (EC) in the saturated paste was determined, as well as the ionic composition of the saturation extract, using the methods described in the Soil Survey Laboratory Methods Manual (USDA 1996).

3. Results and Discussion

At the spatial level, there were no statistically significant changes in the EC values between the surface and subsurface horizons; although a flow of salts between these horizons related to management and seasonality is observed, statistically it is not significant.

The EC values of the soil, overall (in the arable layer and at 60 cm depth), underwent very notable changes during the study period (**Figure 1A**), ranging from a minimum close to 2 dS m^{-1}, in February 2017, to a maximum of 10 dS m^{-1}, in May 2018. This represents a change in the degree of salinity of the soil (Chhabra 1996) from non-saline to strongly saline. This difference in values over a relatively short period of time confirms the large temporal oscillation of this parameter and its dependence on soil management, in particular on the quality of the water used for irrigation, an aspect that is also evident in **Figure 1A**. This figure shows a parallel between the EC of the irrigation water and the average EC values of the horizons. This hypothesis is further reinforced if we analyze the evolution in the soil of some major ions: Cl^-, SO_4^{2-}, and Na^+ (**Figures 1B, 1C, and 1D**) and, to a lesser extent, Mg^{2+} (**Figure 1E**). This evolution is similar to that of the study by Hernández et al. (2010) and the behavior over time is very similar to that shown in **Figure 1A**. The Pearson's correlation coefficients between the ions in the soil and those in the irrigation water confirm the close relationship between soil salinity and the quality of water, as shown in studies carried out by Hernández et al. (2005). In contrast, the presence of NO_3^- in the soil (**Figure 1F**) was more responsive to the deep application of mineral fertilizers, for which the highest concentrations were found, as can be seen in the third quarters of 2016 and 2017.

This result gives us an idea of the importance of regular *in situ* monitoring of EC, in order to be able to properly manage this soil and prevent and/or correct its degradation.

Climatic factors, such as the episodes of heavy rain at the end of 2016, as well as the type and quantity of fertilizers used, also influenced the degree of salinity and the ionic composition of the soil. There are strong storms associated with the DANAs (Depresión Aislada en Niveles Altos - isolated depressions at high altitude or upper level lows) of the Mediterranean area; the one that took place in December 2016 caused leaching of salts and an apparent improvement in the soil, as seen in the minimum EC found in the first quarter of 2017 (**Figure 1A**). This phenomenon does not usually occur in this type of soil and under arid conditions, since the scarcity of water prevents the removal of salts from the soil (Hernández et al. 2005).

Finally, fertilization programs, either through background applications or fertigation, provide crops with the nutrients they need for their development. In this sense, when these nutrients are provided in amounts greater than those actually needed by plants, they can accumulate in the soil, increasing the ionic concentration (**Figure 1B**), or, if they are very soluble, leach to deep horizons and even reach the water table, with the consequent environmental problems.

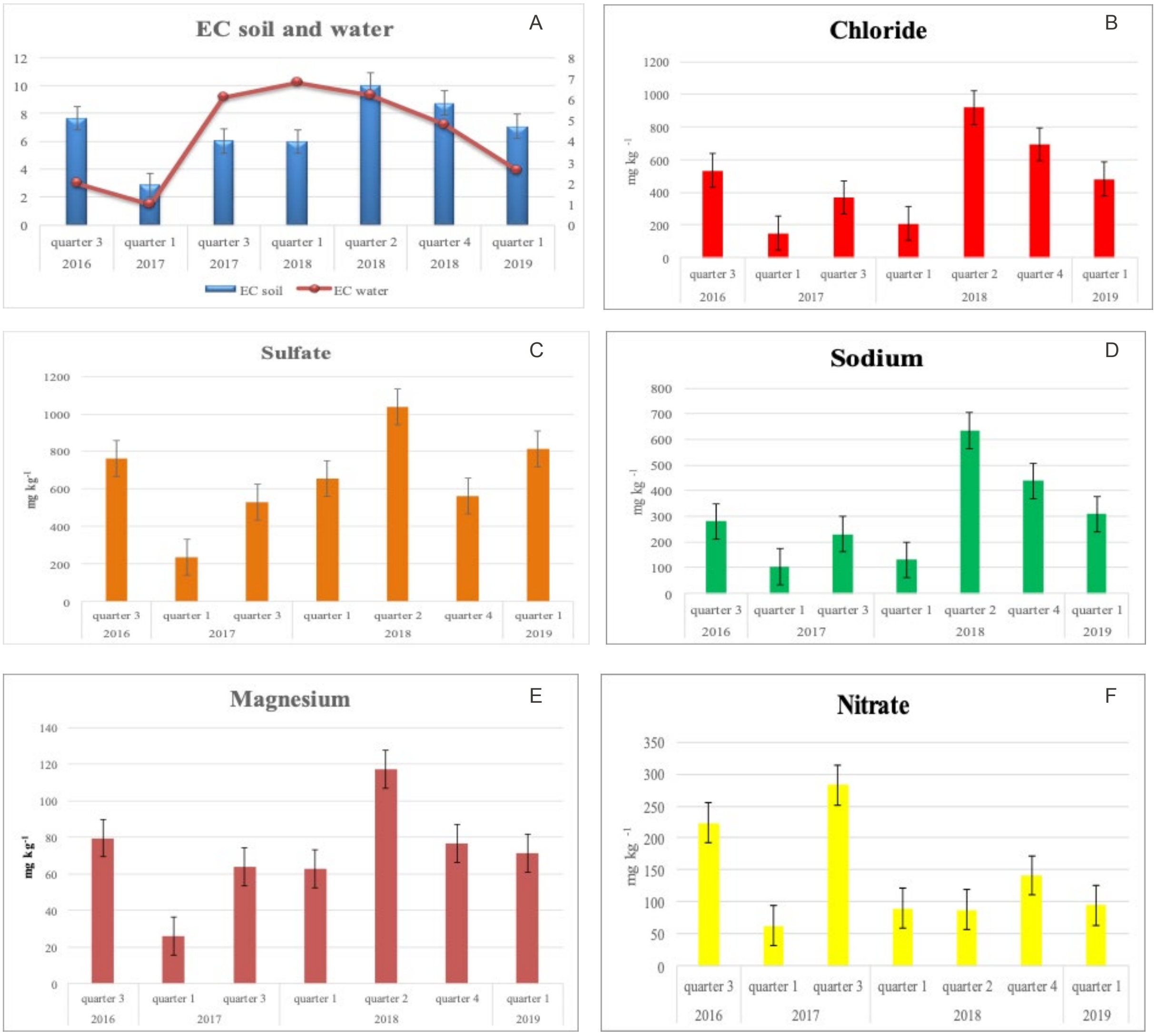

Figure 1. Evolution of the EC in the irrigation water and soil (A) and of the ionic composition of the soil solution (B-F). EC expressed in dS m^{-1}.

4. Conclusions

In conclusion, the establishment and monitoring of an experimental plot of vegetables in the open air in a Haplic Calcisol in the Campo de Cartagena for four years has given us a clear image of the fluctuations experienced by the EC and the ionic composition of the soil, as well as the relationships of these parameters with the agronomic management carried out in the trial plot and, in particular, with the quality of the irrigation water used. Therefore, in modern and sustainable agriculture - which is the model that should be promoted, especially in vulnerable places under strong agricultural pressure, such as the site where this research has been carried out - it is essential to monitor agro-ecosystems. This should be done by establishing a network of experimental plots in the different types of soils present, where the monitoring and follow-up of sensitive indicators of soil degradation are carried out to detect inappropriate tasks in the management of this resource and, therefore, to allow preventive and/or corrective measures to be taken to minimize degradation.

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