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AVAILABILITY OF IRON FROM THE SOILS OF THE VEGA MEDIA DEL RIO SEGURA (MURCIA, SOUTHEAST OF SPAIN)

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Abstract: In the present paper, the availability of iron in the soils of the Vega Media of the Segura river (Murcia) is studied, a peri-urban area of traditional orchards in which a wide variety of fruit and vegetable crops are installed and with an industrial zone, since there are several industrial estates. The soils present in the study area are calcaric Fluvisols, in use or abandoned, and calcaric Regosols (IUSS-WRB, 2022) dedicated to industrial use. Its pH and calcium carbonate content are studied, finding that only a very small part of the total iron is assimilable, at these pH values and calcium carbonate content. There are highly significant statistical differences between both types of soils in terms of assimilable iron (0.001712 for $p<0.001$) but not in total iron. Regarding use, there are also significant differences between agricultural and industrial use, but not between abandoned soils and those currently cultivated. The objective is to achieve sustainable and resilient agropolitan systems.
Keywords: Agricultural soils, orchard, assimilable iron, total iron, sustainable development.

INTRODUCTION

The challenge facing world society, in general, and Murcian society in particular, in the coming decades, is to achieve developed, sustainable and resilient agropolitan systems (Batara et al.2021). We must produce healthy food for an urban population that does not stop growing, with less and less physical space to cultivate and with scarcity of water, particularly in arid areas such as the Region of Murcia, and all this in a scenario of climate change and economic uncertainty. and social, aggravated by the global covid-19 pandemic and the war in Ukraine,

Egea and Egea (2017) in their book "Huerta de Murcia" consider the direct benefits of Urban and Peri-urban Agriculture, to which must be added its enormous potential to mitigate the effects of climate change, reduce energy consumption, contribute to the environmental and human health in cities (Illeva et al., 2022; Reyes-Riveros et al., 2021), as well as increasing the social integration of the poorest. In this sense, urban planning (Simón et al., 2012) must articulate the productive, ecological, landscape and urban functions of peri-urban agricultural spaces, establishing a gradient between rural and urban areas.

Iron is the fourth most abundant element in the earth's crust after Si, O and Al, it represents 5.1 % of its total weight and its content in the soil is estimated at 3.8 % (Lindsay, 1979). From the weathering of primary minerals, such as ferromagnetic silicates, soluble iron is released that can be used by organisms, bind to different organic ligands, or be transformed into secondary minerals such as sulfides, carbonates, clay minerals, but fundamentally oxides and hydroxides, which will be the ones that mainly control the solubility of this element in the soil (Lindsay, 1979; Murad and Fisher, 1988). Due to the extremely low solubility of $Fe+3$ oxides in the normal pH range in soils, the released iron will precipitate rapidly as oxide or hydroxide. Colombo et al. (2014) carried out a bibliographic review regarding the biotic and abiotic reactions that can influence the availability of iron in soils.

The solubility of iron minerals in soils is usually very low; The interaction with plants, microorganisms and organic substances can favor the formation of soluble iron complexes, which increase its availability to plants. (Colombo et al., 2014).

It is intended with this work to know the iron agricultural potential of these soils and relate it to the types and uses of the same to redirect the change of uses. The final objective is to reach a rational planning of the territory, giving each land its most appropriate use according to its intrinsic and extrinsic characteristics. And all this focused on achieving a sustainable and resilient agropolitan system from the Murcian orchard.

MATERIALS Y METHODS

The area selected for the study has been the central sector of the Vega Media of the Segura river (Murcia), with an approximate extension of 65 km^2 and integrated by the municipalities of Molina de Segura, Alguazas, Las Torres de Cotillas and Lorquí. (Figure 1). A 1x1 km^2 mesh was designed and a sampling of 68 samples of arable layer (30 cm deep) was carried out.

The necessary analytical determinations have been made for the typological characterization of the soils studied according to the IUSS Working Group WRB system (2022). For the pH, the measurement has been used in a 1:5 suspension of soil in water. To determine calcium carbonate, the volumetric method of Bernard's calcimeter (USDA, 1996) was used. Inductively coupled plasma has been used to determine the assimilable iron after its extraction with 0.005M DTPA, 0.01 M CaCl2 and 0.1 M triethanolamine solution at pH 7.3 (Lindsay and Norvell, 1978). Acid digestion with HCl and HNO3 in a microwave oven was selected to determine total iron. (Ure, 1996). Quantification was performed using ICP as well.

In order to carry out a statistical study of the results obtained from the arable layer samples, the statistical package R (R Development Core Team, 2008) has been used to analyze whether the differences observed between the samples with respect to the variables studied were significant in Regarding the type and use of the land, using non-parametric methods (Kruskal-Wallis and Wilcoxon) since it was not possible to ensure the normality and homoscedasticity of the analyzed variable. For the cartographic representation, QGIS 2.0 Dufour (Quantum GIS Development Team, 2013) was used, which allows the interpolation of the values by IDW (Inverse Weighting to Distance).

RESULTS AND DISCUSSION

In the Vega Media del Río Segura, the rural landscape has been transformed by urbanization and industrialization. The irrigated landscape decreases due to the expansion of traditional nuclei, the dispersed medium-density residential area and the creation of a series of industrial estates (La Serreta, La Estrella, etc.).

In the studied area there are two types of soils, which are found in a similar proportion: Calcaric Fluvisols and Calcaric Regosols (IUSS-WRB, 2022). The Fluvisols have a current agricultural use or were dedicated to cultivation in the past and are now fallow or abandoned. Calcaric Regosols are located in industrial estates or urban areas. Haplic Solonchaks occasionally appear in salt marshes. These soils have been studied in detail by Gómez García (2016).

The mean pH value in calcaric Fluvisols is 8.54, very similar to the mean value in calcaric Regosols, which is 8.33, with no statistically significant differences between them (Table 1). Regarding the use, statistically significant differences are observed between the currently cultivated soils and those dedicated to industrial use; not being observed between the abandoned soils and those that are under cultivation according to the Wilcoxon test. The distribution of this value can be seen in Figure 2 and corresponds to usual values in the Region of Murcia (Ramírez et al., 1999). The values obtained are those expected, since these soils have high CaCO3 contents.

The soils under study are very calcareous, in fact they are Calcareous Regosols and Fluvisols in both cases, with an average calcium carbonate content of 363 g kg-1 for

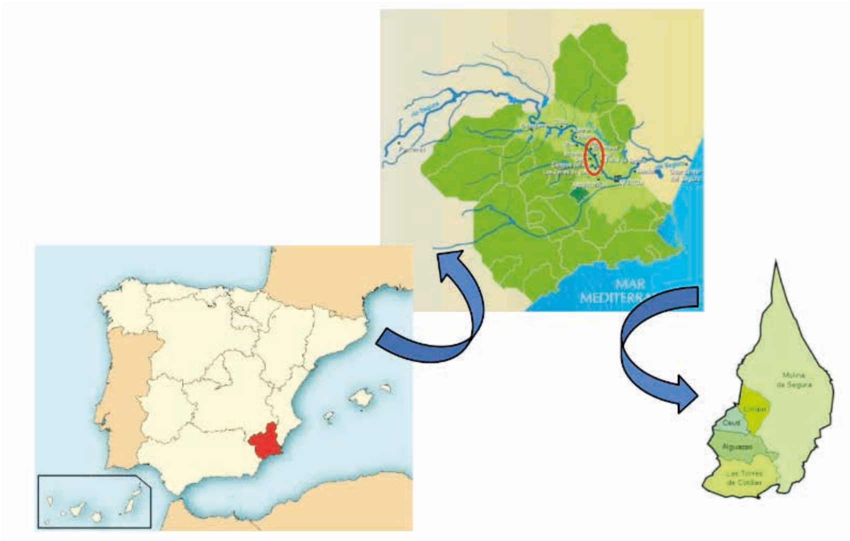

Figure 1. Location of the study area

Variable	Average		SD		Kruskal (df=2)	
	Fluvisol N=33	Regosol N=34	Fluvisol N=33	Regosol N=34	Chi-square	p value
pH	8,546	8,337	0,301	0,387	56067	0,06061
$CaCO_3$	351.793	363.379	60.563	77.569	1606	0.448
$Fe_{available}$	1,758	0,555	1,858	0,540	265556	0,001712***
Fe_{total}	11599,68	10553,33	2350,327	2041,302	45552	0,1025
ratioFe	0,000172	0,00005603	0,0002611	0,00006365		

Table 1. Statistics of the variables studied depending on the type of soil: pH, calcium carbonate (g/kg), total iron (mg/kg) and available iron (mg/kg).

Variables	Uso						Kruskal (df=2)	
	Abandoned N=15		Cultivated N=20		Industrial N=33		Chi-cuadrado	p,value α =0,05
	mean	SD	mean	SD	mean	SD		
$CaCO_3$	360,44	51,60	346,46	65,59	362,20	78,46	1,396	0,4975
pH	8,55	0,34	8,55	0,27	8,32	0,38	6,998	0,03023*
$Fe_{available}$	1,567	1,651	1,791	1,977	0,556	0,549	26,13	2,12E-006***
Fe_{total}	11890,350	2596,268	11289,950	2078,535	10572,780	2069,751	4,01	0,1349
ratioFe	0,000	0,000	0,000	0,000	0,000	0,000	24,594	0,000004565***

Table 2 Statistics of the variables studied based on land use. Kruskal Wallis non-parametric test: CaCO3 (g kg-1), pH, available Fe (mg/kg), total Fe (mg/kg).

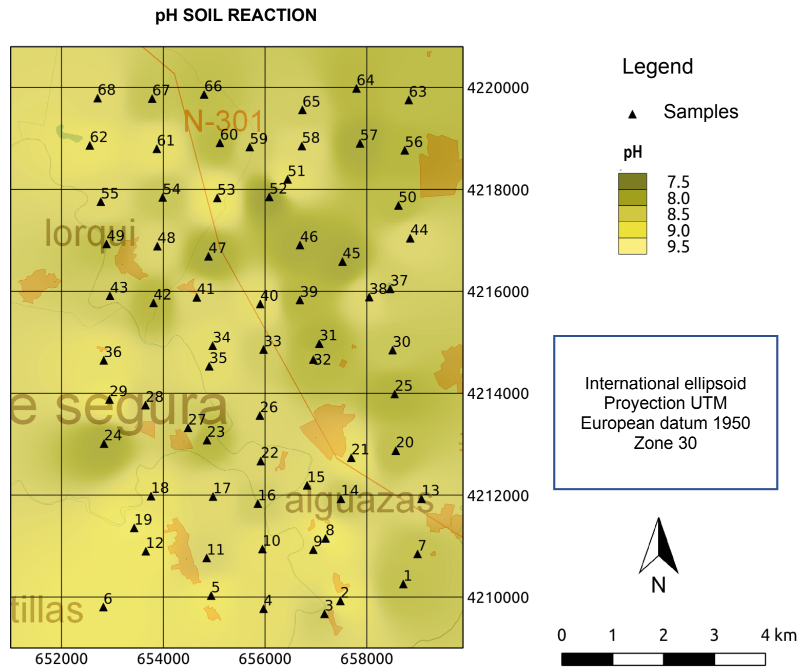

Figure 2. Interpolation of pH in the study area.

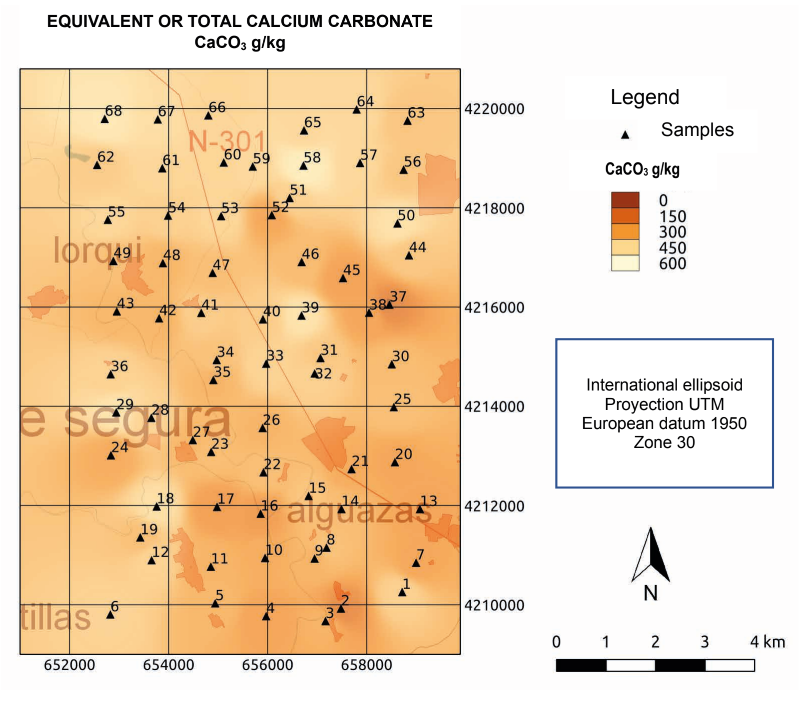

Figure 3. Interpolation of carbonates in the study area.

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Regosols and 352 g kg-1 for Fluvisols. They show a homogeneous spatial distribution in terms of carbonate content (Figure 3), with no statistically significant differences observed with respect to soil type or soil use.

The calcium carbonate content shows a statistically significant negative correlation with most of the assimilable micronutrients, which can be justified by their immobilization at high pH.

Iron, copper, manganese and zinc are considered micronutrients for plants as they are consumed in small quantities by them, but are essential for their vital functions. Their functions in plants are generally catalytic, intervening in multiple enzymatic reactions vital to the plant, such as the synthesis of chlorophyll. However, the excess of micronutrients in an assimilable state for plants can be toxic, in small concentrations, since the range between the optimum and the toxic level is very narrow.

These elements are very soluble at pH below 5.5 and as soil pH increases, their solubility decreases, so that in alkaline soils, such as those of the study area with a water pH above 8 and close to 8.5, their absorption by plants is very low, most of them being found as non-assimilable forms for the plant. For this reason, their total and assimilable contents have been determined to determine what fraction of the total is available to plants.

The assimilable iron values of the soils sampled can be qualified as very low according to the classification established by Lindsay and Norvell in 1978, which is still valid according to Cobertera (1993), because they are lower than 2 ppm, even in the currently cultivated soils with a mean value of 1.79 ppm (Table 2), presenting statistically very significant differences between the cultivated soils and those dedicated to industrial use ($p=0.0000$). These assimilable iron values are similar to those obtained by Marín in 1992 in the Ap horizons of his sampled profiles (1.65 ppm).

Its assimilability index (Table 1) is practically nil, since of the average values of total iron (11,600 ppm in Fluvisols and 10,553 ppm in Regosols), the assimilable part is less than 0.01%, justified by the high pH of these limestone soils, which means that practically all of this element is immobilized in the form of precipitated and insoluble oxides and hydroxides. This low availability of iron is responsible for the iron chlorosis that affects vegetation, since when there is a lack of iron in the formation of the leaf, the chlorophyll molecule cannot provide greenness. Because of this problem with the immobility of iron, it is fertilized with chelates that keep them in solution. On the other hand, the role of organic matter is also very positive, since the formation of chelates between organic matter and iron favors its passage to available forms.

Vidal et al. (2004) studied the behavior of heavy metals in calcareous Fluvisols dedicated to agriculture in the Vega Baja of the Segura River and considered it likely that the mobility of heavy metals was influenced by the mineral fraction to which they were bound.

Assimilable iron, whose spatial distribution is presented in Figure 4, presents a statistically significant positive correlation with organic carbon (0.349 for $p<0.001$) and total nitrogen (0.354 for $p<0.01$). It presents a statistically significant negative correlation with soluble calcium (-0.348 for $p<0.01$) and sulfates (-0.329 for $p<0.01$).

Total iron, whose spatial distribution is presented in Figure 5, has a statistically significant correlation with organic carbon (0.35 for $p<0.01$) and total nitrogen (0.361 for $p<0.01$). Total iron also has a negative correlation with calcium carbonate content (-0.511 for $p<0.001$) and with electrical conductivity (-0.319 for $p<0.01$).

Total iron has a positive correlation with total manganese (0.695) and total zinc (0.517)

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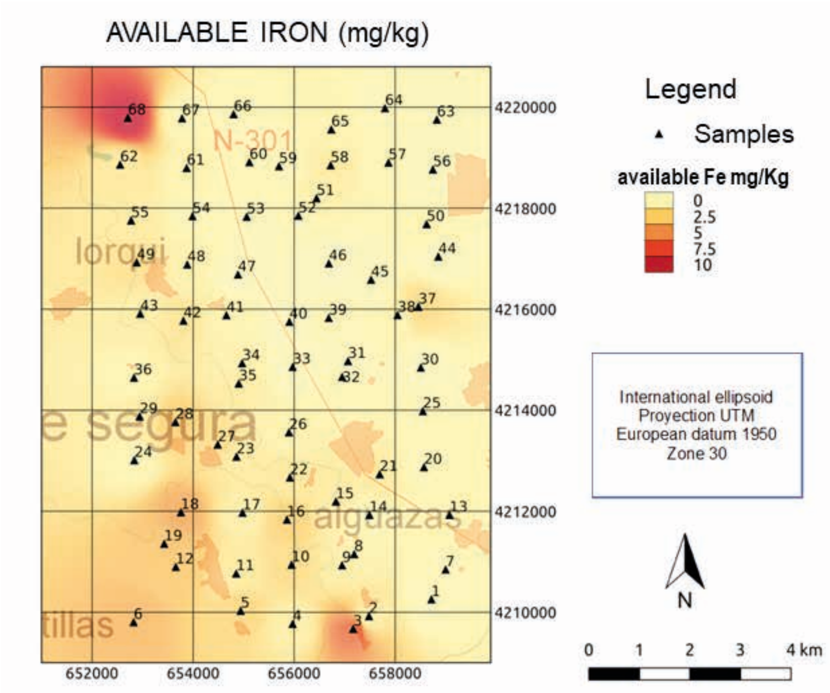

Figure 4. Interpolation of assimilable iron in the study area.

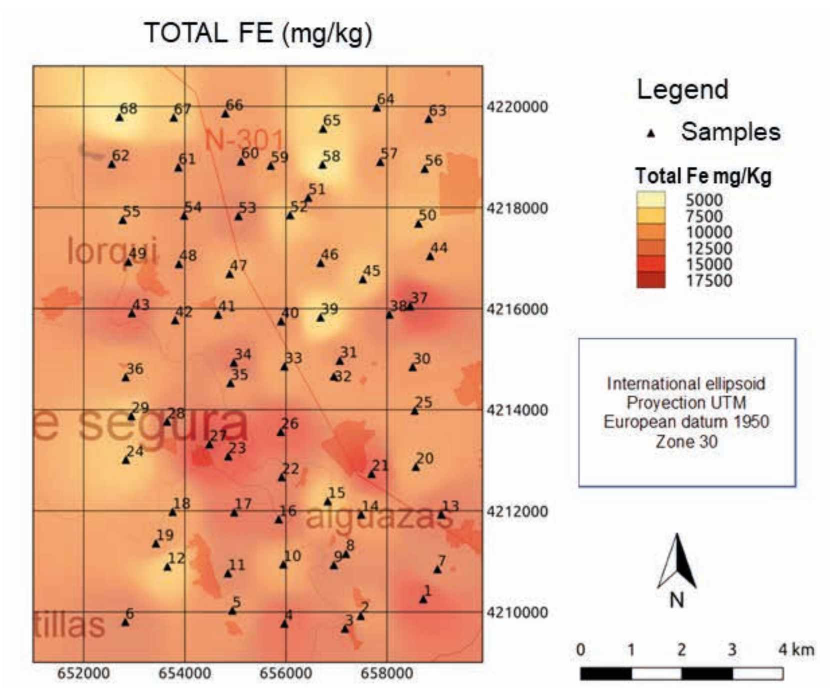

Figure 5. Interpolation of total iron in the study area.

both with $p<0.001$.

CONCLUSIONS

The soils studied have very low assimilable iron values, with respect to total iron, due to their high pH and limestone character. There are no statistically significant differences between the different types and uses of soils in terms of total iron content, but there are significant differences in assimilable iron. Controlled iron fertilization and application of low-salt fertilizers are recommended in order not to increase soil salinity. It would also be necessary to make improvements in irrigation techniques since, due to the climatic characteristics of the area, the type of soil and the quality of irrigation water, blanket irrigation should be replaced by drip irrigation. It would also be advisable to introduce crop varieties with genetic improvements that are more tolerant to salinity and drought.

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