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RELATIONSHIP BETWEEN SOIL CHEMICAL FERTILITY AND LAND USE IN MEDITERRANEAN SEMIARID CONDITIONS: CAMPO DE CARTAGENA (MURCIA), SE SPAIN

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Introduction

The Campo de Cartagena is an agricultural area covering almost 10% of the province of Murcia (SE Spain). It is one of the most representative agronomic areas and 85% is dedicated to agricultural activities (CREM, 1998). It is a very gently sloping plain extending from the southern slopes of the sierra de Carrascoy to Cartagena and the Mar Menor. It has complex socio-economic dynamics where, agricultural activities play a very important role, especially in the municipalities of Torre Pacheco and Los Alcázares.

Meteorological data from the last 30 years point to an average temperature of 17.5 ºC and a mean annual rainfall of 300 mm. These data and the potential evapotranspiration of the area (close to 900 mm) define, according to the Soil Survey Staff (1999), an edaphoclimate characterised by an Aridic Soil Moisture Regime (SMR) and a Thermic Soil Temperature Regime (STR).

Geologically, it is a plain in the Betic Zone covered by recent continental sediments derived from the erosion of topographically higher zones that have formed a superficial ochric horizon and a subsurface calcic or petrocalcic horizons. Dominant soil in the area studied are the Haplic Calcisols, followed by Petric Calcisols (FAO-ISRIC, 1999), depending on the depth of the calcareous crust (Faz *et al.,* 2000 a).

Along the coast, the influence of the marine water table has led to the formation of salic horizons, which, in turn, has given rise to Solonchaks, not very representative however of the soils of the area. Regosols occur as well. These soils have been studied and mapped by Alías *et al.,* (in press a and b).

This area represents one of the driest regions of continental Europe. It is facing many problems associated with agriculture and the environment, including scarcity of water, salinisation, soil erosion, and desertification. The explosion of greenhouse cultivation within the last two decades in the region, using advanced plantation technologies, has created new challenges regarding soil use and management, which has responded to external demand rather than taking into account the suitability of the soil to produce appropriate crops.

Therefore, new agricultural practices have created many edaphic and environmental problems that, hopefully, may be reversible, although this will require changes of agricultural structure and in the varieties grown.

Since degradation (as defined by FAO-PNUMA, 1980) is a process which lowers the qualitative and quantitative capacity and the potential of soil to produce goods or services, the main objetive of this work is to evaluate the chemical fertility of the soils in order to understand the present degree of anthropization and the possible relationship with agricultural use.

Material and Methods

For the present study, we chose the municipal areas of Torre Pacheco and Los Alcázares, which lie in the Campo de Cartagena, Murcia, SE Spain, and that cover in total 209 km^2. Of this area, 80 % is set aside to agriculture. The main land use corresponds to irrigated horticultural varieties, extensive herbaceous, dry trees, citrus trees, along with uncultivated soils with their unaltered natural vegetation.

In the winter of 1998-99 a systematic study was made for every square kilometre of the study area (Figure 1) by taking samples from the top 0-30 cm, meaning a total number of 206 samples. Existing topographic maps (1:50,000 and 1:25,000 scale), aerial photographs (E: 1:20,000) and The Guideline for Soil Descriptions (FAO, 1990) were used during the study.

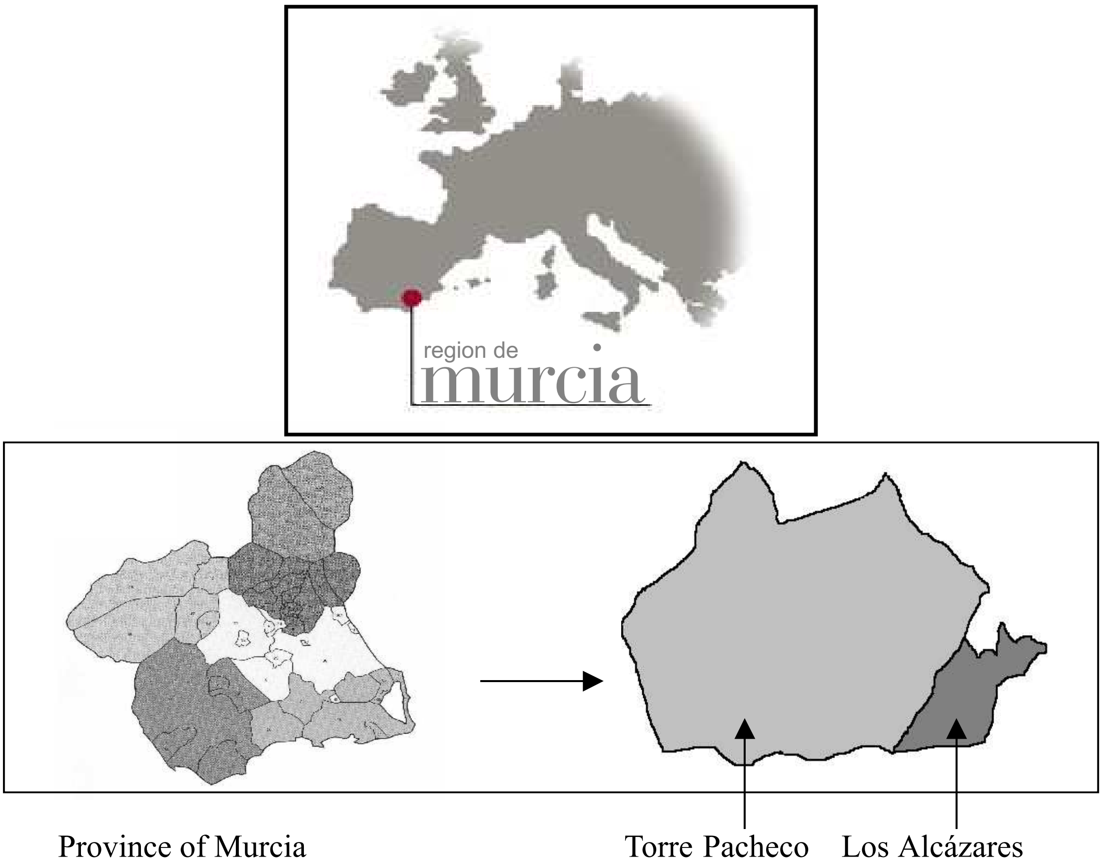

Figure 1. Location of the study area

The following analytical determinations were made: total organic carbon, Anne's method modified by Duchafour (1970); total nitrogen, Kjeldahl's method as described by Duchaufour (1970); cation exchange capacity, Chapman (1965); available sodium, potassium, calcium and magnesium, Pratt's method (1965); available iron, copper, manganese and zinc (Lindsay and Norwell method's, 1969); available phosphorus, according to Olsen and Dean modified by Watanabe (1965).

Results and Discussion

The study area is almost completely dedicated to the agricultural sector and, in recent years, thanks to the irrigation water sources of the River Tajo-Segura the area has undergone considerable conversion from traditional dryland farming to intensive irrigation agriculture (Arnaldos, 2001). Table 1 shows the different forms of land use.

Table 1. Different land use percentages

Horticultural products	Extensive herbaceous	Dry trees	Citrus trees	Prepared for cultivation	Not cultivated	TOTAL
40 %	10 %	9 %	7 %	17 %	17 %	100 %

Horticultural crops represent 40% of the total agriculture activity of the studied area, of which broccoli is the main crop (present in 25 cases-12% of sampled sites). This is followed, in decreasing order, by artichoke (20 cases-9.6% of sites), melon (16 cases-8.2%), lettuce (nine), celery (four), broad beans and potatoes (three each) and cabbage and chard (one site each). In 70% of cases, the horticultural crops were irrigated by drip irrigation, receiving a combination of organic and inorganic fertilisation.

The samples being prepared for cultivation represented 21.7% of the total. In decreasing order, after horticultural crops come herbaceous crops, which were found in 23 cases. Cereals such as wheat, oats and barley represent 9.6% of the total and cotton 1.4%. In 75% of the cases these crops receive no irrigation and little organic amendment, making them marginal crops.

Dryland woody crops were found in eighteen cases, almond representing 7.2% of the total and carob 1.4%. Although these are traditional dry crops of the area, 60% are now drip irrigated.

Citrus (orange, lemon and mandarin) represent 6.7% of the total. Slightly more than 70% are drip irrigated and receive organic amendment and sufficient fertilisation.

Finally, 25 sampled sites (12% of the total) were not used for agricultural (Marin *et al.*, 2000**)**. Among them there are soils, which are intended for buildings, uncultivated land, coastal salt marshes, and land previously cultivated but at present abandoned.

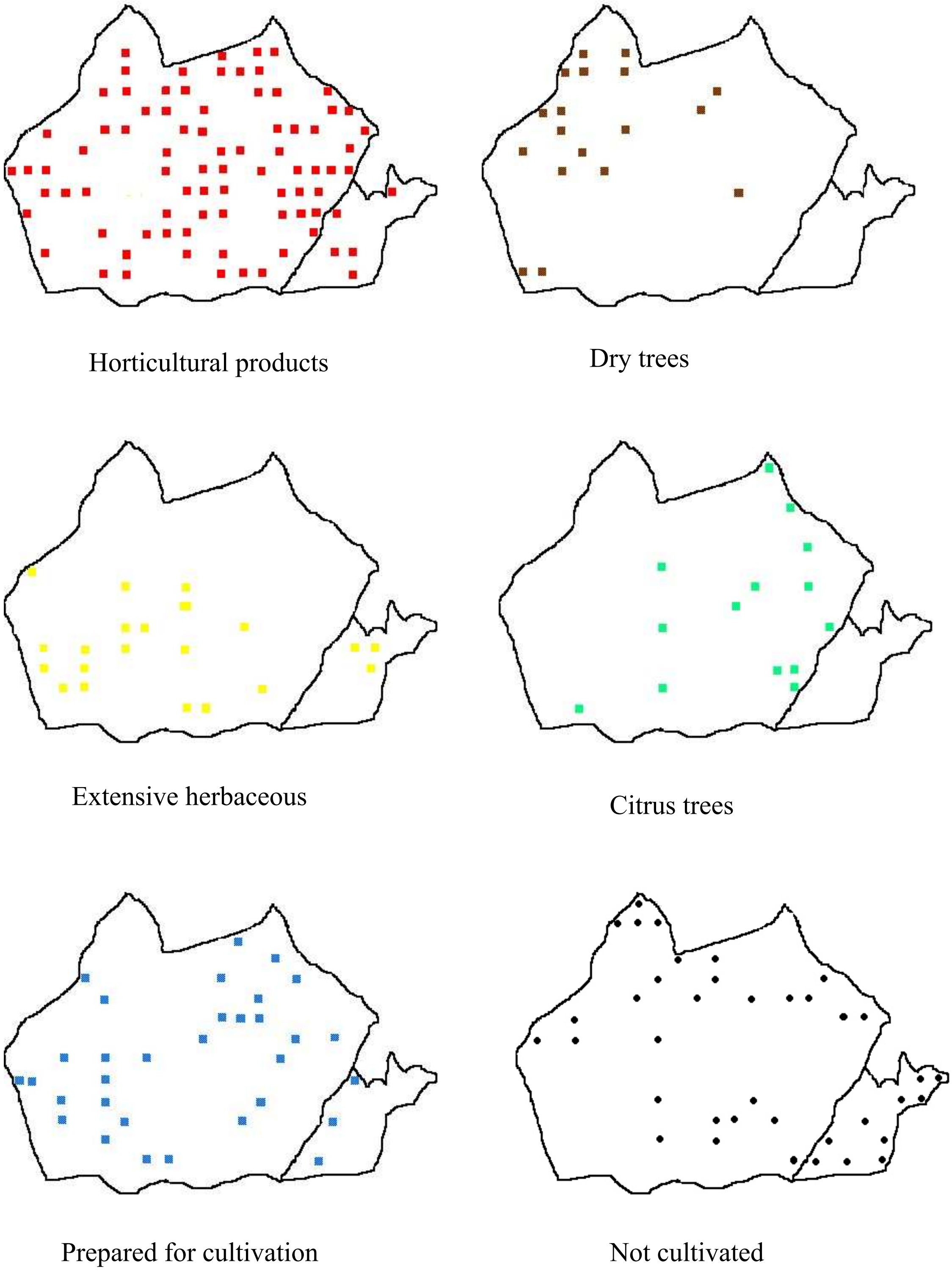

Figure 2. Distribution of different land uses

The general analytical data of the soils as a function of their use are shown in Table 2.

Table 2. Analytical data according to land use

	Horticultural products	Extensive herbaceous	Dry trees	Citrus trees	Prepared for cultivation	Not cultivated	Average
Organic carbon g kg^{-1}	7.2	5.6	4.1	6.9	6.4	8.2	6.7
Nitrogen g kg^{-1}	1.00	0.80	0.60	0.90	0.90	1.10	0.94
C/N	7.2	7.0	6.8	7.7	7.1	7.5	7.1
Active calcium g kg^{-1}	185.7	163.0	152.3	175.5	180.2	199.0	180.8
Phosphorus mg kg^{-1}	31.36	18.87	12.21	15.50	24.67	20.46	24.41

The organic matter content of soils strongly influence their physical (water holding capacity, structure, aeration) and chemical (CEC, regulatory capacity etc.) properties, so that its determination is of prime importance for evaluating soil fertility. The organic matter content, along with the climate and vegetation or crop type, permit to establish environmental risks and the intensity of agricultural activity.

The uncultivated samples contained a mean of approximately 8.2g kg^{-1} of organic carbon, while the soils covered with horticultural crops had a value of 7.2g kg^{-1}, approximately 13% less. The samples deriving from citrus cultivation had a mean of OC of 6.9g kg^{-1} (16% less), while the soils prepared for non specific cultivation showed a mean 6.4g kg^{-1} (33% less). The soils covered by dry woody vegetation had as little as 4.1g kg^{-1}, which is about 50% less than that observed in the uncultivated soils (Faz *et al.,* 2000 b**).**

It is obvious to note that the content of total nitrogen is low or very low in the soils, regardless of their use. This content rises slightly in soils planted with irrigation crops and soils prepared for cultivation, both characterised by high inputs of nutrients. The samples dedicated to dry tree cultivation have lower values. This reflects the low organic matter content of the soils since organic nitrogen is always represents more than 90% of total nitrogen. The fact that greater concentrations were not observed in cultivated soils suggests that nitrogen fertilisers are not commonly applied.

The mean C/N ratio is 7.1 in uncultivated soils and slightly higher in soils with citrus, but in general there are no significant differences resulting from the use to which soils are put.

The mean calcium carbonate equivalent of the soils is approximately 450g kg^{-1}. The excess of calcium would hinder the assimilation of iron, manganese, phosphorus and other elements (Faz *et al.,* 2000a). The mean active calcium content is 181g kg^{-1}, which is approximately 40% of the total. The distribution of calcium is quite homogeneous depending on soil use, as it is spatially distributed throughout the study area.

The highest values for phosphorus (32 compared with the average of 24.4 mg kg^{-1}) were recorded in the soils dedicated to horticultural crops, probably due to its importance in the fertilisation of the same, while the lowest values corresponded to the soils with dryland woody species, which generally received no fertilisation. Table 3 shows the CEC and exchangeable bases as a function of land use.

Table 3. Cation Exchange Capacity according to land use

	Horticultural products	**Extensive herbaceous**	**Dry trees**	**Citrus trees**	**Prepared for cultivation**	**Not cultivated**	**Average**
Cation exchange capacity $cmol_{(+)}\ kg^{-1}$	12.70	12.07	10.46	12.25	13.36	12.55	12.61
Potassium $cmol_{(+)}\ kg^{-1}$	0.96	0.93	0.77	0.88	0.90	1.08	0.96
Sodium $cmol_{(+)}\ kg^{-1}$	2.21	2.12	1.54	1.87	1.52	1.04	1.79
Magnesium $cmol_{(+)}\ kg^{-1}$	2.94	2.07	1.83	2.78	2.62	2.83	2.84
Calcium $cmol_{(+)}\ kg^{-1}$	7.01	6.14	6.33	6.74	8.32	7.56	7.52

The cation exchange capacity depends mainly on the texture and on the organic matter content of the soil in question. The soils of the area have a mean clay content of almost 30%, silt content of 40% and almost 30% sand, making them silty-clay-loam, clay-loam, loam or silty clay (Arnaldos, 2001). The cation exchange capacity is very similar in the different samples, although it is slightly higher in samples where an insensitive fertilisation programme has been carried out.

The relative abundance of ions in the exchange complex is, from highest to the lowest: calcium, magnesium, sodium and potassium. Calcium is by far the most plentiful in almost all the samples. This is the most abundant cation in neutral and basic soils, playing a very important role in the saturation of the adsorbent complex, since it is both abundant and possesses a high electric valence, which determines its predominance in all non-acidic soils.

Since the soil is saturated with calcium, available iron, phosphorus, boron, copper and zinc are blocked and insoluble compounds are being precipitated (Cobertera, 1993). Furthermore, the excess of calcium provokes antagonism in the exchange complex with other cations of a given affinity, such as magnesium and potassium, so that the Ca^{+2}/Mg^{+2} and Ca^{+2}/K^{+} ratios are very low in all the soils studied, hindering the assimilability of these elements.

The least abundant element is potassium with an average value of < 1 $cmol_{(+)}\ kg^{-1}$. The exchange cation content does not seem to be related with land use since the values are in all cases close to the mean, except in the case of sodium and magnesium which show slightly higher levels in the soils cultivated with horticultural crops, probably due to the use of groundwater with a high soluble salt content (Marín, 2000).

Table 4 shows the values of the available elements according to land use.

Table 4. Available microelements according to land use

	Horticultural products	Extensive Herbaceous	Dry trees	Citrus trees	Prepared for cultivation	Not cultivated	Average
Iron mg kg^{-1}	0.89	0.88	0.79	0.68	0.90	1.15	0.91
Copper mg kg^{-1}	1.19	1.06	0.93	1.07	1.21	1.67	1.23
Manganese mg kg^{-1}	6.62	6.96	3.90	4.83	7.25	6.63	6.41
Zinc mg kg^{-1}	2.15	1.98	1.53	2.00	1.78	2.85	2.12

The availability of oligoelements to plants depend in part on soil pH, the value of which in the area studied is 8.0 down to 60cm according to recent studies (Arnaldos, 2001). The greatest degree of assimilability for all elements is between pH 6.0 and 7.0, while at values of between 7.5 and 8.0 deficiencies appear for manganese, iron, boron, zinc and phosphorus (Cobertera, 1993). The chemical fertility of these soils is marked by the low degree of availability linked to basic pH values than by the actual nutrient content.

In general, manganese is present in much higher concentrations than iron, copper and zinc. The highest iron, copper and zinc contents were recorded in the uncultivated soils, where even the manganese content is higher than the mean value.

Available phosphorus is also higher in samples where irrigated horticultural plants are grown. These results clearly illustrate that inadequate management is detriment to soil quality, and that a chemical evaluation of the soils prior to their use is essential. If we want to consider also the quantities of nutrients extracted by different crops, and especially the yield of the crop (Dominguez, 1989), we calculate that the present status of soil fertility is only sufficient to cover the needs of 20 to 30 harvests (depending on the crop in question). Certainly, the productivity will decline and after the soil will be totally devoid of these nutrients if they are not added in the form of fertiliser.

Conclusions

The chemical fertility of these soils is marked by their high pH and high calcium content, rather than by the use the form of land use. Organic fertilisation does depend on land use since the highest values correspond to horticultural crops and citrus species, which are the only ones to receive this type of amendment. Inorganic fertilisation is not influenced by land use.

Macroelements are more conspicuous in uncultivated zones or in those covered by horticultural crops, either because natural environmental conditions apply or because they are added in the form of fertiliser in an attempt to prevent their depletion.

The availability of calcium, sodium and magnesium depends on the physical-chemical properties of the original soil material and climatic conditions. An excess of calcium leads to problems regarding the availability of iron and phosphorus due to the precipitation of insoluble compounds and, in the case of magnesium and sodium, due to antagonism, as demonstrated by the low Ca^{+2}/Mg^{+2} and Ca^{+2}/K^{+} ratios with their average value of 2.6 and 7.8, far below the recommended value of 8 and 20, respectively.

The cation exchange capacity and active calcium are more influenced by the slope, original soil material, clay, and organic matter content than by land use. In general, the fertility of the soils studied is good and the use to which they are put is correct enough. The best soils are used for the most profitable crops (horticultural), while the less fertile soils are dedicated to less demanding crops (e.g. dryland woody). However the state of these soils must be monitored carefully and soil fertility programmes should be applied if they are to be used in a sustainable way in the future.

References

Alías, L.J., Ortiz, R., Martínez, J., Linares, P., Alcaraz, F., Sánchez, A. y Marín, P. (en prensa a). Proyecto L.U.C.D.E.M.E. Mapa de suelos. Escala 1:100,000. San Javier (956). Dirección General de Conservación de la Naturaleza. Ministerio de Medio Ambiente. Lerko Print, S.A., Madrid.

Alías, L.J., Ortiz, R., Martínez, J., Linares, P., Alcaraz, F., Sánchez, A. y Marín, P. (En prensa b). Proyecto L.U.C.D.E.M.E. Mapa de suelos. Escala 1:100.000. Fuente Álamo de Murcia (955). Dirección General de Conservación de la Naturaleza. Ministerio de Medio Ambiente. Organismo Autónomo Parques Nacionales. Lerko Print, S.A. Madrid.

Anne. 1945. Ann., Agro. 2, 161-172.

Arnaldos, R. 2001. Estudio de la salinidad de los suelos del Sector Centroriental del Campo de Cartagena (Murcia). Tesis de Licienciatura. Universidad de Murcia. 249 pp.

Chapman, H. D. 1965. Cation exchange capacity. En C.A. Black, Ed. Methods of soil Analysis. Amer. Soc. Agronomy, Inc. Madison, Wisconsin, EE.UU. 2, 891-900.

Comité Científico del Buró Europeo de Suelos. 1999. Una base de suelos georeferenciada para Europa: manual de procedimientos. Editado por Comité Científico del Buró Europeo de Suelos; Joint Research Centre; European Commission; Consejo Superior de Investigaciones Científicas: Space Applications Institute. 206 pp.

Cobertera, E. 1993. Edafología aplicada: suelos, producción agraria, planificación territorial e impactos ambientales. Ediciones Cátedra. Madrid. 326 pp.

Duchaufour, Ph. 1970. Précis de Pedologie. Masson y Cie. París.

F.A.O.-I.S.R.I.C. 1990. Guidelines for soil description. 3rd Edition (Revised). Food and Agriculture Organization of the United Nations. Roma. 70 pp.

F.A.O.-I.S.R.I.C.-S.I.C.S. 1999. Base Referencial Mundial del Recurso suelo. Organización de las Naciones Unidas para la Agricultura y la Alimentación. Roma. 93 pp.

F.A.O.-P.N.U.M.A. 1980. Metodología provisional para la evaluación de la degradación de los suelos. Organización de las Naciones Unidas para la Agricultura y la Alimentación. Roma. 86 pp

Faz, A., Arnaldos, R., Marín, P. and Mermut, A.R. 2000 b. Reservas de carbono orgánico y su relación con el uso y manejo del suelo en el Campo de Cartagena (SE de España). 11 International Soil conservation Organization Conference. Buenos Aires. Book of abstracts.

Faz, A., Marín, P., Arnaldos, R. Ortiz, R. 2000 a. Fluctuación en profundidad de la costra caliza como limitación para el uso agrícola de los suelos del Campo de Cartagena (Murcia). VI Reunión Nacional de Geomorfología. Sociedad Española de Geomorfología. Madrid. 163-164.

Lindsay, W.L., Norwell, W.A. 1969. Development of a DTPA micronutrient soil test. Agron. Abstr., 84 pp.

Marín, P., Faz, A. And Arnaldos, R. 2000. The relationship between salinity and soil use in the central-eastern sector of the Campo de Cartagena (SE Spain). III International

Congress of the European Society for Soil Conservation. Valencia. Book of abstracts, p 307.

Olsen, S. R. and Dean, L. A. 1965. Hydrogen-ion activity. In C.A. black, ed. Methods of soil analysis. Amer. Soc. Agronomy, Madison. Wisconsin. U.S.A. 1044-1045.

Pratt, M. 1965. Potassium and sodium. En C.A., Black, Ed. Methods of soil Analysis. Amer. Soc. Agronomy, Inc. Madison, Wisconsin, EE.UU. 2, 1022-1234.

U.S.D.A. 1999. Soil Taxonomy. A basic System of Soil Classification for Making and Interpreting Soil Surveys. United States Department of Agriculture and Natural Resources Conservation Service. United States Department of Agriculture Printing Office, Washington, DC. 869 pp.

Watanabe, F. S. And Olsen, S. R., 1965. Test and ascorbic acid method for determining phosphorus in water and NaHCO3. Extracts from Soil. Soil Sci. Soc. Proceedings; 677-678.