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Aridisols of Spain

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Abstract

This paper reviews the distribution and classification of Spanish Aridisols and discusses some taxonomic problems and major management practices. Little literature is available about Spanish Aridisols. Most of the information contained in this paper comes from soil maps and from the authors' unpublished data. The discussion covers the update of Soil Taxonomy, the unsuitability of Newhall's method for some Spanish Mediterranean areas, and the taxonomic status of the gypsiferous soils.

Many of the soils classified as Aridisols (S.S.S., 1975) are now distributed into several Orders because the EC_e criterion has been dropped at this hierarchic level. Recently, a new method for soil moisture regime calculation has been developed in Spain. This method improves the delineation of the aridic regions. Micromorphology provides a better knowledge of gypsiferous soils, and two kinds of gypsic horizons have been identified. Apart from marginal uses, the management of Spanish Aridisols is based on water supply and/or water saving and on taking advantage of early cropping.

The following conclusions can be made: (i) the new model of soil moisture regime calculations can be applied to the presumed aridic areas of Spain and calibrated with soil moisture measurements in the field, (ii) the inclusion of gypsiferous soils into three Orders disagrees with their distinct morphology and behavior, (iii) refinement in the gypsic horizon definition is needed to link microscopic features and field criteria, and (iv) both old and new management practices in Aridisols must be reported in detail for improvement, the adaptation of new technologies, and extension of management practices to new areas.

Introduction

In areas with a Mediterranean climate in Spain, irrigation is often the only way for sustainable agriculture. Historical notes show that small irrigation canals (acequias) were built more than 2000 years ago; and some 31000 Km^2 were under irrigation in 1984-85 (León and Delgado, 1988).

Spain has great expanses subject to a semiarid climate, and early soil scientists such as Huguet del Villar (1929, 1950) and Kubiena (1953) created specific categories for Spanish soils associated with aridity. In many Mediterranean countries, soil moisture is limiting for agriculture, and the concept of Aridisol is useful. Although the management of arid soils is well known in Spain, their classification and mapping according to S.S.S. (1975, 1987) or to FAO (1974) still poses significant problems.

Physiological drought is the essential feature used in defining the Aridisols. They must lack plant available water for some reason, at least for defined periods, and have pedogenic horizons.

The initial concept of Aridisol included both water and salinity stress (S.S.S., 1960). The criterion of electrical conductivity (EC_e) was introduced by the 7th Approximation (EC_e > 1 dS/m at 25°C) and was maintained in *Soil Taxonomy* (S.S.S., 1975) (EC_e > 2 dS/m) but has been eliminated recently (S.S.S., 1987). At present, emphasis is given to the soil moisture regime, and now the aridic regime is required for all Aridisols, with the exception only of salic horizon occurrence.

Soil Moisture Regime as a Base for the Definition of Aridisols

The weakness in the estimation of soil moisture regime from data collected by meteorological observatories is apparent when the results of calculations are compared with the kinds and amounts of natural vegetation produced in major soil areas (Guthrie, 1985). The same disagreements were observed when applying Newhall's model to predict the soil moisture regime in some Spanish semiarid regions (Làzaro et al., 1978; Porta et al., 1983; Alberto et al., 1984; Jarauta, 1989). Spanish areas having a typical Mediterranean climate and vegetation

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are included in the ustic soil moisture regime after Newhall's method (Tavernier and Wambeke, 1976).

The model of moisture accretion and depletion developed for soils in the Great Prairies (S.S.S., 1975; Newhall, 1976) uses mean monthly precipitation and temperature to calculate the soil moisture regime, assuming a general available water capacity of 200 mm. The need for dichotomy in the diagnosis criteria and the consequent changes in the calculations were pointed up in Spain (Elìas and Ibànez, 1979; Gascò and Ibànez, 1979; Ibànez and Gascò, 1983). Very few field measurements of soil moisture contents are available around the world, and the same is true for Spain.

Jarauta (1989) has investigated the soil moisture contents in some sites of northeastern Spain with an ustic soil moisture regime, using Newhall's method. These sites have Mediterranean vegetation, and their crop production is affected by soil moisture shortage during the plant growing season. A new model of moisture accretion and depletion has been proposed, after four years of field measurements of soil moisture by the gravimetric method. This model has been designed to allow for the incorporation of local climate and soil characteristics.

Jarauta's model precisely defines the soil moisture regimes and allows different soil control sections and water retention capacities as well as different rain dates during the month to be considered. This model approximates better than Newhall's model to field measurements of soil moisture. Its results allow for improved knowledge of the distribution of aridic soils in Spain, separating aridic-xeric from ustic regimes. In the Ebro basin (NE Spain), this has caused the ustic regime to be rejected reference to either by soil moisture effects on soil production or four years' measurement of soil moisture content in the soil moisture control section.

The soils having argillic or natric epipedon are excluded from Aridisols if their epipedon is both massive and hard or very hard when dry (S.S.S., 1975, 1987). This is a useful criterion because the data about soil moisture regimes are often unavailable.

Areas in Spain with an Aridic Soil Moisture Regime

The application of Jarauta's method will allow a better understanding of the true extent of the aridic regime in Spain. It can be hoped that this model will be applied to more observatories

Table 1. Diagnostic horizons in the Aridisols of Spain.

	Horizon	Frequency
Epipedons	Ochric	+ + + + +
Endopedons	Calcic	+ + + +
	Cambic	+ + +
	Petrocalcic	+ + +
	Gypsic and "Hypergypsic"	+ +
	Argillic	+ +
	Salic	+
	Natric	+

and to sites where soil moisture data will be gathered. So far, the map by Làzaro et al. (1978) with some modifications can be used for Peninsular Spain.

Because of the lack of field measurements, several authors have proposed pragmatic criteria in order to attempt to define the extent of the aridic soil moisture regime. Neither the selected site characteristic s nor their proposed values are agreed on by the different authors. The most common criterion is elevation (Dìaz, 1987; Iñiguez et al., 1988; Pèrez et al., 1987a) or elevation plus slope orientation (Alìas et al., 1987a,b, 1988; Torre and Alìas, 1987). In other cases the distance from the Mediterranean Sea or longitude (Alberto et al., 1984; Pèrez et al., 1987b) also are included. In the future, satellite data (Milford, 1987) or hand-held sensors may furnish valuable data about the soil moisture content of bare or range soils.

The Aridisols of Spain are distributed into three main regions, (i) the Ebro Valley in northeastern Spain, (ii) the southeastern region of Spain, and (iii) small areas in the Canary Islands. The first two regions are the most arid in Western Europe. Their vegetation is quite specific and contains species whose nearest localities are in the Eastern Mediterranean or in North Africa.

Taxa of Aridisols in Spain

The recent dropping of the electrical conductivity criterion (EC_e > 2 dS/m at 25°C) forces a review of the bibliographical references of Aridisols. Soils having an EC_e > 2 dS/m must be excluded from Aridisols if they do not fit in the aridic regime or if they do not have a salic horizon fitting the requirements for Aridisols. Most of the saline Aridisols after S.S.S. (1975) are now in several Orders, having their saline characteristics reflected at the phase level (Porta and Boixadera, 1988).

An accurate interpretation of available data about Aridisols of Spain needs a definition of the salic horizon based on EC. In practice, salinity is measured as EC, and nomograms or approximate calculations are used for conversion to salt percentage for classification purposes. The updating of the definition of salic horizon should state an EC threshold in the standard extract at the soil:water ratio of 1:5.

Table 1 shows the estimated frequencies of diagnostic horizons in Spanish Aridisols, based on a bibliographical search and the authors' field experience.

Silica cementations producing duripans do not occur in Spanish aridic areas. Calcium carbonate, gypsum, and more soluble salts move, producing specific categories of soils.

Salorthids are not common in salt-affected areas of Spain. Salorthids are associated with a shallow saline water table under an ascensional soil moisture regime; their vegetation is *Arthrocnemum glaucum* and *Salicornia sp.* Soils with salic horizon occur in small areas; they are mappable only at detailed scales and references to them are scattered in the literature.

Table 2 displays the taxa of Spanish Aridisols and their location. The table was prepared after a critical review of the bibliography, and most of the references come from LUCDEME soil maps.

Gypsiferous Soils: An "Erratic" Type of Soil

In Spain, gypsiferous materials outcrop only in the east, having an extent of 35487 km^2 (Macau and Riba, 1965). Many of these outcrops are in the aridic regions. The soils developed from gyprock and other gypseous soils are well distinguished and easily separated from saline soils, both by farmers and by early soil scientists (Huguet del Villar, 1929). The *Soil Taxonomy* approach allows reflection of the genetic and management specifities of gypsiferous soils.

Gypsiferous soils in former *Soil Taxonomy* approximations

The soils enriched with "calcium sulfate" were considered in the *Soil Survey Manual* (S.S.S., 1951) and in the 5th Approximation of *Soil Taxonomy* (Cline, 1979).

Table 2. Great Groups of Aridisols cited in Spain.

Great Group	Region	Province	Area	Reference
Haplargids	S.E.	Almerìa	Las Negras	Aguilar & al.,1973
			Campo de Dallas	Martìnez-Raya, 1987
			Macael	Aguilar & al.,1987
			Roquetas	Pèrez & al., 1987
			Los Nietos	authors
Natrargids	N.E.	Huesca	Fraella	authors
		Zaragoza	Bardenas	Martìnez-Beltràn, 1978
	Canary Islands	Tenerife	Tenerife	Rodrìguez-Hdez.& al., 1980
Paleargid	S.E.	Almerìa	Rodalquilar	Aguilar & al.,1973
			Fiñana	Aguilar & al.,1987
			Roquetas	Pèrez & al., 1987
			Tabernas	Pèrez & al., 1987
		Murcia	C. Cartagena	Gisbert, 1973
Calciorthids	S.E.	Alicante	Maigmò	Allas & Torre, 1987
		Almerìa	Nìjar	Aguilar & al., 1973
				Porta & al., 1980
			Fiñana	Aguilar & al., 1987
			Macael	Aguilar & al., 1987
			Tabernas	Pèrez & al., 1987
			Guadix	Ortega & al., 1988
		Granada	Cùllar	Simòn & al., 1980
		Murcia	C.Cartagena	Gisbert, 1973
			Cehegin	Allas & al., 1987
			Coy	Allas & al., 1987
			Lorca	Allas & al., 1988
			Puerto-Lumbreras	Allas & al, 1988
	Canary Islands	Tenerife	Tenerife	Escobar & al., 1973
				Fdez-Caldas & al., 1978
Camborthids	N.E.	Navarra	Bardenas	Arricibita, 1987
				Iñiguez & al., 1988
	S.E.	Almerìa	Nìjar	Aguilar & al., 1973
				Porta & al., 1980
			Huèrcal-Overa	Alonso, 1983
			Campo de Dallas	Martìnez-Raya, 1987
			Roquetas	Pèrez & al., 1987
		Murcia	C.Cartagena	Gisbert, 1973
			Lorca	Allas & al., 1988
	Canary Islands	Tenerife	Tenerife	Escobar & al., 1973
Gypsiorthids	N.E.	Navarra	Lodosa	Arricibita, 1987
			Bardenas	Iñiguez & al., 1988
		Teruel	Hìjar	Porta, 1986
	S.E.	Alicante	Maigmò	Allas & al., 1987
		Almerìa	Tabernas	Pèrez & al., 1987
		Murcia	—	Sànchez & al.,1982
			Puerto Lumbreras	Allas & al., 1988
			Lorca	Allas & al., 1988
	Canary Islands	Tenerife	Gomera	Jimènez & al., 1988
Paleorthids	N.E.	Huesca	Lanaja	authors
		Lèrida	Suñer	Porta & al., 1983
	S.E.	Almerìa	Nìjar	Porta & al., 1980
			Campo de	Martìnez-
		Dallas	Raya, 1987	
		Murcia	Cehegin	Allas & al., 1987
			Coy	Allas & al., 1987
			Lorca	Allas & al., 1988
			Puerto Lumbreras	Allas & al., 1988
	Canary Islands	Tenerife	Tenerife	Escobar & al., 1973
Salorthids	N.E.	Zaragoza	Bujaraloz	Herrero, 1982
	S.E.	Almerìa	Vega de Pulpì	Alonso, 1983
			Campo de Dallas	Martìnez-Raya, 1987
			Roquetas	Pèrez & al., 1987
		Granada	Cùllar	Simòn & al., 1980
		Murcia	—	Sànchez & al.,1982
	Balears	Majorca	Alcudia	Porta & al., 1987
	Central	C. Real	La Mancha	Porta, 1975
		Toledo	Ocaña	Gumuzzio & al., 1984
	South	Huelva	Doñana	Ayerbe & al., 1978
		Càdiz	Puerto de Santa Marìa	Gòmez & al., 1982

The gypsic horizon was defined in the 7th Approximation (S.S.S., 1960), but soils enriched with gypsum were included in the Aridisols, together with soils having a calcic horizon, as Orthic Calcorthids. This situation was unsatisfactory, both from a genetic point of view and for land evaluation from large scale maps.

The Great Group of Gypsiorthids was developed in the Galley Proofs of *Soil Taxonomy* (1970-1973). The new Great Group was introduced in the order of Aridisols (S.S.S.,1975). A water solution saturated with gypsum (2.6 g/l at 25°C) shows an EC > 2dS/m. Accordingly, all soils having a gypsic horizon (except those with a mollic epipedon) were included in the Gypsiorthids.

The present status of gypsiferous soils

In the last revision of *Soil Taxonomy* (S.S.S., 1987), the soils with a gypsic horizon can belong to three different Orders: those with a xeric moisture regime and a mollic epipedon are Calcixerolls; those without a mollic epipedon are Xerochrepts; and those with an aridic moisture regime are Gypsiorthids. This situation increases the heterogeneity of the Great Group of the Xerochrepts, because a new Subgroup must be created: Gypsic Xerochrepts. Both the current definition of Gypsiorthids and that proposed for Gypsids (ICOMID, 1989) are based on their moisture regime. This results in problems in the location of these soils because soil moisture calculations must be made from scarce field measurements of soil moisture.

Soil moisture regime criteria may not be good enough to discriminate soil behavior and land use when a well developed, massive gypsic horizon is present. Most of these horizons may be classified as hypergypsic (ICOMID, 1989) and under xeric or aridic regimes are impenetrable for roots in the dry season (Porta et al., 1977). The placement of these gypsiferous soils into different Orders (Aridisols and Inceptisols) is not fully satisfactory.

The need for refinement in the gypsic horizon definition

The process of gypsum accumulation in the Aridisols can lead to highly gypsum-rich horizons. Field and micromorphological data about gypsic and petrogypsic horizons around the world has been reviewed by Herrero (1990). Tavernier et al. (1981) used the concept of hypergypsic, and Witty (1985) discussed this, pointing out that some relevant features such as subsidence or erosion that are currently associated with the gypsic horizon can be explained by the gypseous substratum and identified as a phase. It can be concluded that there is a need for refinement of the gypsic horizon definition, and worldwide research is necessary in order to give it a broad scope.

In the xeric and aridic soils studied in Spain (Porta and Herrero, 1990), the gypsic horizons in Gypsic Xerochrepts and in Gypsiorthids commonly have similar micromorphological characters. Moreover, the low water retention capability of gypsum enhances the arid conditions of these soils.

The gyprock often produces a mass of microcrystalline gypsum that can be richer in gypsum than the parent gyprock. So, a gypsum enrichment process can be accepted, although the causes of the formation of this kind of gypsum crystals remain unknown. This material either stands on the parental gyprock or moves along the slope as mud-flow. This weathering product with an upper epipedon may be identified as a gypsic horizon from the morphology and fits the definition of hypergypsic horizon.

Terms affecting the composition and quantification criteria are misused in some cases. Gypsum and calcium sulfate are misused as synonymous, and even $CaSO_4$ (anhydrite) is employed instead of $CaSO_4 \cdot 2H_2O$ (gypsum).

Land Use of Aridisols in Spain

Non irrigated lands

The Aridisols are an important soil resource in Spain, but their moisture is usually too low to support rainfed agriculture. In dry farming, only winter cereals are possible, barley and wheat being the most common. Short duration cereals are often preferred because of drought at the end of each cycle. In some aridic areas in transition with xeric, crops of almond and olive trees are possible. In other areas, dry farming must be alternated with range for grazing sheep, or even only range may be possible. The marginal harvesting of plants such as *Lygeum spartum* for fiber and other plants for soap has been abandoned. Recreation and wildlife could be other alternative uses for these lands.

Irrigated lands

Flooding is the traditional irrigation system in Spain, as in most places in the world. In the new irrigation districts of Spain, sprinkler irrigation is commonly used for extensive crops, and trickle irrigation for fruit trees and vegetable crops.

In the northeast aridic region (Ebro basin), water of good quality was abundant, and rice and drainage were used for salt removal. Notwithstanding, salt-affected Aridisols occur in some irrigated districts of the Ebro basin (Martìnez-Beltràn, 1978; Herrero and Aragüès, 1988). Severe problems remain in soils whose high silt content, sodicity and adverse micromorphological features make pipe drainage difficult (Rodrìguez et al., 1989).

In the southeast aridic region, scattered plots began to be irrigated from small earth reservoirs built for the prevention of flash floods due to storms (Leòn et al., 1987). The increase in irrigated surface has led to some water shortage and quality problems.

Special management practices

After the end of the 19th century, a special soil management system for vegetable production was developed in the southeast of Spain and in the Canary Islands. Shortage of irrigation water and/or low water quality requires the use of this system, which is called "enarenado" (sand mulching). Many effects of "enarenado" have been cited (Martìnez-Raya, 1987): (i) reduction of water loss by evaporation, (ii) atmospheric water condensation, (iii) soil temperature regulation, (iv) advancement of harvest date, and (v) saving in fertilizer. Depending on local soil and climate circumstances or on market considerations, each of these effects can be decisive for the profitability of a crop.

In two decades, a great surface area has been developed with polyethylene covered crops in the aridic zones of southeastern Spain (Leòn and Delgado, 1988). This technique is often combined with "enarenado," and high profitability is being obtained with extra-early horticultural crops.

Conclusions

The broad distribution of Aridisols in Spain is well known. A more accurate discrimination between aridic and xeric in Mediterranean conditions has been attained with Jarauta's mèthod of soil moisture regime calculation. The method was tested in the Ebro basin and could be useful in other areas using soil moisture measurements for control.

Some gypsiferous soils, e.g., in central Spain, that were classified as Aridisols, belong now to Gypsic Xerochrepts. This approach underlines the differences in crop production, but field and micromorphological studies show a convergence in the morphology, behavior, and management of gypsiferous soils in Spain, in spite of their classification in different Orders.

Advances in knowledge of the soil moisture regime of aridic soils must contribute to the planning of soil and water management in wide areas of Spain and to the transfer of agricultural technology.

Literature Cited

Aguilar, J. & al. 1987. Mapa de Suelos 1:100.000. Fiñana. LUCDEME. M.A.P.A. Madrid.

Aguilar, J. & al. 1987. Mapa de Suelos 1:100.000. Macael. LUCDEME. M.A.P.A. Madrid.

Aguilar, J., J. Fernàndez, A. Garcìa, and J. Iñiguez. 1973. Estudio edàfico de la zona de Cabo de Gata. II. Estudio de Mollisuelos y Aridisuelos. An. Edaf. y Agrobiol. 32:299-340.

Alberto, F., J.L. Arru è, and J. Machìn. 1984. El clima de los suelos de la Cuenca del Ebro. I. Reg ìmenes de Humedad. Anales Estaciòn Experimental de Aula Dei 17(1-2):7- 20.

Allas, L.J. & al. 1987a. Mapa de Suelos 1:100.000. Cehegin. LUCDEME. M.A.P.A. Madrid.

Allas, L.J. & al. 1987b. Mapa de Suelos 1:100.000. Coy. LUCDEME. M.A.P.A. Madrid.

Allas, L.J. & al. 1988a. Mapa de Suelos 1:100.000. Lorca. LUCDEME. M.A.P.A. Madrid.

Allas, L.J. & al. 1988b Mapa de Suelos 1:100.000. Puerto Lumbreras. LUCDEME. M.A.P.A. Madrid.

Allas, L.J., and A. de la Torre. 1987. Suelos de la Sierra del Maigmò (Alicante), II: Descripciòn de perfiles. Datos analìticos, clasificaciòn y distribuciòn. An. Edaf. Agrobiol. 46:909-930.

Alonso, A. 1983. Estudio de los suelos de "El Saltador" (Huèrcal-Overa) y "La Vega" (Pulpì), en Almerìa. Doc. Thesis, Univ. Madrid.

Arricibita, F. J. 1987. Tipologìa de suelos salinos en Navarra. Doc. Thesis. Univ. Navarra.

Ayerbe, M. & al. 1978. Guìa de las excursiones cientìficas. VII Reuniòn Nacional de Suelos. Sevilla. CSIC-SECS.

Cline, M.G. 1979. Soil Classification in the United States. Agron. mimeo N° 79-12. Dept. of Agron. Ithaca. 207 p.

Dìaz, J.L. 1987. Estudio edfico y evaluaciòn forestal en la Sierra de los Filabres. I.A.R.A., Sevilla.

Ellas, F., and V. Ibàñez. 1979. Comparaciòn de dos modelos matem àticos para estimar el règimen de humedad del suelo. An. INIA, Ser. General, 6:49-76.

Escobar, F., and C. Roquero. 1973. Estudios agroedafològicos de las àreas con aptitud para producir tabaco en la isla de Tenerife. Min. de Agricultura, Madrid.

FAO. 1974. Soil map of the world 1:5.000.000. Vol. I. Legend. UNESCO. Paris. 59 p.

Fernàndez-Caldas, E., and C.M. Rodrìguez-Hernàndez. 1978. Suelos formados sobre materiales volc ànicos (Islas Canarias). Aridisoles: Natrargids, Calciorthids. An. Edaf. Agrobiol. 37:717-731.

Gascò, J.M., and V. Ibàñez. 1979. Criterios para la estimaciòn del règimen de humedad de los suelos. An. INIA, Ser. General, 6:61-76.

Gisbert, J. 1973. Estudio edafològico del Campo de Cartagena. Desarrollo del Orden de los Aridisoles. Doc. Thesis. Univ. of Valencia.

Gòmez, V., J. Pèrez, and R. Roquero. 1982. The soils and water table properties of polders area Castillo de Do ña Blanca, Puerto de Santa Marìa (Càdiz, Spain). Internat. Polders Symp., The Netherlands.

Gumuzzio, J., J.B. Alvarez, A. Gutièrrez, and J. Guijarro. 1984. Aproximacin a la capacidad de uso de los suelos de Ocaña (Toledo). An. Edaf. y Agrob. 43:93-111.

Guthrie, R.L. 1985. Refinement of taxa based in soil moisture regimes. Proceed. 5th Int. Soil Class. Workshop: 37-38.

Herrero, J. 1982. Salinidad del suelo en salobrares de Monegros y Somontano oscense 'como condicionante de la vegetaciòn. Inst. Fernando el Catòlico. Zaragoza.

Herrero, J. 1990. Morfolog ìa y gènesis de suelos sobre yesos. INIA, Madrid. (in press).

Herrero, J., and R. Aragüès. 1988. Suelos afectados por la salinidad en Aragòn. Surcos de Aragòn 9:5-8.

Huguet del Villar, E. 1929. Geobot ànica. Ed. Labor, Barcelona.

Huguet del Villar, E. 1950. Geoedafolog ìa. (Edition of 1983 by the Univ. of Barcelona).

Ibàñez, V., and J.M. Gasò. 1983. Modificaciones al modelo matem àtico propuesto por Newhall, F. para la estimaciòn del règimen de humedad del Suelo. Comunicaciones INIA. Serie Recursos Naturales. N. 18.

ICOMID. 1989. Aridisols, version 6.0. Internat. Committee on Aridisols.

Iñiguez, J., I. Sànchez-Carpintero, R. Val, F. J. Arricibita, M. Vidal, M. Garjòn, and G. Vitoria. 1988. Mapa de Suelos de Navarra, Hoja 207 y 245. Dep. Edafologìa. Univ. Navarra.

Jarauta, E. 1989. Modelos matem àticos del r ègimen de humedad de los suelos. Aplicaci òn al àrea meridional de Lleida. Doc. Thesis. Univ. Politècnica de Cataluña, Barcelona.

Jimènez Mendoza, C., A Rodrìguez and M.L. Tejedor. 1988. Suelos de la isla de Gomera (Canarias). II. An. Edaf. Agrobiol. 47:1159-1169.

Kubiena, W.L. 1953. The soils of Europe. Thomas Murby & Co. London.

Làzaro, F., F. Elìas, and M. Nieves. 1978. Regìmenes de humedad de los suelos de la España peninsular. Monografìas INIA, 20. Madrid.

Leòn, A., F. del Amor, and A. Torrecillas. 1987. El riego en la regiòn de Murcia. CSIC, Murcia.

Leòn, A. de, and L.F. Delgado. 1988. Memoria del Mapa de cultivos y aprovechamientos de España. M.A.P.A. Madrid.

Macau, F., and O. Riba. 1965. Situacòn, caracterìsticas y extensiòn de los terrenos yes ìferos en España. Serv. Geolgico de O.P., Madrid.

Martìnez-Beltr àn, J. 1978. Drainage and reclamation of salt-affected soils in the Bardenas Area, Spain. ILRI Wageningen.

Martìnez-Raya, A. 1987. Comportamiento del riego bajo enarenado en invernadero. Doc. Thesis. Univ. Madrid.

Milford, J.R. 1987. Problems of deducing the soil water balance in dryland regions from Meteosat data. Soil Use and Manage. 3(2):51-57.

Newhall, F. 1976. Calculation of soil moisture regimes from the climatic record. USDA-SCS.

Ortega, E. & al. 1988. Mapa de suelos 1:100.000. Guadix. LUCDEME. M.A.P.A. Madrid.

Pèrez, A. & al. 1987a. Mapa de Suelos 1:100.000. Roquetas de Mar. LUCDEME. M.A.P.A. Madrid.

Pèrez, A. & al. 1987b. Mapa de Suelos 1:100.000. Tabernas. LUCDEME. M.A.P.A. Madrid.

Porta, J. 1975. Redistribuciones iònicas en suelos salinos: influencia sobre la vegetaciò n halòfila y recuperaci òn de suelos con horizonte gypsic ò y otros suelos halmorfos del r ìo Gigüela. Doc. Thesis. Univ. of Madrid.

Porta, J. 1986. Edafog ènesis en suelos yesìferos en medio semiàrido. Unpubl., E.T.S.I.A. Lèrida.

Porta, J. & al. 1983. Los suelos de Catalu ña: 1. Area meridional de Lèrida. Generalitat de Catalunya. Barcelona.

Porta, J. & al. 1987. Introducci ò al coneixement dels s òls. AEAC, Barcelona.

Porta, J., and J. Boixadera. 1988. Suelos y salinidad en el valle del Ebro. In I. Romagosa & al. (eds.) The basis of Crop Production. AEAC, Barcelona: 177-201.

Porta, J., and J. Herrero. 1990. Micromorphology and genesis of soils enriched with gypsum. Developments in Soil Science 19:321-339. Elsevier.

Porta J., M. Lòpez-Acevedo, and R. Darès. 1980. Los suelos del Campo de Nìjar. C.R.P. Almerìa.

Porta, J., M. Lòpez-Acevedo, and C. Roquero. 1977. Morfometrìa y clasificaciòn de algunos Gypsiorthids en España. Anales INIA, 5:85-111.

Rodrìguez, J., J. Herrero, and J. Porta. 1989. Micromorphological assessment of soil siltation risk indexes in a saline-sodic soil in Monegros irrigation district (Spain). Proc. Work. Meeting on Soil Micromorphology. San Antonio, TX, 1988.

Rodrìguez-Hernàndez, C.M., C. Rodrìguez-Pascual, and E. Fernàndez-Caldas. 1980. Aridisoles formados sobre materiales volc ànicos (Islas Canarias). Natrargids. An. Edaf. Agrobiol. 39:1415-1441.

Sànchez, J.A., and F. Artès. 1982. Gènesis, clasificaciòn y cartograf ìa de los suelos de la regiòn de Murcia. Caja Ahorros Provincial. 72 p.

Simòn, M., J. Aguilar, and C. Sierra. 1980. Los suelos halomorfos de la provincia de Grana da. II.- An. Edaf. Agrobiol. 39:101-120. Soil Survey Staff. 1951. Soil Survey Manual. USDA Handbook no. 18.

Soil Survey Staff. 1960. Soil classification, a comprehensive system. Soil Conserv. Serv. U.S. Dep. Agr. U.S. Govt. Print. Off. Washington DC.

Soil Survey Staff. 1975. Soil Taxonomy. USDA-SCS. Agric. Handb. 436.

Soil Survey Staff. 1987. Keys to Soil Taxonomy (3rd printing). SMSS technical monograph n° 6. Ithaca, N.Y.

Tavernier, R., A. Osman, and M. Ilaiwi. 1981. Soil Taxonomy and the soil map of Syria and Lebanon. Proc. 3rd Int. Soil Class. Workshop. ACSAD, Damascus: 83-93.

Tavernier, R., and A. van Wambeke. 1976. Determinacòn del règimen hìdrico de los suelos de España segùn el modelo matem àtico de Newhall. Agrochimica 20(4-5):406-412.

Torre, A. de la, and L.J. Alìas. 1987. aracterìsticas bioclim àticas de interès edafol ògico de la Sierra del Maigmò (Alicante, S.E. España). Anales de Biologìa 12:29-41. Univ. Murcia.

Witty, J.E. 1985. Diagnostic horizons of carbonate and gypsum accumulations. Proc. 5th Int. Soil Class. Workshop: 269-273.