

## ON THE EARLY IRRIGATION OF GYPSEOUS LANDS IN SPAIN

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### ABSTRACT

Gypseous lands occur mainly in arid regions of the world, where irrigation is required for profitable agriculture. The study of gypseous soils has been neglected for years in the main stream of the soil science. Agriculture and more recently the environmental concerns are  
10 challenging research in the countries that have extensive gypsum outcrops. Those challenges became obvious at least from the 1960's, when the development of some of these countries led to the construction of new irrigation schemes and associated infrastructures. This paper presents examples of documents about agriculture on gypseous soils in Spain which might be illustrative for similar situations in other regions of the world.

15 KEY WORDS: agriculture; aridity; gypsic; gypsum; irrigation; soils.

### INTRODUCTION

The study of crop systems on gypseous soils has been neglected for years, in part because of the scorn of these soils given their constraints for supporting life (Fig. 1). Botanists and ecologists distinctly recognized gypsophilous plants in countries that have gypsiferous  
20 soils, e.g.: Huguet (1925, 1929), Johnston (1941), Braun-Blanquet and Bolòs (1957), Le Houérou (1960), or Parsons (1976), while until recent years, studies on agronomy, soils, or related subjects have been scarce or absent. The world extent and distribution of gypseous soils is not fully known, but estimates range from one to two millions km<sup>2</sup> (Casby-Horton *et al.*, 2015), being noteworthy that these soils are most common in arid and undeveloped countries  
25 where the soils are now under pressure for agriculture and also pose concerns about the environment and biodiversity.

Others have reviewed some of the reasons why gypseous soils have been neglected in research, e.g., Herrero and Poch (1998), Herrero *et al.* (2009), Casby-Horton *et al.* (2015). The references in these articles show that neglect affected the methods of description and  
30 classification, and the study of the genesis, constitution and properties. The lability of gypsum (CaSO<sub>4</sub>•2H<sub>2</sub>O) necessitates simple precautions in the preparation of the samples of gypseous

soils for lab analyses but it provides easy and reliable methods for the gypsum content determination, as reviewed by Herrero *et al.* (2016). In addition, determining the particle-size distribution has been a challenge (Pearson *et al.*, 2015). Specific concepts and terms for soil profile (Fig. 2) descriptions in the field (Schoeneberger *et al.*, 2012) and under the microscope (Poch *et al.*, 2010) have been developed recently. Most of the approaches used in the reviewed studies are penetrating the soil science despite some misunderstandings (Herrero and Mandado, 2016), which occur commonly when new methods or perspectives appear in any field of knowledge.

#### 40 RESEARCH ON GYPSIFEROUS SOILS IN SPAIN

The references cited above provide general information about the research on gypsiferous soils. In the mid-20<sup>th</sup> Century, soil scientists in Spain studied lab methods for quantifying gypsum content in soils (Albareda *et al.*, 1954, 1962) perhaps motivated by the inconveniences that occurred during and after the transformation of rainfed gypseous lands to irrigation (Fig. 3). In their book, which was published in three editions since 1945, Tamés & Peral (1965) note the frequent presence of gypsum in Spanish soils, and the importance of its presence for the correct interpretation of the chemical analyses of soils. The book discriminates the methods for determining sodium, potassium and magnesium based on whether the soil is gypsiferous. Ruiz (1977) studied the routine rapid determination of sulfate and moisture content of gypsiferous materials for public works. In Spain, further advances in methods for the analysis of gypsum in soils occurred at the beginning of 21st century (Artieda *et al.*, 2006; Lebron *et al.*, 2009).

Huguet (1929) and Kubiëna (1952) emphasized the scientific importance of gypseous soils in Spain and adopted specific terms for them. In the 1960s, several contracts with the European Research Office of the US Department of Army produced reports in which the gypsiferous soils were recognized and described, e.g.: Albareda *et al.* (1960, 1961, 1964, 1966). The memories accompanying the maps produced by Guerra *et al.* (1968); Guerra & Monturiol (1970) also described gypseous soils, and Hernando *et al.* (1963) conducted experiments on soil fertility. Other documents might be in the gray literature. Later, the concepts and nomenclature of several versions of the Soil Taxonomy System (Soil Survey Staff, 1999) were used in Spain [see the review by Herrero & Porta (1991) for documents from 1973 to 1988].

#### FLOOD IRRIGATION OF GYPSEOUS SOILS IN THE EBRO VALLEY, NE SPAIN

Spain is the only European country in which gyprock outcrops are common. The Ebro Valley, NE Spain, has a significant extent of surficial gypsiferous materials, resulting in an average annual supply to the sea of 35 Tm of gypsum per km<sup>2</sup> of surface area, or 2.95 10<sup>6</sup> Tm per year (Navas, 1991). Mariño (1986) provides additional information about the export of soluble salts by the Ebro River.

Gypsiferous materials caused damages to irrigation canals that were built from the 19<sup>th</sup> Century to the 1960s (Llamas, 1958), which required practical solutions for their repair (Faci, 1959). The economic assessments of the new irrigation schemes (Gómez-Ayau, 1961) recognized the difficulties in building irrigation canals in gypseous terrains and in identifying crops that are suited for gypsiferous soils. In 1962, the frequent failures related with gypsum in canals, tunnels, roads, and other infrastructures led to a dedicated meeting, the “I Coloquio Internacional sobre las Obras Públicas en los Terrenos Yesíferos” (First International Colloquium on Public Works in Gypsiferous Terrains), in which the problems in the many public works undertaken in previous years were discussed. The Colloquium provided the occasion for publishing the first comprehensive account of the gypsiferous geological materials in Peninsular Spain and Balearic Islands (Macau and Riba, 1962), which contains two very useful maps. The document was a key source for information on the extent and distribution of gypsiferous terrains in Spain, until the review by Escavy *et al.* (2012).

From 1945 to 1970, Spain faced soil problems in the implementation of several new irrigation schemes; however very few scientific publications on these subjects were produced. One example treating soil salinity but also gypsum is Ayers *et al.* (1960) while for gypseous soils the most widely cited is the booklet by van Alphen and De los Ríos (1971/1960), while for gypseous soils, the most widely cited is the booklet by Van Alphen & De los Ríos (1971), which was a substantial information source for different kinds of documents, for example, Stoops & Ilaivi (1981), and FAO (1986, 1990).

The world scarcity of agricultural research about gypseous soils, coupled with linguistic and cultural barriers, and the general difficulties for communication constituted a drawback for the irrigation schemes built in the 20<sup>th</sup> century. Many problems had to be solved by engineers in charge of new irrigation districts based on the empirical knowledge of farmers. This was the case of the central Ebro Valley, where the aridic soil moisture regime (Soil Survey Staff, 1999) necessitates irrigation for profitable agriculture, a need exacerbated by the low water retention capacity of gypseous soils (Moret and Herrero, 2015).

95 Roman inscriptions about irrigation found at the banks of Ebro River (Fatás & Beltrán,  
1997; Beltrán, 2006) allow surmising that tracts of gypseous lands were already irrigated at the  
Roman times, 2100 years ago. Continuous agriculture for more than 200 years is documented  
on gypseous soils irrigated by the Canal Imperial de Aragón whose construction ended in 1790.  
It is noteworthy that its final projected section, with about 30 km long, was not completed  
100 because of the collapse and dissolution of the gypseous materials (Bolea-Foradada, 1986, p.  
300).

Included here as Supplementary material is a transcription of an unpublished 1967  
Report (in Spanish) by F. De los Ríos whose role as the agronomical engineer responsible for 40  
years of the irrigation projects starting in the 1940`s in the Ebro Valley reinforces the  
105 significance of this document. The report contains information about yields, water  
management, ground collapses, land prices, and other details of farmers' experience with  
irrigating gypseous soils by basin and border inundation, the irrigation technology available at  
the moment based on the precise leveling of each plot. The report summarizes the direct  
experience of the farmers, some of whom were using water diverted from the Ebro River via  
110 the Canal Imperial and others were using the then ten-year-old irrigated districts in which  
water came from the Pyrenees.

De los Ríos (1984a) published some of the data contained in his Report. His favorable  
valuation of the yields in irrigated gypseous lands appeared in newspapers (De los Ríos,  
1984b). The observations of De los Ríos conform to the current local experience about  
115 irrigated crops in the Ebro Valley and are consistent with the results of Laya *et al.* (1998) who  
used an objective method to study the relationship between gypsum content in the soil and  
irrigated alfalfa yield.

## CONCLUSIONS

The information and references provided here should be useful in other regions of the  
120 world and inspire research about the agriculture on gypseous lands, especially those under  
irrigation. The advent of pressurized irrigation and the use of plastics have lessened many of  
the problems associated with flood irrigation, and research on hydric and other properties of  
gypseous soils are needed. The new era in irrigation marked by increasing competition for  
water and the use of pressurized systems ought to consider the practical knowledge gained by  
125 engineers and technicians in charge of the irrigation districts installed in the last century.  
Several pertinent references are provided in this article, and the Section "Supplementary  
material" revives one rare document about the irrigation of gypseous lands. The rampant loss

of the farmers experience caused by the rural exodus and the industrialization of agriculture underscores the relevance of gathering information from all sources, which often involves  
130 exhuming documents from the gray literature and making them accessible on the internet.

#### ACKNOWLEDGEMENTS

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### **Figure captions**

Figure 1. The arid landscape on the Miocene gypsum rock outcropping in Alfajarín, Spain, hosts valuable biodiversity. Plowing is restricted to the flat bottoms of the valleys, filled with gypsum and fine materials detached from the slopes. The density of the gypsophilous  
255 vegetation is related to the aspect of the slope.

Figure 2. Gypsic soil horizon developed near Zaragoza, Spain. This flour-like gypseous material is common at the toeslopes of the flat-bottomed valleys. The composition of the pictured soil is 99% gypsum.

260 Figure 3. Sink hole in a gypseous soil in Penelles, Spain, cultivated with chamomile (*Matricaria chamomilla* L.). These flour-like materials, with >60% gypsum, easily dissolve under irrigation.

### **Supplementary material**

The transcript of a Report (in Spanish) by F. de los Ríos appeared in the published article.

265 The two following pages contain the letters between the author and F. de los Ríos in 1983.

*Juan Ignacio Herrero Isern*

*Unidad Nacional, 8, 9.º - A*

*Huesca*

, a 17 de octubre del 1983

Sr. D. Francisco de los Ríos Romero

Camino de las Torres, 35

ZARAGOZA.-

Muy señor mío:

En su obra "Gypsiferous soils" viene citado su trabajo "Terre nos yesososen el valle del Ebro"(I.N.C.).

Tras varias gestiones infructuosas para localizarlo, me decido a dirigirme a Vd. por si pudiera facilitarme algún ejemplar de dicho trabajo.

Agradeciendo de antemano su atención, queda a su entera disposición su s. s.,

*Francisco de los Rios Romero*  
*Zaragoza*

19 de Octubre de 1983

*Fernando el Católico, 12*  
*Teléfono 257399*

Sr. D. Juan Ignacio Herrero Isern  
Huesca.

Distinguido amigo:

El trabajo "Terrenos yesosos en el Valle del Ebro" no fué publicado; fué simplemente un informe que redacté en la Delegación del Ebro del Instituto Nacional de Colonización. Puede ser que tengan algún ejemplar en sus actuales oficinas, hoy IRYDA (Vazquez de Mella 8. Zaragoza) o en la Central del mismo Organismo en Madrid en el Paseo de la Castellana, creo que en el 116.

Ya sabe que queda de uste afectísimo amigo.

