Journal of Hydrology 528 (2015) 122–126

Contents lists available at ScienceDirect

Journal of Hydrology

journal homepage: www.elsevier.com/locate/jhydrol

Technical Note

Effect of gypsum content on soil water retention

D. Moret-Fernández, J. Herrero *

Departamento de Suelo y Agua, Estación Experimental de Aula Dei, Consejo Superior de Investigaciones Científicas (CSIC), Ave. Montañana 1005, 50059 Zaragoza, Spain

ARTICLE INFO

Article history:
Received 14 November 2014
Received in revised form 5 June 2015
Accepted 13 June 2015
Available online 20 June 2015
This manuscript was handled by Konstantine P. Georgakakos, Editor-in-Chief, with the assistance of Venkat Lakshmi, Associate Editor

Keywords:
Calcium carbonate equivalent
Gravimetric water content
Gypsic

SUMMARY

Many gypsiferous soils occur in arid lands, where the water retention capacity of the soil is vital to plant life and crop production. This study investigated the effect of gypsum content on the gravimetric soil water retention curve (WRC). We analyzed calcium carbonate equivalent (CCE), equivalent gypsum content (EG), soil organic carbon content (SOC), and electrical conductivity of 43 samples collected from various horizons in soils in the Ebro Valley, NE Spain. The WRC of the fine earth was determined using the pressure-plate method (pressure heads = 0, −33, −100, −200, −500, and −1500 kPa), and the gravimetric water retention curves were fitted to the unimodal van Genuchten function. Soil gypsum content had a significant effect on water retention. Soils that had high gypsum content made WRC with higher water retention at near saturation conditions, and steeper WRC slopes. The EG threshold at which gypsum content had an effect on WRC was about 40%, and EG was positively and negatively correlated with the α and n parameters of the WRC, respectively.

1. Introduction

The hydrophysical properties of soil, which depend on the soil management and the soil's intrinsic textural and chemical characteristics, have a significant effect on crop growth and development. Under high annual water deficit conditions, hydro-physical properties drive infiltration and evaporation, which are the most important soil-controlled processes that influence soil water storage. Limited, irregular precipitation and high evapotranspiration constrain agricultural production on the arid lands in the Ebro Valley, NE Spain, where gypsum-rich soils are common because the moderate solubility of gypsum ($CaSO_4 \cdot 2H_2O$) allows it to persist as a significant component of the soil.

In some of the agricultural areas within the Central Ebro Valley, a noticeable feature is the contrasting colored patches (from tens to hundreds of square meters, and irregularly shaped), which are commonly referred to as *blanqueros* (white patches, WPs) and *fosqueros* (dark patches, DPs), which have winter cereals that differ in their development (Castañeda and Moret-Fernández, 2013). WPs have soils that have high gypsum content, typically with gypsic or petrogypsic horizons (sensu Soil Survey Staff, 2014). In WP soils, often gypsum co-occurs with calcium carbonate in proportions that have to be measured by chemical analysis because their similar white color makes it difficult to assess by eye their relative proportions in the field. The parent materials –lutite, limestone, and gyprock–, and the aridic soil moisture regime are responsible for the abundance of those minerals, and WPs often occur in areas of high ground relief. In the WPs in which the gypsum –or gypsum plus calcium carbonate– content is high, mineralogical clays and organic matter are negligible. In general, gypseous soils occur in areas that receive <400 mm annual rainfall (FAO, 1990), and gypsiferous materials cover about 22% of the Ebro Valley (Navas, 1983).

Primarily, hydro-physical and mechanical characteristics are the basis for the physical limitations of gypsiferous soils in supporting plant life. Very high gypsum content causes high soil mechanical impedance (Herrero and Boixadera, 2002; Moret-Fernández et al., 2013a), and reduces soil water infiltration rates (Poch et al., 1998; Moret-Fernández et al., 2011), as well as soil water retention capacity (Moret-Fernández et al., 2013a, 2013b). Moret-Fernández et al. (2011) compared the hydro-physical properties of gypseous (from 50% to 92%) and non-gypseous soils under various soil conditions and found that the non-gypseous soils exhibited a more defined microstructure and retained more water at near saturation conditions than did the gypseous soils.

Despite recent research into the relationship between gypsum content and the hydro-physical properties of soils, information about the influence of gypsum content on the soil water retention curve is very limited. The purpose of this study was to investigate the effects of soil gypsum content on the water retention curve and the parameters of the van Genuchten (1980) model.

* Corresponding author.
E-mail address: jhi@eead.csic.es (J. Herrero).

http://dx.doi.org/10.1016/j.jhydrol.2015.06.030
0022-1694/

2. Materials and methods

Samples were collected from twelve gypsiferous soils on the Barbastro Gypsum Formation, a Late Eocene-Early Oligocene evaporitic Formation outcropping in the core of the Barbastro–Balaguer anticline (Lucha et al., 2012), and from one gypsiferous soil on the Zaragoza Gypsum Formation, a Miocene evaporitic Formation in the center of the Ebro Valley (Quirantes, 1978). The main outcrops of these Formations are depicted in Fig. 1. The mineralogy of the soils and parent materials was examined in thin sections of undisturbed blocks under a polarizing microscope.

Forty-three soil samples were collected from various horizons (Table 1). To prevent the loss of soluble salts, the soil samples were spread over plastic trays and air-dried in the lab at room temperature for several weeks. To minimize the fracturing of the gypsum crystals, the samples were crushed gently by hand using a wooden roller, and sifted by hand through a 2-mm mesh sieve. Most of the samples contained no or negligible coarse fragments. Subsequent chemical and physical analyses were conducted on the fine earth.

Calcium carbonate equivalent (CCE) was measured using a Bernard calcimeter. The equivalent gypsum (EG); i.e., the total sulfates expressed as gypsum, was calculated based on the gravimetry of total sulfates after attack with hot HCl and precipitation as barium sulfate in a glass filtering crucible. Standard methods for the preparation of soil samples involve drying at 105 °C, which can cause the loss of the constitutional water of the gypsum crystals ($CaSO_4{\cdot}2H_2O$), and the artifactual production of other calcium sulfate minerals, bassanite ($CaSO_4{\cdot}½H_2O$) and anhydrite ($CaSO_4$) (Steiger, 1910; Artieda et al., 2006; Herrero et al., 2009; Lebron et al., 2009), which would create spurious results in subsequent analyses; e.g., water retention capacity. Therefore, soil samples were dried at 40 °C (Herrero et al., 2009). Soil organic carbon (SOC) was measured using the Walkley–Black Method. Electrical conductivity was measured in extracts at a 1:5 soil-to-water weight ratio (EC1:5, dS m^{-1}), with 24 h of soil–water contact. Saturated pastes (United States Salinity Lab, 1954) were prepared and saturation percentage was recorded. The pastes were left overnight before extracts were made and electrical conductivity (ECe, dS m^{-1}) was measured immediately. EC measurements were converted to the standard temperature (25 °C). The difference between 100 and the sum of EG plus CCE of each sample is considered as remaining soil material, i.e., non-EG non-CCE contents.

The gravimetric water retention capacity of the samples was measured on disturbed 2-mm sieved soil using the pressure-plate method at the pressure heads (Ψ) of −33, −100, −200, −500, and −1500 kPa. Water content of the saturated pastes was taken as the 0 kPa pressure head. Measurements were duplicated and, if the difference was >5%, additional measurements were taken, and the results are based on the mean of the two or more replicated measurements. When the samples that came from the plates were dried, the temperature never exceeded 40 °C (Klute, 1986). Under the assumption that residual volumetric water content is equal to zero, the SWRC Fit V.1.2 software (Seki, 2007) (http://seki.webmasters.gr.jp/swrc/) was used to fit the gravimetric water retention curve (WRC) and the corresponding effective saturation curves, S_e, to the unimodal van Genuchten (1980) model

$$w(\psi) = w_s\left[\frac{1}{1+(\alpha\psi)^n}\right]^m \tag{1}$$

$$S_e = \frac{w(\psi)}{w_s}$$

where w_s and $w(\Psi)$ are the gravimetric saturated and water content at pressure head Ψ, respectively, n is the pore-size distribution parameter, $m = 1-(1/n)$ and α [kPa] is the scale factor.

Fig. 1. Locations of the main outcrops (in grey) of the Zaragoza Gypsum Formation and the Barbastro Gypsum Formation, in the Ebro Valley where soil samples were collected from thirteen sites.