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Pore size distribution in relation to soil physical properties in two irrigated semiarid Mediterranean soils as affected by management

I. Virto, M.J. Imaz, P. Bescansa and A. Enrique

Área de Edafología y Química Agrícola. Dpto. Ciencias del Medio Natural.

Universidad Pública de Navarra. Campus Arrosadía s/n. 31006 Pamplona (Spain)

inigo.virto@unavarra.es / Fax: +34 948 168930 / Phone: +34 948 169166

INTRODUCTION

Most authors studying soil quality from a holistic point of view agree with Miedema (1997) in the need of understanding the processes involved in the formation/destruction of soil structure in order to better comprehend the effect of agriculture and its consequences on soil in the long term. The effect of some agricultural practices such as irrigation and crop rotation on soil structure will depend both on the soil natural properties (particle-size distribution, organic matter content, etc.) and the intensity of such practices.

Pore space measurements are being increasingly used to quantify soil structural changes following agricultural activities (Pagliai et al., 2004). Among other techniques, the soil pore system can be characterized through image analysis of soil thin sections (Stoops, 2003). When some stereological considerations and technical parameters are taken into account, pores can be characterized according to their size and shape and pore-size distribution (PoSD) can be defined.

According to Greenland (Carter & Ball, 1993), pores can be classified as fissures ($>$ 500 μm of equivalent pore diameter (epd)), transmission pores (500-50 μm), storage pores (5-50 μm) and residual pores ($<$ 0,5 μm). Since soil thin sections are usually 20-30 μm thick, only pores bigger than this size can be characterized in this case. Several pore shape factors (PSF) have been developed, that are in general an estimation of their roundness.

MATHERIALS AND METHODS

Two characteristic agricultural soils from a semi-arid area in NE Spain were selected for the study. Soil 1 was classified as *Typic Xerofluvent* (Soil Taxonomy, 1998). It was developed on unconsolidated material from the Quaternary and it supported a crop rotation under flood irrigation. Soil 2 (*Cambic Gypsiorthid* (Soil Taxonomy, 1998)) was developed on a higher terrace. As a consequence of its situation close to a gypsic formation, its principal characteristic was the abundance of pedogenetic gypsum and fragments of gypsum rock. This soil supported an irrigated alfalfa sod with sprinklers.

Undisturbed soil samples were collected after four years of continuous cropping using Kubiëna boxes in Fall 2001 at 0-15 cm depth in two sites per soil (sites 1A, 1B, 2A and 2B). Thin sections 20 μm thick were obtained from the impregnated blocks, which had an area of 55 $\times$ 85 mm. Fifty-four points were randomly selected in each section and two photographs were taken in each point at 10x magnification. One photograph was taken under transmitted polarized light (PL), and the other under circularly polarized light (CPL) according to Marcelino et al. (2000). For each point, both images were transferred to gray-scale and then the PL image was subtracted to the CPL image, so that a gray image was obtained in which only pores were black (Fig.2). This image was transformed into a binary (black&white) image through manual segmentation.

Also undisturbed samples were collected in duplicate in steel rings in the area adjacent to the ones sampled for thin sections. These were used to determine soil permeability in a laboratory constant-charge water permeameter. Simultaneously, disturbed soil samples were collected at the same locations in sets of 6 replicates for particle size analysis (PSD) and other chemical determinations (Virto et al., 2004). Soil hydraulic conductivity was determined in situ with a double-ring permeameter.

RESULTS AND DICUSSION

Soil physical characteristics

Differences in PSD were observed between the two sampling sites in soil 1. A bigger amount of fine particles and less coarse fragments were observed in site 1B. This was directly related to the lower values of saturated hydraulic conductivity and permeability detected in this area. Due to the long periods of flooding occurred in the area as a consequence of irrigation and low permeability, crop development was also poorer in site 1B than in site 1A..

Results were different in soil 2.. Despite of no textural differences occurring, differences in permeability were detected and were contrary to those in hydraulic conductivity. The relatively high content in expansible clays and gypsum might be related to the low values of permeability. Saturated hydraulic conductivity was higher in site 2B than in site 1B

Porosity

Parameters used to characterize pores through image analysis were area, perimeter, elongation, roundness, sfericity, equivalent pore diameter (epd) and compactness. PSF was inferred from the area and perimeter of each pore.

Data obtained from binary images were used for the calculation of the PoSD. Pores from sites 1A and 1B fitted with high significance to a log-normal distribution, as described by Giménez (2002). However, the shape of the PoSD curves was different in the two sites. The relative abundance of smaller pores was bigger in site 1B. The statistical analysis of both pore populations showed significant differences in pore size, but not in their shape. When pores were split into categories according to their shape (rounded, irregular and elongated) it was found that most of them were irregular pores in both sites. It was also observed that elongated pores were bigger in size, according to the idea that soil pores trend to be more elongated when their size increases (Pachpesky et al., 1996).

When pores size and shape were statistically studied together, it was observed that irregular storage pores were bigger in site 1B than in site 1A, that had, on the contrary, a bigger percentage of elongated pores bigger than 50 μm in epd. These results were in accordance with differences found in PSD and explained the hydraulic limitations described in site 1B.

The study of PoSD in the two sites in soil 2 showed different results. The adjustment to a log-normal distribution was good, but unlike in soil 1, no differences were found in the shape of the curves (i.e. in the relative abundance of pores of different sizes).

The statistical analysis of pore data in sites 2A and 2B showed no differences in size but in shape. However, when these differences were studied in the size categories described above, it was found that they took place in the smallest studied category (20-50 μm of epd), as it can be observed in figure 4.

It can be seen how the only significant difference happened to be the percentage of irregular and elongated pores smaller than 50 μm in epd. The physical interpretation of this fact seems unimportant, since these are storage pores, although elongation is usually linked to better connectivity and water transport characteristics.

CONCLUSSIONS

PoSD in soil 1 was directly related to soil properties and hydraulic characteristics.

Besides the finer texture, the poorer crop growth and irrigation technique (flooding) were likely related to the smaller average pores found in site 1B.

However, differences observed in soil 2 were only in the percentage of irregular and elongated storage pores that were more abundant in site 2A. Since no differences in PSD were found between the two sites, the slight differences found in the saturated hydraulic conductivity might be related to this fact.

According to our results, image analysis as described showed to be a reliable and accurate technique for soil PoSD characterization.

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