Two-Dimensional Porosity of Crusted Silty Soils: Indicators of Soil Quality in Semiarid Rangelands?

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Little is known about the morphological characteristics of pores in soil crusts. The objective was to characterize the two-dimensional (2D) porosity (amount, shape, size, and area of pores) of soil crusts to ascertain their potential as indicators of soil quality for natural crusted soils. The 2D-porosity was described in thin sections and measured by image analysis of polished resin-impregnated soil blocks. Physical soil crust and incipient biological soil crusts appear to be the lowest-quality soils in terms of number of pores (average of 131–133 cm^{-1}) and area occupied by pores or meso-macroporosity (3.5–4.2%). Their most abundant pore types were small unconnected rounded pores. Soil crust infiltration coefficients (65–72% annual) were among the lowest and their high erosion rates (81–204 g m^{-2} yr^{-1}) were not only due to their lower total porosity, but also to their pore shapes and sizes. Biological soil crusts appear on higher-quality soil, where the higher the organic C content, the more evolved the soil crust is (with lichens and cyanobacteria). Such soil crusts have better developed pore-systems with specific meso- and macropore morphologies, for example, large, interconnected elongated and irregular pores. Biological soil crusts (BSCs) dominated by lichens have the largest meso-macroporosity (up to 23.65%) due to the predominance of elongated pores. In many cases, infiltration is low (46–57%) because the biological crusts are somewhat detached from the soil underneath, but the armouring effect decreases erosion rates (7–23 g m^{-2} yr^{-1}). Soil crust pore numbers, size, and shape were useful indicators of soil quality.

Abbreviations: AP, area occupied by meso-macropores divided by the total ROI area, in percentage or meso-macroporosity; BSC, biological soil crust; CVS, crusted vegetated surface; IBC, incipient biological soil crust; LC, lichen crust; NP, number of macropores in every ROI divided by its surface; PSC, physical soil crust; ROI, region of interest; 2D, two dimensional.

Physical and biological soil crusts (PSC and BSC, respectively) constitute the main types of soil cover in most arid and semiarid areas worldwide. Although they are an almost negligible portion of the soil profile, they play a significant role in ecosystems (Belnap et al., 2001), as they control vertical and horizontal fluxes of nutrients, water, gases and heat to and from the soil (Beymer and Klopatek, 1991; Belnap, 1995; Belnap and Gillette, 1998). Physical soil crusts are transient soil-surface layers (ranging in thickness from <1 mm to a few centimeters) that are structurally different from the material immediately beneath them. Biological soil crusts are a complex mosaic of cyanobacteria, green algae, lichens, mosses, microfungi, and other bacteria (Belnap et al., 2001).

Considering that arid and semiarid regions cover about 40% of the Earth's land surface (Reynolds et al., 2007), the mentioned effects on the ecosystems where soil surface crusting appears may play a crucial role in soil quality (NRCS, 1996). At present, soil quality is defined not only in terms of soil production capacity, but also in terms of stability or resilience to environmental perturbation (Hartemink, 1998; Miralles et al., 2009). However, despite the fact that soil quality has been subjected to extensive research (Singh and Tripathy, 1992; Jurgensen et al., 1996; Sahani and Behera, 2001, and references therein), most studies are performed at humid sites and very few in arid or semiarid zones (Miralles, 2007; Miralles et al., 2009). In such zones, physical and biological crusts are especially

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