Catena 110 (2013) 24–31

Contents lists available at SciVerse ScienceDirect

Catena

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

Can occurrence of soil hydrophobicity promote the increase of aggregates stability?

E.S. Vogelmann [a,*], J.M. Reichert [a], J. Prevedello [b], G.O. Awe [c], J. Mataix-Solera [d]

[a] Soil Department, Federal University of Santa Maria, Santa Maria, Brazil
[b] Forestry Sciences Department, Federal University of Santa Maria, Santa Maria, Brazil
[c] Soil, Crop and Environmental Sciences Department, Ekiti State University, Ado Ekiti, Nigeria
[d] Agrochemistry and Environment Department, University Miguel Hernández, Elche, Alicante, Spain

ARTICLE INFO

Article history:
Received 25 March 2013
Received in revised form 6 June 2013
Accepted 7 June 2013

Keywords:
Water repellency
Sorptivity
Water content
Organic matter

ABSTRACT

The soil hydrophobicity can be understood as soil water repellency or difficulty in wetness. This phenomenon is associated with the covering soil particles and hydrophobic organic compounds reducing the soil sorptivity and hence infiltration of water. The objectives of this study were to determine the level of hydrophobicity in the soil and assess its relationship with resistance and size distribution of water stable aggregates, particle size distribution and organic matter content of different soils in southern Brazil. Undisturbed soil samples were collected in different soil layers, 0–5, 5–10 and 10–20 cm, to determine soil sorptivity, geometric mean diameter and aggregate stability index while granulometric composition and organic matter content were determined using disturbed soil samples. The sorptivity test was conducted using a tension micro-infiltrometer, with two different liquids, distilled water and ethanol (95% v/v). The proportions of sand, silt and clay did not correlate significantly with the occurrence of hydrophobicity. In the hydrophobic soils, hydrophobicity index is directly associated with high organic matter contents and did not correlate with the particle size distribution. For the hydrophobic aggregates, cohesive forces between the particles acted for long period as a result of slow wetting, which led to an increase in geometric mean diameter, stability index of water stable aggregates and consequently greater resistance to the disintegrating actions of associated agents.

1. Introduction

Hydrophobicity is a phenomenon widely documented in several countries (Doerr et al., 2007; Hallett, 2008; Jaramillo, 2006). Recently, in Oceania (Deurer et al., 2011) and South America (Jaramillo, 2006; Johnson et al., 2005; Vogelmann et al., 2010) regions, it was observed that hydrophobicity affects large areas and can cause reductions in crop yields. Positive correlation between hydrophobicity and aggregates stability in soils was recently reported after bush fires by Arcenegui et al. (2008) and Jordán et al. (2011). Mataix-Solera et al. (2011) and Vogelmann et al. (2012) found that areas subjected to forest fires are being induced to exhibit soil hydrophobicity, mainly due to the accumulation of hydrophobic substances released during burning, which form on the surfaces of aggregates and act as cementation agents, thereby increasing the stability of soil aggregates.

However, hydrophobicity does not manifest in the soil permanently, the intensity is maximum during dry periods and decreases or even disappears in the wet season (Wahl, 2008). Therefore, in a non-repellent soil with low water content, the initial wetting process may be faster theoretically due to high matric potential of the dry soil. However, in hydrophobic soils, this process can be extremely slow, even under conditions of low soil moisture (Dekker and Ritsema, 1994). This difficulty in wetting can attenuate the disaggregation of the soil against the erosive action of agents such as, because, cohesive forces are more pronounced in increasing its resistance to breakdown.

Mataix-Solera et al. (2011) reported that in hydrophobic soils, there was a reduction in the infiltration rate while the hydrophobic aggregates remain dry for long periods, and thus, it is possible to infer that the cohesive forces between particles will act longer due to slow wetting. This increases the structural stability of soil aggregates indirectly and therefore the resistance to the disintegrating action of erosive agents. However, affirmed that further studies are needed for validation in contrasting soil textures and environmental conditions, with a view to making accurate and valid conclusions about the relationship between the aggregate resistance and the presence of hydrophobic compounds in soils.

Therefore, we hypothesized that due to the organic matter content of soils correlate with the hydrophobicity index, hydrophobic soils indirectly would present high strength water-stable aggregates and thus greater resistance to disaggregation. Thus, the objective of this

* Corresponding author at: Centro de Ciências Rurais, Universidade Federal de Santa Maria, Santa Maria, RS, Brazil. Tel.: +55 55 3220 8157.
E-mail address: eduardovogelmann@hotmail.com (E.S. Vogelmann).

0341-8162/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.catena.2013.06.009

study was to evaluate the effect of organic matter content and the level of soil hydrophobicity in the resistance and size distribution of water stable aggregates of different soil classes.

2. Materials and methods

2.1. Description of study site

A laboratory study was conducted during the 2011 summer season on soil samples from different soil types from Rio Grande do Sul state, southern Brazil. According to Köppen climatic classification, the climate of the area is Cfa, subtropical humid, with mild winters and hot summers, intermediate stations separated by about three months and well distributed rains throughout the year. The average annual rainfall ranges from 1500 to 1700 mm and the mean annual temperature is 17 °C (Nimer, 1990).

2.2. Description of soil morphological attributes and vegetal composition

Prior to sampling, classification and description of the soil morphological attributes of the sites were performed according to the methodology described by Schoeneberger et al. (2002). The diagnostic horizons were identified and the soils were classified according to the Brazilian system of soil classification (EMBRAPA, 2006) and soil taxonomy (Soil Survey Staff, 2010) (Table 1). Composite soil samples were collected for the determination of chemical and physical parameters. The geographical coordinates of the sampling points were recorded and a location map was made with those data (Fig. 1).

The sampling sites showed no evidence of recent anthropogenic changes, such as land preparation and management, however, all areas are being used as pasture for beef cattle. Also the vegetal composition was observed visually to ensure that the sampling sites are composed solely of natural grassland. The main species present in the area are grasses: *Andropogon lateralis Nees*, *Axonopus affinis Chase*, *Paspalum* spp. and *Aristida laevis* (*Nees*) *Kunth*.

2.3. Soil samples collection

At each site, we sampled three different points, all with the same floristic composition. At each point (Fig. 1), undisturbed soil samples were collected from soil layers, 0–5, 5–10 and 10–20 cm for the determination of bulk density and sorptivity using core samples of 5.7 cm diameter. In each soil layer, 4 samples were collected, totaling 12 samples per point and 36 samples for each soil type. Also, disturbed soil samples were collected at the same locations and layers for the determination of particle size, particle density, organic matter content and aggregate stability.

Table 1
Classification of the nine soils analyzed according to soil taxonomy (Soil Survey Staff, 2010), Brazilian system of soil classification (EMBRAPA, 2006) and geographical coordinates of sampling points.

Soil taxonomy	SiBCS*	Latitude	Longitude
Dystrudept	Cambissolo Háplico Eutrófico	S 29° 38′ 41.5″	W 53° 45′ 19.6″
Hapludox1	Latossolo Vermelho Distrófico	S 28° 40′ 30.8″	W 53° 35′ 47.0″
Hapludox2	Latossolo Vermelho Distroférrico	S 27° 54′ 27.2″	W 53° 18′ 08.5″
Haplohumult	Argissolo Vermelho-Amarelo Alumínico	S 29° 43′ 35.7″	W 53° 45′ 23.3″
Paleudalf	Argissolo Vermelho Distrófico	S 29° 43′ 12.4″	W 53° 42′ 10.8″
Haplaquents	Gleissolo Háplico Distrófico	S 29° 43′ 08.7″	W 53° 42′ 07.2″
Albaqualf	Planossolo Háplico Eutrófico	S 30° 02′ 26.6″	W 53° 40′ 42.7″
Endoaqualf	Luvissolo Háplico Órtico	S 30° 08′ 26.6″	W 53° 35′ 37.7″
Hapludert	Vertissolo Ebânico Órtico	S 30° 43′ 14.7″	W 55° 47′ 41.5″

* SiBCS — Brazilian system of soil classification.

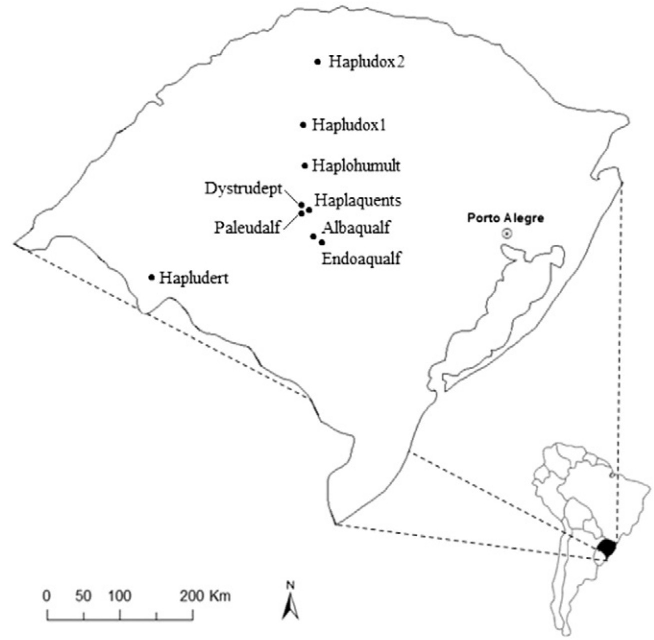

Fig. 1. Location of the sampling points in nine soil profiles in Rio Grande do Sul state, Brazil and in South American perspective.

2.4. Characterization of soil physico-hydric properties

2.4.1. Bulk density and porosity

Particle size distribution was determined using the pipette method (Gee and Bauder, 1986) while the particle density was by the volumetric flask technique (Flint and Flint, 2002). The undisturbed samples were saturated by capillary rise in a water bath for 48 h and oven dried at 105 °C to constant weight to determine the bulk density. Total porosity (Tp) was obtained by Eq. (1):

$$Tp = \left(1 - \frac{Bd}{Pd}\right) \times 100 \quad (1)$$

where: Bd is the bulk density (g cm^{-3}) and Pd is the particle density (g cm^{-3}).

2.4.2. Aggregate stability

In the laboratory, soil samples were separated manually by observing the cleavage surface until aggregate sizes smaller than 8 mm were obtained. The structural stability in water was determined by the modified method of Kemper and Chepil (1965). For this determination, the aggregates were shaken in water using a vertically oscillating device (Yoder, 1936) with sieve mesh 4.76, 2.00, 1.00, 0.50, 0.25 and 0.105 mm.

The structural stability was expressed as the geometric mean diameter (GMD) and aggregate stability index (ASI) following the methodology proposed by Tisdall et al. (1978), and was calculated according to Eqs. (2) and (3) respectively:

$$GMD = EXP\left[\frac{\sum_{i-1}^{n} AGR_i \times \ln_{(ci)}}{\sum_{i-1}^{n} AGR_i}\right] \quad (2)$$

$$ASI = \frac{GMDh}{GMDd} \quad (3)$$

where: GMD is the geometric mean diameter size of the aggregates, $\sum_{i-1}^{n} AGR_i$ is the total mass of aggregate (less the weight of sand); ln is the natural logarithm; ci is the average aggregate class i; ASI is the aggregate stability index; GMDh is the geometric mean diameter