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Development of pedotransfer functions for estimating water retention curve for tropical soils of the Brazilian savanna

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ABSTRACT

Pedotransfer functions developed especially for predicting soil-water retention for tropical soils are very scarce and the existing ones still need improvement. The aims of this work were to create a consistent database about the physical properties of the Brazilian savanna tropical soils and to develop specific pedotransfer functions for estimating their soil-water retention characteristics. The soil database, which consisted of soil-water retention curves and related soil-physical characteristics, came from 413 locations and various depths, totalizing 1401 soil layers. Two non-linear models were proposed to estimate the four parameters of the van Genuchten equation, used to describe soil-water retention curves. The performance of the proposed models was statistically evaluated and their estimation efficiency was compared with the Tomasella's pedotransfer function considered as a reference for Brazilian soils. The soil database generated in the scope of this study is quite representative of the Brazilian savanna region. The success in predicting soil-water retention curve by using the herein developed pedotransfer functions was about 70%, which is much higher than the percentage of success obtained by Tomasella's model level 1 (20%) for the same soil database.

1. Introduction

The Brazilian savanna (Cerrado biome) covers about 204 million ha which corresponds to 24% of the Brazilian territory (IBGE, 2004). Oxisols, Entisols, and Ultisols represent approximately 50%, 15%, and 14% of the Cerrado soils, respectively (Reatto et al., 2008a). The prevailing soils in this region (Oxisols) are characterized by poorly differentiated horizons, week macrostructure, and strongly developed fine-granular structure (Embrapa, 1999), resulting in subrounded micro-aggregates 50 to 200 μm in size (Balbino et al., 2002; Vollant-Tuduri et al., 2005). The strong microaggregation observed in a majority of these soils has been suggested as a possible explanation for their hybrid behavior in terms of soil-water retention (SWR) (Holzhey and Kimble, 1988; Sanchez, 1976; Sharma and Uehara, 1968). Usually, at lower matric potentials (−100 to −1500 kPa), the SWR of this type of soils reflects the clay content and thus behaving as soils from temperate regions; at intermediate matric potentials (−0.3 to −100 kPa) it reflects the characteristics of low silt content; and at higher matric potentials (0 to −0.3 kPa) it resembles sandy soils, expressing the presence of large number of pores with diameter greater than 0.1 μm (Holzhey and Kimble, 1988). This rather unusual soil-water retention behavior, as compared to soils from temperate regions, has been appointed and suggested as the main reason why many of the developed pedotransfer functions do not predict adequately soil-water retention values for tropical areas (Hodnett and Tomasella, 2002; Minasny and Hartemink, 2011; Tomasella and Hodnett, 1998, 2004; Tomasella et al., 2000).

The development and importance of pedotransfer functions (PTF) for many applications in soil-water modeling have been well documented (Pachepsky and Rawls, 2004; Wösten et al., 2001). Most of the existing PTF models have been developed on the basis of one of the following approaches: simple lookup tables for particular textural classes (Carsel and Parrish, 1988; Wösten et al., 1995); linear and non-linear regression-based models (Minasny et al., 1999; Rajkai et al., 2004; Rawls and Brakensiek, 1985; among others); physically-based relationships derived from the soil-water flow phenomena (Arya and Paris, 1981; Haverkamp and Parlange, 1986; Nimmo et al., 2007; Tyler and Wheatcraft, 1989); artificial neural network (Minasny et al., 1999; Pachepsky et al., 1996; Tamari et al., 1996); group method of data handling (Pachepsky and Rawls, 1999); or nonparametric neighbor technique (Nemes et al., 2006a, 2006b).

Pedotransfer functions developed especially for predicting soil-water retention for tropical soils are very scarce and the existing ones (Barros et al., 2013; Hodnett and Tomasella, 2002; Tomasella and Hodnett, 1998; Tomasella et al., 2000) still need improvement. The soils included in the database used for generating their functions are somewhat limited in relation to their ability to represent the wide variety of Brazilian soil classes. Their pedotransfer functions really represent a significant advancement for modeling SWR for tropical soils, however, as they clearly recognize (Tomasella et al., 2000), it is necessary to promote additional studies to enlarge the soil database and recalculate the model coefficients in order to turn their pedotransfer functions more

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capable to predict the water retention characteristics of these types of soils.

The aims of this work were to create a consistent database about the Cerrado soil physical properties and to develop specific pedotransfer functions for estimating their soil-water retention characteristics.

2. Material and methods

2.1. Data collection and use

The database used for estimating and validating the model parameters of the proposed pedotransfer functions was formed by measured data of soil-water retention and soil physical properties, such as bulk and particle density, clay (<0.002 μm), total sand (2.000–0.050 μm), silt (0.050–0.002 μm), and organic matter with soil samples collected at various depths from 413 locations, mostly within the boundaries of the Cerrado biome (Fig. 1). The sample locations were situated in the following Brazilian States: 3 locations in Amazon (AM); 37 in Bahia (BA); 209 in the Federal District (DF); 75 in Goiás (GO); 2 in Maranhão (MA); 48 in Minas Gerais (MG); 25 in Mato Grosso (MT); 3 in Pará (PA); and 11 in Tocantins (TO). Most of these locations are inside the boundaries of the Brazilian Central Plateau, however, some of them come from bordering areas of Cerrado and Amazon biomes.

Whenever possible, the soil samples were collected from the following layers: a) top soil surface (0.00–0.05 m); b) intermediate layer (0.15–0.20 m); and c) soil diagnostic layer (0.60–0.65 m). The main idea behind this sampling strategy was to get from each location, if possible, information from the two soil layers where physical and chemical properties are normally altered if it is a cultivated soil and also from a deeper soil layer where these properties would be kept relatively unchanged and thus serving as a reference for the soil diagnostic horizon as it was in its natural condition. This soil survey was also done in collaboration with other studies which sometimes had their own sampling strategy in terms of soil depths and locations, so that some of the soil profiles included in this database had their samples taken from other soil depths. Each data set obtained from a given sampled soil layer was catalogued as one data entry for the database, thus totalizing 1401 soil layers.

The available database was split into two data sets as follows: a) a database formed by the first analyzed 1092 soil layers, randomly collected, to serve as the basis for adjusting the model parameters of the proposed pedotransfer functions; and b) the other set was composed by the remaining 309 soil layers which were collected and used to validate the proposed pedotransfer models and also to verify the performance of the Tomasella's PTF (Tomasella et al., 2000). The soil samples that compose the estimating data set came from 333 locations while the ones used to form the validating data set came from 80 locations. All the samples were georeferenced (Fig. 1).

2.2. Soil-sample analysis

For the estimating data set, each soil-water retention curve was formed by the mean value of the gravimetric water content measured at either six points (1; 6; 10; 33; 304; and 1520 kPa) or nine points (1; 3; 6; 10; 35; 85; 405; 1027; and 1515 kPa) of matric potential values as defined by Silva et al. (2006). The resulting mean values for each matric potential were obtained from either two replications (154 sampled layers), three replications (771 layers), or four replications (167 layers), totalizing 3289 entries. For each sampled layer, a set of soil property data composed of non-replicated bulk and particle density,

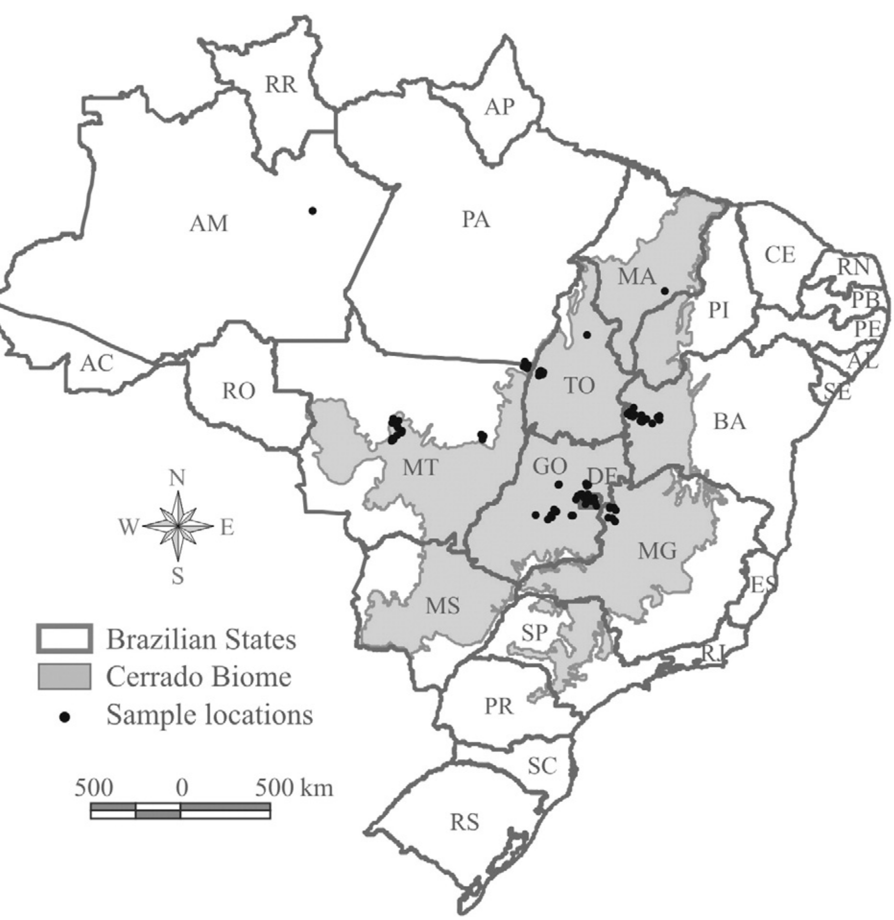

Fig. 1. Location of the soil profiles that were used to either estimate or validate the proposed pedotransfer functions (413 locations).