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Accuracy of Pedotransfer Functions to Estimate Soil Bulk Density in Brazil

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Thematic Session: Legacy data: How turn it useful?

Abstract

Soil bulk density is an important soil physical property, used as a quality indicator. Its variation influences soil water content and carbon stock estimates. This study aims to evaluate the accuracy of pedotransfer functions that predict bulk density in Brazil. The predictive capacity of 14 pedotransfer functions were evaluated using the Pearson correlation (*r*), the mean standard error (MSE), and the root mean square error (RMSE). The best results were obtained by Benites *et al*. (2006) – B, Botula (2013), and Souza *et al*. (2016). However, the inaccuracy is not acceptable for some applications and new functions considering a hierarchical system of soil data considering soil class and depth (surface or subsurface), land use (agriculture, pasture, and forest) and management (no-tillage, conventional or livestock farming forest integration) will be developed and tested.

Introduction

Soil bulk density (BD) is not determined in routine soil laboratories (De Vos *et al*., 2005), mainly due to its specific applications and limited use in fertilizer recommendations. However, BD is a means to evaluate sustainable soil management practices (Botula, 2013), especially for soil structure quality, as it reflects compaction (Assouline, 2006). Additionally, Agricultural Zoning of Climatic Risk (ZARC) provides information on planting dates and the probability of unfavorable weather events for the entire territory. ZARC uses a time series of climate data, phenological information and available soil water (ASW). ASW data came from pedotransfer functions estimatives that in nowadays are estimated by a particle size distribution (Teixeira *et al*., 2021). BD data may improve the ASW estimatives. Moreover, crop models as Decision Support System for Agrotechnology Transfer - DSSAT (Hoogenboom *et al*., 2019) need the BD values of soil horizons to run the analyses and predictions. Another demand or BD data is as to estimate soil stock of carbon for the inventory Measurement, Reporting and Verification of greenhouse gas (GHG) mitigation, especially from agriculture (Bernoux *et al*., 1998; De Vos *et al*., 2005; FAO, 2020). Considering its importance, the lack of BD data and the possibility of using pedotransfer functions (PTFs) to estimate missing information, the objective of this study was to evaluate the accuracy of available PTFs to predict soil BD for Brazil.

Methodology

The BD data associated with soil chemical and physical properties were obtained in the Hydrophysical Database for Brazilian Soils - HYBRAS (Ottoni *et al*., 2018) and other data sets totaling 2,635 soil samples data. The soil samples, parameters ranged as follows: 0.4, 0 and 0% for sand, silt, and clay minimum contents respectively; 98.8, 83, and 96% respectively for maximum values. Organic carbon (OC) values ranged from 0 to 62.1%; pH (water) ranged from 2.4 to 9.6, and the sum of bases from 0.3 to 502 $mmol_c\ kg^{-1}$. 14 PTFs were analyzed. These PFTs were created for a large variety of soils from different locations. They use as estimator parameters: sand, silt and clay content, organic carbon (OC), pH, partial sum of cations, and sum of bases. For each BD-PTF estimative, the range limits were respected. The Pearson correlation coefficient (*r*) represents the precision of results. *i.g*., the higher *r* values are the best, the mean standard error (MSE), and the root mean square error (RMSE), were used to analyze the accuracy of BD estimate values. Coefficient of variation (CV) was also used. The lower MSE and RMSE indicate the higher accuracy in the prediction.

Results and discussion

The 14 BD-PTF equations used in this study, the location where the most data are from, the predictive soil parameters and the precision and accuracy indices are shown in Table 1. The best indices (*r*, RMSE and MSE) were observed for the Benites – B, Botula and Souza PTFs (Table 1). Due to the dispersion of measured values in relation to deviations, the Benites – B function showed greater variation, especially for low BD values (Figure 1). The proposed function considered few samples with low BD, as well as high BD samples. Thus, low BD values are underestimated, and high BD values are overestimated. Similar trend was observed with the PTFs proposed by Botula (2013) and Souza *et al*. (2016). Our dataset has many sandy soil samples, which differs from the datasets used to generate these three PTFs, presenting a BD maximum value of 2,1 g cm^{-3}.

Boschi *et al*. (2016) obtained good performance for the PTF proposed by Benites *et al*. (2006) – B (RMSE=0.19) and other, after evaluating 25 PTFs for a set of 222 soil profiles from all Brazilian biomes.

Table 1 – Statistical metrics of precision and accuracy to describe the performance of 14 PTFs to estimate Bulk Density.

PTF	Location	Parameters	n	*r*	MSE	RMSE	CV %
Alexander (1980)	California – USA	OC	2627	0.37	0.00	0.22	11
Manrique & Jones (1991) – A	USA	OC	2630	0.39	0.00	0.22	12
Manrique & Jones (1991) – B	USA	OC	2626	0.42	0.00	0.20	9
Bernoux *et al*. (1998) – A	Amazon - Brazil	Clay	2538	0.45	0.00	0.28	7
Bernoux *et al*. (1998) – B	Amazon - Brazil	Clay, OC	2282	0.61	0.00	0.25	9
Bernoux *et al*. (1998) – C	Amazon - Brazil	Clay, OC, pH	1103	0.44	0.00	0.25	8

Bernoux *et al*. (1998) – D	Amazon - Brazil	Clay, sand, OC, pH	1054	0.44	0.00	0.24	8
Tomasella & Hodnett (1998)	Amazon - Brazil	Clay, silt, OC	1769	0.50	0.00	0.23	10
Kaur *et al*. (2002)	Almora - India	Clay, silt, OC	2413	0.58	0.01	0.38	30
Benites *et al*. (2006) – A	Brazil	Clay	2635	0.49	0.00	0.20	7
Benites *et al*. (2006) – B	Brazil	Clay, OC	2385	0.63	0.00	0.19	11
Benites *et al*. (2006) – C	Brazil	Clay, OC, SB*	963	0.40	0.00	0.18	9
Botula (2013)	Lower Congo	Clay, sand, OC	2047	0.46	0.00	0.19	3
Souza *et al*. (2016)	Rio Doce Basin - Brazil	Clay, OC, pH, SB	688	0.35	0.01	0.18	10

SB*: partial sum of cations (Ca. Mg and K); n: number of samples; *r*: Pearson correlation coefficient; RMSE: root mean square error; MSE: mean standard error; CV: coefficient of variation.

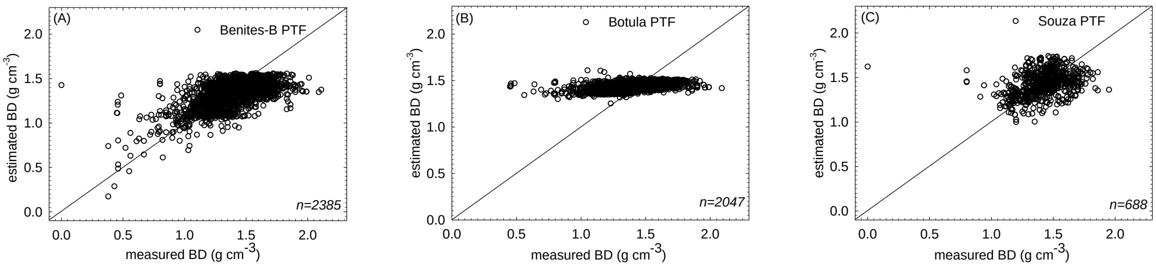

Figure 1 – Measured BD values *vs* deviation of estimates of three PTFs: Benites *et al*. (2006) – B (A). Botula (2013) (B), Souza *et al*. (2016) (C).

Conclusions

BD predictions from all PTFs tested, show relatively low accuracy. It may be unacceptable in some BD data applications. New PTFs using hierarchical approaches to estimate BD are already under analysis.

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