Pedotransfer functions for estimating soil hydraulic properties in Portugal. State-of-the-art.

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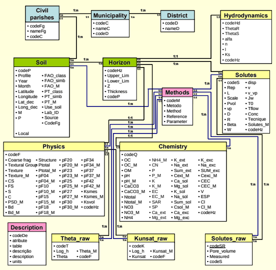
Introduction

The first pedotransfer functions (PTFs) for estimating the unsaturated soil hydraulic properties of Portuguese soils were developed in 1994 from limited data. Gonçalves et al. (1997) related the parameters of van Genuchten's retention model (van Genuchten, 1980) and Gardner's conductivity model (Gardner, 1958) with basic soil properties. Later, Gonçalves et al. (1999) also developed PTFs for estimating the parameters of the Mualem-van Genuchten model from basic soil data. As more data on unsaturated soil hydraulic properties has been slowly made available, the existing PTFs for Portugal have also been revised.

These PTFs are essential for providing reliable data for hydrological modeling since no other information on the hydrological behavior of the Portuguese soils is available and direct measurements in large scale applications are impractical. We present here two alternatives for upscaling the soil hydraulic properties based on the information provided by these PTFs and the information already available in Portugal. The first approach is the simplest one and makes use of Class PTFs for providing information on hydraulic properties to the existing soil maps. The second one is more complex and makes use of geoestatistical algorithms to interpolate the existing soil information and to develop maps of soil hydraulic properties for Portugal.

Objectives

- *Revise the existing PTFs (point and parametric) for estimating the unsaturated soil hydraulic properties of Portuguese soils;*
- *Assess the usefulness of class PTFs for providing information on water retention properties for the Portuguese soil maps;*
- *Upscaling soil hydraulic properties based on geoestatistical algorithms.*



The soil database PROPSOLO

** Atribute_M gives the analytical method to the soil property*

The soil data

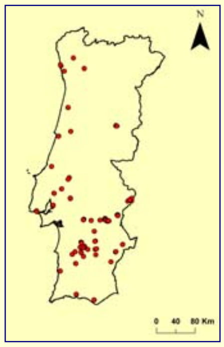
The information available in the PROPSOLO database was used to derive the PTFs for the Portuguese soils. The soil database gathers all the information on soil hydraulic properties produced in the research institute 'Estação Agronómica Nacional', and currently includes:

- 345 georeferenced soil profiles;
- 880 soil horizons/layers;
- 734 soil water retention curves θ(h);
- 288 hydraulic conductivity curves K(h).

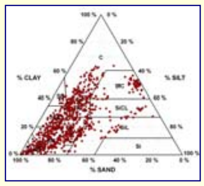
The soil water retention curves were mainly determined using suction tables for h>-50 kPa, the pressure plate apparatus for -33>h>-1585 kPa, and the evaporation method for -5>h>-80 kPa. The hydraulic conductivity curves were mainly determined using the crust method for h>-5 kPa, the hot air method for h<-5 kPa, and the evaporation method for -5>h>-80 kPa. The soil hydraulic properties were determined on undisturbed samples (100 to 4700 cm³).

The PROPSOLO database also contains the parameters of the Mualem-van Genuchten model (MvG) for all θ(h) and K(h) curves, wherein θ_r and θ_s denote the residual and saturated water contents, respectively, *Ks* is the saturated hydraulic conductivity, and α, η, and ℓ are empirical shape parameters.

The database further includes the corresponding soil texture, dry bulk density (*BD*), and organic carbon (*OC*) values, among other physical and chemical properties determined in the studied horizons/layers.



Location of the soil profiles.



Distribution of the soil hydraulic data in the texture triangle. The particle size distribution is based on the Atterberg scale, i.e., clay (*C*) fraction <2 µm; silt (*Si*) <20 µm, fine sand (*FS*) <200 µm, and coarse sand (*CS*) <2000 µm.

Revised PTFs

Class PTFs

Class PTFs were developed by averaging soil hydraulic properties after grouping data by soil texture, bulk density, and soil horizons (top and bottom).

	RMSE (cm³ cm⁻³)
FAO texture classes	0.057
FAO texture classes + Horizon	0.056
FAO texture classes + BD	0.044
FAO texture classes + Horizon + BD	0.043
ISSS texture classes	0.052
ISSS texture classes + Horizon	0.049
ISSS texture classes + BD	0.039

Point PTFs

Point PTFs were developed using multiple regression techniques to estimate the total porosity (φ) and soil water contents at 0.25, 1, 3.2, 6.3, 10, 33, 100, 250, and 1585 KPa from particle size distribution, bulk density (BD), and organic carbon content (*OC*).

Example:

$$\varphi = 0.874 + 6.80E^{-4}\,Si + 1.04E^{-3}\,C - 0.309\,BD - 2.20E^{-4}\,Z$$
($RMSE$ = 0.031 cm³ cm⁻³)

$$\theta_{33} = 0.294 + 2.18E^{-3}\,Si + 2.75E^{-3}\,C - 0.086\,BD - 0.223\,GPD + 1.88E^{-2}\,OC - 2.30E^{-4}\,Z$$
($RMSE$ = 0.040 cm³ cm⁻³)

$$\theta_{1585} = -0.002 + 1.16E^{-3}\,Si + 4.10E^{-3}\,C + 1.17E^{-2}\,OC + 2.81E^{-3}\,GSD + 1.82E^{-4}\,Z$$
($RMSE$ = 0.036 cm³ cm⁻³)

GPD – Mean particle diameter;
GSD – geometrical standard deviation.

Parametric PTFs

Parametric PTFs were created also using multiple regression techniques and considering a hierarchical approach where input data needs increase progressively permitting the optimal use of available input data.

Example:

$$\text{Log}(Ks) = 3.27 - 1.87E^{-2}\,FS - 1.32E^{-2}\,Si - 6.48E^{-2}\,GSD$$
(*RMSE Soil texture= 0.609*)

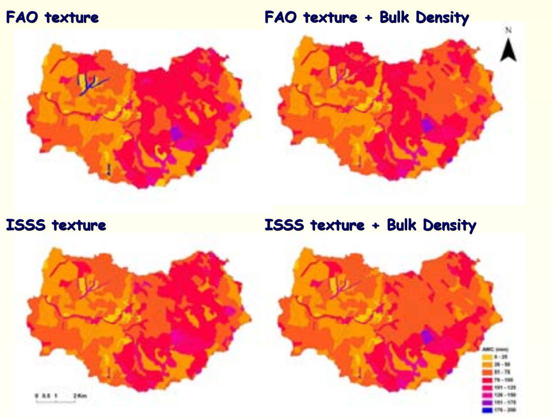
$$\text{Log}(Ks) = 5.35 - 1.90E^{-2}\,FS - 1.54E^{-2}\,Si - 9.10E^{-3}\,C - 3.22E^{-2}\,GSD - 1.41\,BD$$
(*RMSE soil texture + Bulk density= 0.588*)

$$\text{Log}(Ks) = 7.18 - 1.30E^{-2}\,CS - 3.50\,GSD - 2.14\,BD - 8.98\,\theta_{33} + 6.70\,\theta_{1585}$$
(*RMSE soil texture + Bulk density + water contents = 0.533*)

Upscaling soil hydraulic properties

Approach I – Make use of the existing soil maps to integrate Class PTFs and aggregate the information into larger spatial units, i.e., the soil mapping units.

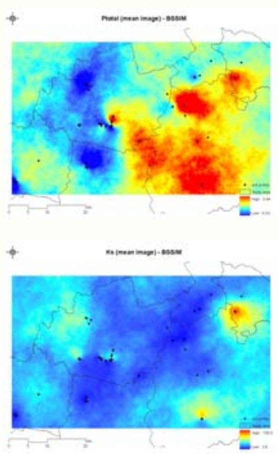
Soil maps in Portugal cover most of the territory but are useless for modern hydrological modeling applications since they do not provide information of the hydraulic behaviors of Portuguese soils. However, they may become valuable either by integrating Class PTFs into what we already know (texture information, soil depths, etc., from representative soil profiles) or into minimum surveyed soil data (texture classes and bulk density). This is the simplest, cheapest and most feasible approach available today to modelers.



Available water capacity (AWC) in a small watershed (60 km²) in Portugal. AWC was calculated based on the information (field capacity, wilting point) obtained from different class PTFs and the soil information already available in literature (soil mapping units, number of horizons, soil texture, soil depths of representative soil profiles).

Approach II – Make use of geostatistical algorithms to map the spatial variability of soil hydraulic properties and to quantify its spatial uncertainty.

Uncertainty evaluation is important to validate the spatial distribution and to assess new sampling locations. When soil hydraulic properties are measured in different supports (i.e different sampling volumes), Block Sequential Simulation (Liu and Journel, 2009) can be used to integrate different soil supports and to perform the simulation of soil properties.



Average of 30 simulations representing the spatial distribution of Total Porosity and Hydraulic Conductivity in a 3800 km² area located in the South of Portugal. The results reproduce the variability given by the 46 soil profile data used.

Conclusions

The revised PTFs (class, point, and parametric) allow the estimation of unsaturated hydraulic properties for Portuguese soils considering a hierarchical approach.

The upscaling techniques presented here varied from basic to more complex approaches since reliable soil information in Portugal is limited.

Future research will include validation of the soil hydraulic properties maps using watershed modeling tools.

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