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 (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 revisited.

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 on 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 geostatistical tools 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 geostatistical algorithms.

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).

- FAO texture classes: 0.057
- FAO texture classes + Horizon: 0.029
- FAO texture classes + BD: 0.029
- ISSS texture classes: 0.029
- ISSS texture classes + Horizon: 0.029
- ISSS texture classes + BD: 0.039

Point PTFs

Point PTFs were developed using multiple regression techniques to estimate the total porosity (θ) 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, and organic carbon (OC).

Example:
- q = 0.874 + 6.606e+02 * 1.046 * 0.009 = 0.309 - 2.020 * Z
- q = 0.024 + 2.16 * 5.71e+02 - 0.086 - 0.232 * 1.88 * 2.30 - 0.040 * Z
- R2 = 0.002 + 1.18e+02 * 1.17 * 2.81e+02 + 1.42e+02

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:
- Log(CO) = 3.27 + 1.887 * Z - 0.0132 * 1.38e+02 * 6.68e+02
- Log(CO) = 5.35 - 1.59e+02 * 5.54e+02 + 9.16e+02 - 3.22e+02 - 1.41e+02
- R2 = 0.52

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 hydrological behaviors of Portuguese soils. However, they may become valuable either by integrating Class PTFs into what we already know (textural information, soil depths, etc., from representative soil profiles) or by inverting soil data survey (texture classes and bulk density). This is the simplest, cheapest and most feasible approach available today to models.

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 spots (i.e., different sampling volumes), Block Sequential Simulation (Liu and Journal, 2009) can be used to integrate different soil supports and to perform the simulation of soil properties.

Conclusions

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

The upsampling techniques presented here varied from basic to more complex approaches since the behavior of unsaturated soil hydraulic properties in Portugal is varied.

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

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,’’ currently including:

- 345 georeferenced soil profiles:
  - 80 soil horizons/layers:
  - 734 soil water retention curves (θh):
  - 288 hydraulic conductivity curves (Kh).

The soil water retention curves were mainly determined using suction tables for 5-50 kPa, the pressure plates apparatus for 33-60-1585 kPa, and the evaporation method for 5-50-80 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 (1980) for all θh and Kh curves, wherein θh and Kh denote the saturated and unsaturated water contents, respectively. Kh is the saturated hydraulic conductivity, and a, n, and m 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.

References


Average of 3D 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 4x soil profile data set.