ScienceDirect

Science of The Total Environment
Volume 780, 1 August 2021, 146609

New pedotransfer approaches to predict soil bulk density using WoSIS soil data and environmental covariates in Mediterranean agro-ecosystems

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Received 26 December 2020, Revised 24 February 2021, Accepted 16 March 2021, Available online 19 March 2021, Version of Record 27 March 2021.

Editor: Manuel Esteban Lucas-Borja

https://doi.org/10.1016/j.scitotenv.2021.146609

Highlights

- Three PTFs were developed to calculate bulk density of arable top- and subsoil.
- WoSIS, WorldClim, and topographic data of the Mediterranean Basin were used.
- Model transferability of the three new PTFs was validated with external dataset.
- Topsoil ANN-PTF had R^2 of 0.89 in training and 0.45 in model transferability.
- ANN-PTF outperformed the commonly employed PTF by Manrique and Jones.

Abstract

For the estimation of the soil organic carbon stocks, bulk density (BD) is a fundamental parameter but measured data are usually not available especially when dealing with legacy soil data. It is possible to estimate BD by applying pedotransfer function (PTF). We applied different estimation methods with the aim to define a suitable PTF for BD of arable land for the Mediterranean Basin, which has peculiar climate features that may influence the soil carbon sequestration. To improve the existing BD estimation methods, we used a set of public climatic and topographic data along with the soil texture and organic carbon data. The present work consisted of the following steps: i) development of three PTFs models separately for top (0–0.4 m) and subsoil (0.4–1.2 m), ii) a 10-fold cross-validation, iii) model transferability using an external dataset derived from published data.

The development of the new PTFs was based on the training dataset consisting of World Soil Information Service (WoSIS) soil profile data, climatic data from WorldClim at 1 km spatial resolution and Shuttle Radar Topography Mission (SRTM) digital elevation model at 30 m spatial resolution.

The three PTFs models were developed using: Multiple Linear Regression stepwise (MLR-S), Multiple Linear Regression backward stepwise (MLR-BS), and Artificial Neural Network (ANN).

The predictions of the newly developed PTFs were compared with the BD calculated using the PTF proposed by Manrique and Jones (MJ) and the modelled BD derived from the global SoilGrids dataset.

For the topsoil training dataset ($N = 129$), MLR-S, MLR-BS and ANN had a R^2 0.35, 0.58 and 0.86, respectively. For the model transferability, the three PTFs applied to the external topsoil dataset ($N = 59$), achieved R^2 values of 0.06, 0.03 and 0.41. For the subsoil training dataset ($N = 180$), MLR-S, MLR-BS and ANN the R^2 values were 0.36, 0.46 and 0.83, respectively. When applied to the external subsoil dataset ($N = 29$), the R^2 values were 0.05, 0.06 and 0.41. The cross-validation for both top and subsoil dataset, resulted in an intermediate performance compared to calibration and validation with the external dataset. The new ANN PTF outperformed MLR-S, MLR-BS, MJ and SoilGrids approaches for estimating BD. Further improvements may be achieved by additionally considering the time of sampling, agricultural soil management and cultivation practices in predictive models.

Graphical abstract