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Three dimensional soil organic carbon monitoring using vis-NIR spectrometry and hyperscale terrain analysis

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Recent advances in digital soil mapping, soil sensing and machine learning methods represent a great potential to produce (spatially) dense SOC information in a cost-effective way. However there is lack of research on the integration of soil sensing and digital soil mapping techniques for three dimensional monitoring of SOC at the regional scale. In this respect, this work was focused on the development of a methodology for modeling the depth distribution of SOC density based on a combination of visible and near infrared (vis–NIR) spectroscopy and hyper-scale terrain analysis. This study was carried out in agricultural fields in Luxembourg within an area of $\sim$420 km2 which includes 4 of the 5 agro-geological regions of the country.
The soil dataset used for modeling consist of 208 profiles (1655 samples). From these profiles 162 were not sampled specifically for this study (legacy data) while the remaining profiles (46) were sampled for this study in order to further improve the representativeness of the legacy data. The location of these profiles were selected based on a conditioned Latin hypercube sampling (cLHS) of the some terrain derivatives. In addition, 26 profiles were randomly collected in order to produce a fully independent dataset to test the predictive performance of the models. The depth interval at which samples from all the profiles were collected was 10 and the maximum depth was 10 cm.
The strategy for modeling SOC density comprised two main steps: In the first step the SOC density distribution within each profile (vertical distribution) is modeled. Soil vis-NIR spectroscopy and mass preserving splines were used to accurately enhance the depth resolution of the SOC density information within each profile. SOC density values at depth intervals of 1 cm were predicted for all the profiles. The second step involved the spatial (vertical) modeling of the depth information by using contextual terrain (ConMap) features (Behrens et al., 2010). These features are based on the differences in elevation between a given point location in the landscape and its circular neighbors at a given set of different radius. One of the main advantages of this approach is that it allows the integration of several spatial scales (e.g. local and regional) for soil spatial analysis. In this work the ConMap features were derived from a digital elevation model of the area and then used as predictors for spatial modeling of SOC density. Predictive models of SOC density were calibrated using a random forests-kriging modeling strategy. The results show that our proposed methodology can be used for obtaining spatially dense information on the depth distribution of SOC density in an efficient way in terms of accuracy, costs and time.

Keywords: 3D modeling, Digital soil mapping, Depth functions, Terrain analysis.

Reference

Behrens, T., K. Schmidt, K., Zhu, A.X. Scholten, T. 2010. The ConMap approach for terrain-based digital soil mapping. European Journal of Soil Science, v. 61, p.133-143.