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A 3D Mixed Model for Soil Organic Carbon Mapping in Mountainous Subtropics

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Abstract

The need to increase agricultural production leads to rapidly changing landscapes in mountainous South East Asia. As changing soil organic carbon (SOC) concentrations and stocks are a strong indicator for potential soil fertility loss, there is a need to quantify them with high resolution at landscape level. With 3D modelling, soil properties distribution across soil depth and in space can be predicted in one single model. Mixed models can be used in 3D digital soil mapping and especially suitable for upscaling, which we demonstrate with the new "mixed model over continuous depth" (MMCD). Soil sampling at 120 locations to 1 m depth was done in a 43-km^2 study area in southwest China using an optimised sampling design: cost-constrained conditioned Latin hypercube sampling (CCLHS). The MMCD was used for SOC concentration and SOC density mapping. It showed, that SOC was strongly linked to an interaction of elevation with mean horizon depth ($p < 0.001$) and to the land use type ($p < 0.001$). The MMCD was compared to several mapping approaches, including a 2D and two different 3D kriging with external drift approaches and depth interval-based multiple linear regressions. The MMCD proofed to be as powerful as these established techniques, with an overall modelling efficiency (EF) of 0.72. All tested models strongly decreased in accuracy with depth (EF 0.8 in topsoil to 0.2 in deepest subsoil). The MMCD was further used to model highly unbalanced SOC density data with 120 topsoil observations and only 11 locations with subsoil observations (EF of 0.75). Computed prediction intervals (95 %) accurately covered the range of legacy measurements. We found that essential parts of soil carbon were stored in subsoil in this region. On average, 15 and 10 % of SOC stocks are expected in the 60 to 80 cm and 80 to 100 cm soil depth intervals, respectively. The combination of applied sampling scheme (CCLHS) and the new model (MMCD) is particularly suitable for mountainous subtropical areas with poor road networks, given that strong relationships of the soil property of interest with explanatory environmental covariates exist.

Keywords: 3D digital soil mapping, mixed model, SOC stocks, upscaling

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