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Mapping soil phosphorus sorption capacity in four depths with uncertainty propagation

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Phosphorus (P) is one of the most important plant nutrients, and farmers regularly apply P as mineral fertilizer and with animal manures. Typically, reactions with amorphous aluminum and iron oxides or carbonates retain P in the soil. However, if P additions exceed the soil's ability to bind them, P may leach from soil to surface waters, where it causes eutrophication. The phosphorus sorption capacity (PSC) is thus an inherent soil property that, when related to bound P, can describe the P saturation of the soil. Detailed knowledge of the spatial distribution of the PSC is therefore important information for assessing the risk of P leaching from agricultural land.

In weakly acidic soils predominant in Denmark, the PSC depends mainly on the oxalate-extractable contents of aluminum and iron. In this study, we aimed to map PSC in four depth intervals (0 – 25; 25 – 50; 50 – 75; 75 – 100 cm) for Denmark using measurements of oxalate-extractable aluminum and iron from 1,623 locations.

We mapped both elements using quantile regression forests. Predictions of oxalate-extractable aluminum had a weighted RMSE of 13.9 mmol kg^{-1}. For oxalate-extractable iron, weighted RMSE was 33.5 mmol kg^{-1}.

We included depth as a covariate and therefore trained one model for each element. For each element in each depth interval, we predicted the mean prediction value as well as 100 quantiles ranging from 0.5% to 99.5% in 1% intervals. The maps had a 30.4 m resolution. We then calculated PSC by convoluting the prediction quantiles of the two elements, using every combination of quantiles, in order to obtain the prediction uncertainty for PSC.

Oxalate-extractable aluminum was roughly normal distributed, while oxalate-extractable iron had a large positive skew. The age and origin of the parent material had a large effect on oxalate-extractable aluminum, and soil-forming processes such as weathering and podzolization had clear effects on the distribution in depth. Meanwhile, organic matter, texture and wetland processes were the main factors affecting oxalate-extractable iron, so much so that they obscured any trends with depth.

The weighted RMSE of the predicted PSC was 19.1 mmol kg^{-1}. PSC was highest in wetland areas and lowest in young upland deposits, such as aeolian deposits and the loamy Weichselian

moraines of eastern Denmark. The sandy glaciofluvial plains and Saalian moraines of western Denmark had intermediate PSC. In most cases, PSC was highest in the top soil, but in the sandy soils of western Denmark, PSC was highest in the depth interval 25 – 50 cm due to podzolization.