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Combining LIDAR-derived Digital Terrain Indices and Machine Learning, for High Resolution National-scale Soil Moisture Mapping of the Swedish Forest Landscape.

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To meet the sustainable development goals and enable protection of surface waters, there is a strong need to plan and align forest management with the needs of the environment. The number one tool to succeed in sustainable spatial planning is accurate and detailed maps. High resolution soil moisture mapping over spatial large extent remains a consistent challenge despite its substantial value in practical forestry and land management. Here we present a novel technique combining LIDAR-derived terrain indices and machine learning to model soil moisture at 2 m spatial resolution across the Swedish forest landscape with high accuracy. We used field data from about 20,000 sites across Sweden to train and evaluate multiple machine learning (ML) models. The predictor features included a suite of terrain indices generated from national LIDAR digital elevation model and other ancillary environmental features, including surficial geology, climate, land use information, allowing for adjustment of soil moisture maps to regional/local conditions. In our analysis, extreme gradient boosting (XGBoost) outperformed the other tested ML methods (Kappa = 0.69, MCC= 0.68), namely Artificial Neural Network, Random Forest, Support Vector Machine, and Naïve Bayes classification. The depth to water index, topographic wetness index, and wetlands derived from Swedish property maps were the most important predictors for all models. With the presented technique, it was possible to generate a multiclass model with 3 classes with Kappa and MCC of 0.58. Besides the classified moisture maps, we also investigated the potential of producing a continuous map from dry to wet soils. We argue that the probability of a pixel being classified as wet from the 2-class model can be used as an index of soil moisture from 0% – dry to 100% – wet and that such maps hold more valuable information for practical forest management than classified maps.

The soil moisture map was developed to support the need for land use management optimization by incorporating landscape sensitivity and hydrological connectivity into a framework that promotes the protection of soil and water quality. The soil moisture map can be used to address fundamental considerations, such as;

- (i) locating areas where different land use practices can be conducted with minimal impacts on water quality;
- (ii) guiding the construction of vital infrastructure in high flood risk areas;

- (iii) designing riparian protection zones to optimize the protection of water quality and biodiversity.