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Geophysics-based subsurface conceptualization for improved prediction of plant productivity beyond the field scale

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A precise and reliable characterization of the shallow subsurface is vital in hydrological and agronomical modelling. Non-invasive geophysical methods such as electromagnetic induction (EMI) measurements in combination with soil sampling can provide subsurface information with a high spatial resolution. In principle, such geophysical data allow a generalization of the subsurface in homogeneous areas that share similar patterns of soil structural organization (layering and texture) using a reduced amount of resources. However, it is still challenging to derive relevant subsurface information from such geophysical data sets, and the added value of such high-resolution soil information for the analysis of patterns in plant productivity has also not been investigated yet. In this study, we used an image classification method to classify high-resolution multi-configuration EMI measurements obtained in an agricultural area of 102 ha near Selhausen (Germany) where the subsurface structure is known to affect crop productivity during water stress periods. EMI measurements were collected in 2016 within a few days after harvest of each field and were automatically filtered, temperature corrected, and interpolated onto a 1 m resolution grid. The EMI data indicated four main sub-areas with characteristic subsurface heterogeneity and typical impact on plant productivity patterns. To delineate areas with similar subsurface structures, we stacked the ECa maps obtained with different coil configurations in a single multiband image that was subsequently classified using an image classification methodology. In a second step, we selected one hundred soil sampling locations within the study area and obtained soil profile descriptions with type, depth, thickness, and texture of all soil horizons up to 2 m depth. By combining the EMI and soil data, typical soil profiles with soil textural information were assigned to each of the classes obtained from the classification of EMI data. The proposed methodology was effective in producing a high resolution subsurface model in a large and complex study area that extends well beyond the field scale. In order to evaluate the benefits of the derived high-resolution soil information for predictions of plant productivity, we selected a sub-area of 30 hectares located within the larger Selhausen study site, where the subsurface structure is known to be strongly correlated with plant productivity. In this area, the soil profiles of each class were used to run an ensemble of AgroC models to investigate the effect of subsurface conceptualization on sugar beet productivity. AgroC is a one-dimensional model that couples SoilCO_2, RothC, and SUCROS subroutines to predict plant productivity and carbon cycling of cropped ecosystems with an hourly time resolution. The available soil texture information was used to estimate soil hydraulic parameters using the Rosetta pedotransfer functions. The simulated patterns in plant productivity obtained with AgroC were subsequently compared to patterns in leaf area index (LAI) derived from satellite images. The results showed a clear correlation between LAI estimates from satellite images and predicted patterns in plant productivity, which inspires confidence in the reliability of the derived subsurface model. Consequently, the proposed methodology provides a clear added value in environmental modelling and precision agriculture.