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Large-scale subsurface characterization using image classification of multi-configuration electromagnetic induction data assisted by direct soil sampling

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An appropriate characterization of the shallow subsurface with information on the spatial variability of soil properties and layering is vital in hydrological modelling. For areas up to several hectares, such subsurface structures can be investigated with a combination of soil sampling and non-invasive geophysical electromagnetic induction EMI measurements within a quantitative inversion framework. At larger scales, however, the collection and analysis of ground truth and EMI data with high spatial resolution is challenging due to limited field access and the need to acquire measurements in a relatively short timeframe to avoid artifacts associated with dynamic changes in soil properties affecting EMI measurements. In this study, we used an image classification method to analyze high-resolution multi-configuration EMI measurements and characterize patterns of soil structural organization (layering and texture) in an agricultural area of 102 ha near Selhausen (Germany). The area consists of 51 agricultural fields managed with a regular crop rotation. Measurements were collected between April and December 2016 within a few days after harvest of each field. EMI data were automatically filtered, temperature corrected, and interpolated onto a common grid of 1 m resolution. The apparent electrical conductivity (ECa) maps indicated four main sub-areas with characteristic subsurface heterogeneity. Further small-scale geomorphological structures as well as anthropogenic activities such as soil management and buried drainage networks could be identified by comparing the ECa maps with soil maps, historical aerial photos, morphometric data, and satellite images. To delineate areas with similar subsurface structures, we stacked the ECa maps obtained with different coil configurations in a multiband image and applied supervised and unsupervised image classification methodologies. Both showed good results in reconstructing the subsurface structure that is associated with patterns in plant productivity. At our site, the supervised methodology proved more efficient in classifying the whole study area. In a second step, we selected one hundred soil sampling locations within the study area and, in February 2017, we obtained soil profile description with type, depth, thickness, and texture of all soil horizons up to 2 m depth. Using this ground truth data, it was possible to assign a typical soil profile with soil textural information 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. Consequently, this methodology can represent an added value in various applications such as hydrological and agronomic modelling as well as precision agriculture.