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Understanding soil-plant interaction by analyzing quantitative electromagnetic induction measurements and inversions together with airborne hyperspectral data

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Soil structural changes (layering and texture) influence above surface processes such as plant performance and growth, which is visible in airborne hyperspectral measurements. However, the soil structural changes below the ploughing layer are often ignored when studying spatial plant patterns. Here, we investigate the origin of these patterns due to soil structural changes by analyzing airborne hyperspectral data in combination with non-invasive geophysical fixed-boom multi-coil electromagnetic induction (EMI) data. The HyPlant dual channel airborne imaging spectrometer obtains sun-induced red- and far-red fluorescence data as well as derived vegetation indices, which indicate plant performance and growth. The EMI instruments measure the soil apparent electrical conductivity (ECa) that is a weighted average value over a specific depth range depending on the transmitter-receiver coil configuration i.e. coil separation and orientation. After ECa calibration and quantitative EMI data inversion, a layered subsurface electrical conductivity (σ) model reflecting soil structural changes is obtained. At our test site, the fixed-boom multi-coil ECa maps of nine EMI coil configurations spatially indicated soil patterns due to buried paleo-river channels that interact with the plants as observed in the airborne hyperspectral data. After EMI data inversions, the layered quasi-3D σ model showed a relatively homogeneous ploughing layer in the upper 30 cm and the paleo-river channels appeared in the subsoil below approximately 0.85 m depth. The correlation coefficient (r) between the layer σ and hyperspectral data confirmed that not the ploughing layer (r $\sim$ 0.35) but the subsoil (r $\sim$ 0.65) was responsible for plant performance and growth due to differences in soil structure and thus water holding capacity especially during dry periods. For the first time, we combined depth specific 3D soil structural information obtained by quantitative fixed-boom multi-coil EMI data inversions and airborne hyperspectral data to show that the above surface plant performance is strongly influenced by the subsoil at the investigated site. Conclusively, quantitative multi-coil EMI measurements and inversions can deliver valuable information about the top and subsoil structural organization that needs to be included in plant modeling tools for an improved description of above and below surface processes.