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Using machine learning to extract profiles of crop root water uptake from remote sensing data

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Unmanned aerial vehicles (UAV) borne remote sensing can be performed at high spatial resolution and at arbitrary timing, e.g., for assessing the pattern of actual evapotranspiration in arable fields with 10 cm resolution. Thus valuable information can be gained, e.g., about the effects of pests and diseases, of heterogeneous fertilizer application, of soil heterogeneities, etc. on crop growth and yield. However, that information is restricted to surface patterns. Even radar measurements do not provide information about soil moisture at more than a few cm depth. On the other hand, various geophysical techniques provide valuable information about soil structure even at greater depth. But geophysical survey data hardly provide any information about plant behaviour beyond the lab scale.
Merging information from remote sensing and geophysical data thus might be a way to assess plant root behaviour at low effort and with nearly arbitrary temporal resolution. We developed and applied an approach based on data from a set of field trials at Müncheberg, about 50 km east of Berlin, Germany, covering an area of 3.2 ha. In the year of the study two different varieties of maize were grown and partly been irrigated. The Geophilus system (Lueck and Ruehlmann 2013) was used to map soil electric resistivity which gave some information about the soil texture patterns at different layers down to 1.5 m depth. Spatial patterns of actual evapotranspiration were assessed using UAV mounted multi-spectral and thermal sensors, combined with additional on-site measurements. UAV surveys were performed on 16 July and 31 August 2015. After the first survey a drought period developed with high air temperature and with hardly any rainfall which substantially affected maize growth and transpiration on the non-irrigated fields.
We assumed that the spatial pattern of evapotranspiration partly reflected the spatial pattern of subsurface water availability in different soil layers that should be closely related to soil texture, and that the latter was partly at least reflected by the soil resistivity data. Our approach did neither require any detailed information about the nature of those relationships nor any additional information about other factors that affected the spatial pattern of evapotranspiration. Then a non-linear Support Vector Machine regression was performed using the spatial pattern of evapotranspiration as target variable and those of soil resistivity in different soil layers as predictors. The contribution of single soil layers, determined by stepwise pruning of the Support Vector Machine, was taken as a proxy for the share of total root water uptake during the day of the respective UAV survey. These depth profiles were compared to soil moisture data. There were clear differences between the two UAV campaigns, especially in the uppermost soil layers, indicating root adaptation to decreasing water availability on non-irrigated fields.

Reference:

Lueck, E., Ruehlmann, J. (2013): Resistivity mapping with GEOPHILUS ELECTRICUS — Information about lateral and vertical soil heterogeneity. Geoderma 199: 2-11 , DOI: 10.1016/j.geoderma.2012.11.009