

EGU2020-703

<https://doi.org/10.5194/egusphere-egu2020-703>

EGU General Assembly 2020

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Improved spatial modelling of crop productivity using geophysics-based soil mapping: Two case studies beyond the field scale

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Water shortage in soil can result in a considerable reduction in crop yield, thus representing a severe threat to agricultural sustainability and profitability. It is therefore crucial to improve our understanding and prediction of the spatial variability of water stress and crop yield. Within this context, detailed soil maps obtained from the combination of hydrogeophysical methods, such as electromagnetic induction (EMI), and direct soil sampling can prove vital. However, it is still challenging to derive and exploit such data beyond the field-scale and their added value has not been fully investigated yet. In this study, we present results from two case studies where the added value of hydrogeophysical measurements in agriculture have been evaluated. In the first case, high-resolution multi-configuration EMI data was measured on 51 adjacent agricultural fields (102 ha) near Selhausen (Germany). Each field was separately measured and six apparent electrical conductivity (ECa) maps with increasing depth of investigation were obtained. A supervised image classification method was applied to the ECa maps to obtain a 1 m resolution map of the study area that identifies 18 soil units with similar ECa signature. Afterwards, 100 ground truth locations were randomly selected and information on horizon type, depth and texture were collected until a maximum depth of 2 m. Statistical tests proved that each soil unit had unique soil characteristics in comparison to other units, thus confirming the effectiveness of the methodology in producing a highly detailed soil map in a complex environment that extends well beyond the field scale. To test its added value in agricultural applications, this geophysics-based soil map was used as input in agro-ecosystem simulations of crop growth and productivity for the 2016 growing season. For this, the one-dimensional AgroC model was used, which couples SoilCO₂, RothC, and SUCROS subroutines to simulate crop growth. The necessary hydraulic parameters were estimated using pedotransfer functions. The leaf area index (LAI) of six crops simulated with AgroC showed clear correlation with LAI observed in six RapidEye satellite images. At the same time, further AgroC simulations based on commonly available soil maps performed significantly worse in terms of RMSE, model efficiency, and R². Following these encouraging results, further simulations were performed to quantify the costs and benefits of irrigation within the study area in 2016 in terms of economical profit and CO₂ sequestration. Despite the apparent added value of geophysics-based soil information, it was found that additional data recorded during the growing season would allow improving modelling and predictions, for example, through data assimilation. For this reason, the second case study considers a set-up with

additional soil moisture sensors installed in two orchards near Agia (Greece). In each field, EMI and soil sampling were combined to inform the placement of SoilNet soil moisture sensor surrounding a cosmic-ray neutron probe. The purpose of this second case study is to integrate soil data, hydrological modelling, and weather forecasts to provide farmers with an efficient decision support system that would enhance financial gains and sustainability of their irrigation practices in the long term.