Geophysical Research Abstracts
Vol. 19, EGU2017-5524, 2017
EGU General Assembly 2017

Impact of plant-soil feedback on plant traits at field scale, testing the use of UAV-based optical sensors

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Plant responses to biotic and abiotic legacies left in soil by preceding plants is known as plant-soil feedback (PSF). PSF is an important mechanism to explain plant community dynamics and plant performance in natural and agricultural systems. However, most PSF studies are short-term and small-scale due to practical constraints for field scale quantification of PSF effects, yet field experiments are warranted to asses actual PSF effects under less controlled conditions. Here we used Unmanned Aerial Vehicle (UAV)-based optical sensors to test whether PSF effects on plant traits can be quantified remotely. We established a randomized agro-ecological field experiment in which six different cover crop species and species combinations from three different plant families (Poaceae, Fabaceae, Brassicaceae) were grown. The feedback effects on plant traits were tested in oat (Avena sativa) by quantifying the cover crop legacy effects on key plant traits: height, fresh biomass, nitrogen content and leaf chlorophyll content. Prior to destructive sampling, hyperspectral data was acquired and used for calibration and independent validation of regression models to retrieve plant traits from optical data. Subsequently, for each trait the model with highest precision and accuracy was selected. We used the hyperspectral analyses to predict the directly measured plant height (RMSE= 5.12 cm, R^2= 0.79), chlorophyll content (RMSE= 0.11 g m-2, R^2= 0.80), N-content (RMSE= 1.94 g m-2, R^2= 0.68), and fresh biomass (RMSE= 0.72 kg m-2, R^2=0.56). Overall the PSF effects of the different cover crop treatments based on the remote sensing data matched the results based on in situ measurements. The average oat canopy was tallest and its leaf chlorophyll content highest in response to legacy of Vicia sativa monocultures (100 cm, 0.95 g m-2, respectively) and in mixture with Raphanus sativus (100 cm, 1.09 g m-2, respectively), while the lowest values (76 cm, 0.41 g m-2, respectively) were found in response to legacy of Lolium perenne monoculture, and intermediate responses to the legacy of the other treatments. We show that PSF effects in the field occur and alter several important plant traits that can be sensed remotely and quantified in a non-destructive way using UAV-based optical sensors; these can be repeated over the growing season to increase temporal resolution. Remote sensing thereby offers great potential for studying PSF effects at field scale and relevant spatial-temporal resolutions which will facilitate the elucidation of the underlying mechanisms.