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Patterns in Soil-Vegetation-Atmosphere-Systems: Monitoring, Modelling and Data Assimilation

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Workshop on UAV-based Remote Sensing Methods for Monitoring Vegetation

University of Cologne, Germany
September 9th - 10th, 2013

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High-resolution hyperspectral and thermal imagery acquired from UAV platforms for early detection of Verticillium wilt using fluorescence, temperature and narrow-band indices

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Abstract
Verticillium wilt (VW) caused by the soil-borne fungus *Verticillium dahliae* Kleb, is the most limiting disease in all traditional olive-growing regions worldwide. This pathogen colonizes the vascular system of plants, blocking water flow and eventually inducing water stress. The present study explored the use of high-resolution thermal imagery, chlorophyll fluorescence, structural and physiological indices (xanthophyll, chlorophyll a+b, carotenoids and B/G/R indices) calculated from multispectral and hyperspectral imagery acquired from a fixed-wing UAV platform as early indicators of water stress caused by VW infection and severity. The study was conducted in two olive orchards naturally infected with *V. dahliae*. Time series of airborne thermal, multispectral and hyperspectral imagery were conducted with 2-m and 5-m wingspan electric Unmanned Aerial Vehicles (UAVs) operated by the Spanish Laboratory for Research Methods in Quantitative Remote Sensing (Quantalab, IAS-CSIC, Spain) in three consecutive years and related to VW severity at the time of the flights. Concurrently to the airborne campaigns, field measurements conducted at leaf and tree crown levels showed a significant increase in crown temperature (Tc) minus air temperature (Ta) and a decrease in leaf stomatal conductance (G) across VW severity levels, identifying VW-infected trees at early stages of the disease. Higher Tc-Ta and G values measured in the field were associated with higher VW severity levels. At leaf level, the reduction in G caused by VW infection was associated with a significant increase in the Photochemical Reflectance Index (PRI_{570}) and a decrease in chlorophyll fluorescence. The airborne flights enabled the early detection of VW by using canopy-level image-derived airborne Tc-Ta, Crop Water Stress Index (CWSI) calculated from the thermal imagery, blue / green / red ratios (B/BG/BR indices) and chlorophyll fluorescence, confirming the results obtained in the field. Airborne Tc-Ta showed rising temperatures with a significant increase of ~2K at low VW severity levels, and was significantly correlated with G (R^2=0.76, P=0.002) and PRI_{570} (R^2=0.51, P=0.032). Early stages of disease development could be differentiated based on CWSI increase as VW developed, obtaining a strong correlation with G (R^2=0.83, P<0.001). Likewise, the canopy-level chlorophyll fluorescence dropped at high VW severity levels, showing a significant increase as disease progressed at early VW severity levels. These results demonstrate the feasibility of early detection of *V. dahliae* infection and discrimination of VW severity levels using remote sensing. Indicators based on crown temperature, CWSI, and visible ratios B/BG/BR as well as fluorescence were effective in detecting VW at early stages of disease development. On affected plants, the structural indices, PRI, chlorophyll and carotenoid indices, and the R/G ratio were good indicators to assess the damage caused by the disease.

Keywords: stress detection, hyperspectral, thermal, fluorescence, high resolution, UAV, vegetation indices, *Verticillium dahliae*.