Unlocking the Potential of Hyperspectral Imaging of Plants for Precision Agriculture and Plant Phenotyping

Anne-Katrin Mahlein, Abel A. Barreto Alcántara, Facundo R. Ispizua Yamati, Stefan Paulus

Institute of Sugar Beet Research, Associated Institute of the University of Göttingen, Holtenser Landstrasse 77, 37079 Göttingen, Germany

mahlein@ifz-goettingen.de

Abstract: Hyperspectral sensors offer the potential to monitor plants non-invasively. Analysis of spectral signatures enable the detection of specific plant stress. This is a prerequisite for site-specific management strategies and may reduce the input of agrochemicals.

1. Main Text

The detection of plant functional traits and plant stress is relevant in plant science and agriculture. Recently, intensive research has been investigated in the field of precision farming and plant phenotyping to develop and implement new and innovative digital technologies. In contrast to common visual rating and detection methods, optical sensors are able to measure changes in the plant physiology, during growth or exhibition to plant stress such as drought or plant diseases non-invasively and objectively. Several studies showed that especially hyperspectral sensors are valuable tools for characterizing plants on different scales from the tissue to the canopy level [1]. These sensors record the reflection of plants in different wavelengths [2]. This reflection is determined by plant-specific properties. The visible range (VIS) of 400-700 nm reflects the leaf pigment content. In the near-infrared (NIR) from 700-1000 nm, the structure of the plant tissue and the architecture of the stand play a crucial role. The shortwave infrared range (SWIR) of 1000-2500 nm is characterized by the content of various compounds such as lignin, cellulose, amino acids, and especially water. Biotic and abiotic stress influence these factors in a characteristic way, so that the sum of the influences in its complexity leads to specific spectral patterns. Hyperspectral remote sensing methods are, for example, particularly well suited for detecting and differentiating plant diseases that are heterogeneously distributed.

This presentation provides an overview on the basic principles of hyperspectral measurements and different types of available hyperspectral sensor types in plant science. Possible applications of hyperspectral sensors for plant monitoring on different scales are discussed and evaluated. The advantages and disadvantages on each particular scale, as well as the impact of external factors (e.g. light, wind, and viewing angle) for measurements in laboratories, greenhouses and fields, are critically assessed in order to support researchers and agricultural technicians. Especially the potential of hyperspectral sensors as a tool for plant disease identification, based on disease characteristic changes in the plants spectral signature, and its utilisation for precision plant protection will be shown.

For successful implementation in agricultural practice, more specific, robust and cost-effective sensors must be developed. In addition to technologies for recording crop stands, the evaluation of the usually very complex data plays a key role - flying over with the drone alone is not sufficient. Data handling and data interpretation place high demands on storage and computing capacity, and the aim is to provide a basis for decision-making - if possible in real time. Current developments in the field of so-called machine learning, computer vision and deep learning are promising here, but bring with them a high level of complexity in development [3].

A platform for evaluating currently available methods and developments for precision agriculture is being established by the experimental field "Farmerspace" in Göttingen by the project partners Institute for Sugar Beet Research, Department of Agricultural Engineering University of Göttingen, IOSB Fraunhofer and Chamber of Agriculture Lower Saxony. On the topic of "digital crop protection", players from a wide range of categories, from manufacturers of cultivation equipment or agricultural robots to forecasting providers and suppliers of smart sensors, are invited to evaluate their products in the project fields together with the project partners and to show the results at field days.

Acknowledgement: Research is funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany’s Excellence Strategy - EXC 2070 – 390732324 and and the Farmerspace project which is supported by funds of the Federal Ministry of Food and Agriculture (BMEL) based on a decision of the

Parliament of the Federal Republic of Germany. The Federal Office for Agriculture and Food (BLE) provides coordinating support for digitalization in agriculture as funding organisation, grant number FZK 28DE104A18.

2. References

[1] Stefan Paulus and Anne-Katrin Mahlein, “Technical workflows for hyperspectral plant image assessment and processing on the greenhouse and laboratory scale.” GigaScience 9 (8), DOI 10.1093/gigascience/giaa090, 2020.

[2] Anne-Katrin Mahlein, Matheus T. Kuska, Jan Behmann, Gerrit Polder, and Achim Walter, “Hyperspectral Sensors and Imaging Technologies in Phytopathology: State of the Art.” Annu. Rev. Phytopathol. 56 (1), 535-558, DOI 10.1146/annurev-phyto-080417-050100, 2018.

[3] Patrick Schramowski, Wolfgang Stammer, Stefano Teso, Anna Brugger, Hans-Georg Luigs, Anne-Katrin Mahlein, and Kristian Kersting, “Right for the Wrong Scientific Reasons: Revising Deep Networks by Interacting with their Explanations.” Computer Science > Machine Learning 1-22, arxiv:2001.05371v1, 2020.