LEAF NUTRIENT ASSESSMENT FROM DESIS IMAGING SPECTROMETER USING RADIATIVE TRANSFER AND MACHINE LEARNING MODELS

Y. Wang [1] *, L. Suarez [1, 2], D. Ryu [1], P. Moar [3], P. J. Zarco-Tejada [1, 2, 4]

[1] Department of Infrastructure Engineering, Faculty of Engineering and Information Technology (FEIT), University of Melbourne, Melbourne, Victoria 3010, Australia - (wang.y, l.suarez, dryu, pablo.zarco)@unimelb.edu.au
[2] School of Agriculture, Food and Ecosystem Sciences (SAFES), Faculty of Science (FoS), University of Melbourne, Melbourne, Victoria 3010, Australia
[3] School of Science, Computing and Engineering Technologies, Swinburn University, Victoria 3122, Australia - pmoar@swin.edu.au
[4] Instituto de Agricultura Sostenible (IAS), Consejo Superior de Investigaciones Cientificas (CSIC), Avenida Menendez Pidal s/n, 14004 Cordoba, Spain

KEY WORDS: DESIS, Spaceborne, Nitrogen, Nutrient, Hyperspectral, Almond, Plant traits, Airborne, Sentinel-2.

ABSTRACT

Plant nutrients play a crucial role in optimizing plant performance, disease resistance, and the production of high yields and quality fruits. Among these nutrients, nitrogen (N), phosphorus, and potassium are particularly vital for almond cultivation. The most important aspect of fertilizer management is optimising the fertilizer application in order to maximize yields while minimizing environmental impacts. In precision agricultural management, accurately assessing the nutrient status becomes essential for determining the optimal application of fertilizers. Traditional remote sensing methods for nutrient assessment rely on empirical relationships with spectral indices derived from multispectral sensors that are sensitive to changes in plant structure and pigment content. However, hyperspectral imagers provide more detailed spectral signatures that allow for assessing all biochemical constituents more accurately, consequently improved nutrient quantification by establishing stronger physiological links. Moreover, the use of hyperspectral sensors on airborne and satellite platforms allows for large-scale monitoring of nutrient levels across entire farms or agricultural districts throughout different growth stages.

This study investigates the feasibility and performance of nutrient status assessment using the German Aerospace Center (DLR) Earth Sensing Imaging Spectrometer (DESIS) in comparison with high-resolution airborne hyperspectral imagery and Sentinel-2 over a 1,200-hectare almond orchard. An airborne campaign was conducted at the almond pre-harvest stage in January 2021 in Victoria, Australia, employing a hyperspectral VNIR camera (Headwall Photonics, Fitchburg, MA, USA), capturing imagery at 40 cm spatial resolution and 371 bands within the 400-1000 nm spectral range. DESIS hyperspectral sensor onboard the International Space Station (ISS) collected imagery on January 23, 2021, at a spectral resolution of 2.55 nm (FWHM), spatial resolution of 30 m, and 235 spectral bands within the 400-1000 nm range.

Inversion of plant traits based on Fluspect-Cx and 4SAIL radiative transfer models was achieved using an artificial neural network model. Along with Solar-Induced Fluorescence (SIF) that was quantified using the Fraunhofer line depth (FLD) principle, a Random Forest regression model was developed to predict leaf N. This model was validated based on ground truth measurements and high-resolution airborne N maps across the entire orchard at the tree level. We further compared the performance of plant traits retrieval and leaf N models based on hyperspectral sensors using visible and near-infrared spectra with intermediate spatial resolution Sentinel-2 data with the extended spectral region to SWIR.

With hyperspectral imagery from DESIS at 30-m spatial resolution, we demonstrate the feasibility of estimating leaf N in a discontinuous tree-structured orchard with good accuracy (r^2 = 0.83 and RMSE =0.06%). In this study, SIF and Chlorophyll $a+b$ content derived from the RTM were found to be the most important parameters for predicting leaf N across different spatial resolutions. The models based on airborne and spaceborne hyperspectral data outperformed the model based on Sentinel-2, despite Sentinel-2 having higher spatial resolution and reflectance data in the SWIR spectral region. This study will present this method applied to the assessment of other primary nutrient elements, such as phosphorus and potassium.

* Corresponding author