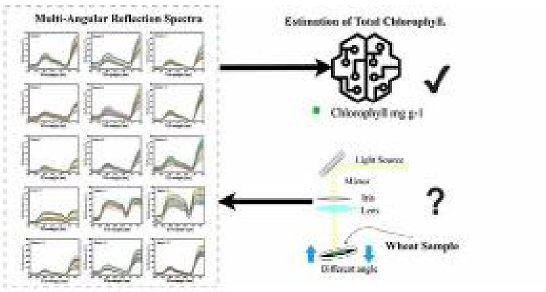
Machine Learning Models for Chlorophyll Content Estimation in Wheat Leaves From Multiangular Reflection Spectra

Publisher: IEEE Cite This PDF

Walter O. C. Flores ; Felipe Hornung ; Katia Christina Zuffellato-Ribas ; Marcia Muller ; José Luís Fabris ; André Eugenio Lazzaretti

All Authors

Abstract:
Chlorophyll is a crucial pigment in plants that converts sunlight into chemical energy during photosynthesis, whereas nitrogen is an essential nutrient associated with the growth and development of crops. As nitrogen and chlorophyll contents in the plants are closely related, monitoring the chlorophyll content allows for ascertaining the photosynthetic rate and dry matter production, which contributes to the optimization of crop production. In this sense, there is great interest in developing nondestructive and reliable methods for chlorophyll quantification in the field. This work proposes a nondestructive method based on the multiangular reflectance spectroscopy assisted by artificial intelligence (AI) for quantifying chlorophyll in wheat leaves. Deep neural networks (DNNs), minimally random convolutional kernel transform (MiniRocket), extreme gradient boosting regressor (XGBRegressor), random forest (RF) regression, and decision tree (DT) regressor models were trained and tested with reflection spectra. The spectral range from 450 to 750 nm was preprocessed by the Savitzky-Golay filter and principal component analysis (PCA). Chlorophyll content was determined using a fresh mass extraction methodology and absorption spectroscopy. Results indicate the effectiveness of machine learning models in predicting total chlorophyll content in wheat leaves from reflection spectra taken at multiple arbitrarily chosen angles. The DNN model determined total chlorophyll content with a mean absolute error (MAE) of 0.022 mg/g and a root mean squared error (RMSE) of 0.032 mg/g. In addition, we provide a Shapley additive explanations (SHAP) analysis to determine the most relevant spectral ranges for the model prediction and their relation with chlorophylls a and b. The results together form a relevant and original contribution to quantifying and interpreting chlorophyll in wheat leaves using nondestructive approaches.



Published in: IEEE Sensors Journal (Volume: 25 , Issue: 15, 01 August 2025)

Page(s): 29252 - 29261

DOI: 10.1109/JSEN.2025.3583256

Date of Publication: 02 July 2025

Publisher: IEEE

ISSN Information:

Print ISSN: 1530-437X

Electronic ISSN: 1558-1748

CD: 2379-9153

Funding Agency:

10.13039/501100003593-Conselho Nacional de Desenvolvimento Científico e Tecnológico (**Grant Number**: 306201/2021-6, 306569/2022-1 and 304297/2022)