ESTIMATION OF CARBOHYDRATE CONTENT IN APPLE TREE USING UNMANNED AERIAL VEHICLE BASED-HYPERSPECTRAL IMAGERY

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Total nonstructural carbohydrate (TNC) in apple trees is an important factor in determining the yield and quality of apple, but there is no research on TNC monitoring using remote sensing technology in the apple cultivation process. Accordingly, the objective of this study is to estimate TNC concentration in apple tree leaves using unmanned aerial vehicle (UAV) based hyperspectral imagery.

This study was conducted in experimental field of the apple tree (cultivar: Hongro/M.9 and age: 3 years old) which in the National Institute of Horticultural and Herbal Science of the Rural Development Administration located in Wanju-gun, Jeollabuk-do, Korea (35.828626 N, 127.031484 E). The hyperspectral image sensor (MicroHSI 410 Shark, Corning Inc., USA) was mounted on an UAV (Matrice 300 RTK, DJI Technology Inc., China) and used on May 23, June 3, June 17, July 4, July 19, July 28, August 16, September 7, and September 21, 2022, to acquire time-series images. After converting hyperspectral image into a normalized difference vegetation index (NDVI) image, the hyperspectral data at each central wavelength (band) of canopy with gyro, geometric, and radiometric correction was extracted by specifying the area of each tree using image processing software (ENVI 5.6, Exeils Visual Information Solutions, USA). Partial least squares regression (PLSR), ridge regression (RR), and gaussian process regression (GPR) based models for estimating TNC concentration were developed with the spectral data in agricultural data analysis platform (FinePro, Hortizen co. Ltd., Korea). For each regression analysis, train (calibration) and test (prediction) models were developed in the dataset at a ratio of 7:3, and the models were validated by setting k-fold to 5. the possibility of efficient image sensor operation was presented by comparing the models developed using the full bands and the model developed by selecting the key bands. The key bands were selected using the variance importance in projection (VIP) method in PLSR and shapely additive explanation (SHAP) method in RR and GPR. The model performance was evaluated depending on the coefficient of determination (R2), root mean squared error (RMSE), relative error (RE).

When using full bands, calibration, and prediction models for all regression analysis of train dataset achieved R2=>0.70, RMSEP<=1.41%, and RE<=7.43%. the validation models yielded R2=>0.57, RMSE<=1.68%, and RE<=8.86%. there was no significant difference in estimation performance between train and test datasets in all regression analysis. In PLSR, the 9 key bands were selected in blue, red edge, and NIR regions. In RR and GPR, the 9 key bands were selected in only NIR region. Calibration and validation models for all regression analysis of train dataset achieved the same performances as the models using full bands. In contrast, there was a difference in estimation performance between regression analysis using the test dataset. In PLS, prediction and validation models yielded R2<=0.30, RMSEP=>2.16%, and RE=>11.4%. In ridge and GP (the highest performance), the models yielded R2<=0.63, RMSE=>1.56%, and RE=>8.23% and R2<=0.68, RMSE=>1.46%, and RE=>7.70%, respectively. This study presents an important result for monitoring TNC in apple tree using remote sensing technology to help control apple yield and quality.

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