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## **REGRESSION MODEL FOR ESTIMATING BRANCH NUMBER OF SOYBEAN USING UAV-BASED MULTISPECTRAL IMAGES**

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### **ABSTRACT**

Soybean (*Glycine max* (L.) Merr.) is a protein-rich crop, and the number of branches is a significant trait associated with yield. This study aims to estimate the branch number of soybeans using vegetation indices (VIs) extracted from multispectral images mounted on a UAV. The study was conducted on the soybean cultivar Seonpung, sown on June 20, 2022, and June 24, 2023. Vegetation growth was investigated on 20 control and 30 treatment samples on August 20 and September 20, 2022, August 21 and September 25, 2023. Multispectral images were acquired on August 22 and September 21, 2022, and August 22 and September 20, 2023. Nine VIs (NDVI, GNDVI, GRVI, RVI, DVI, NDRE, PRI, OSAVI, TCARI) were derived from the multispectral images. Based on any combination of month and year, Ridge (RR), LASSO (LR), Support Vector (SVR), K-Nearest neighbors (KNR), and Random Forest Regression (RFR) models were tested using calibration to validation splits of 6:4, 7:3, and 8:2 with stepwise feature selection except LR. RFR performed best with any combination of datasets, such as month and year. The branch number model with August 2022 showed the best performance at an 8:2 ratio with 0.801, 0.406 ea, and 9.997% for calibration, and 0.913, 0.116 ea, and 3.057% for validation in order of R<sup>2</sup>, RMSE, and MAPE. However, there is a limitation of the model that was established for single-year data with a small sample size. Therefore, the multi-year model with any combination of month and year was compared with the single-year model. The August model was selected as the best-performing multi-year model at an 8:2 ratio, with 0.855, 0.376 ea, and 8.519% for calibration, and 0.784, 0.407 ea, and 8.562% for validation. It is expected that the model's stability and generalizability can be improved through additional time-series data collection and validation.

**Keywords:** Regression, multispectral image, Machine learning, Soybean, UAV

### **INTRODUCTION**

Soybean (*Glycine max* (L.) Merr.) is a protein-rich crop, and the number of branches is a significant trait associated with yield. This study aims to develop machine learning regression models to estimate the branch number of soybean plants by calculating vegetation indices derived from reflectance values extracted from UAV-based multispectral images.

## **MATERIALS AND METHODS**

The study used the soybean cultivar Seonpung, sown at an experimental field in Miryang, Republic of Korea, on June 20, 2022, and June 24, 2023. Growth surveys were conducted on 20 control and 30 treatment samples on August 20 and September 20, 2022, and August 21 and September 25, 2023. Multispectral images were acquired on August 22 and September 21, 2022, and August 22 and September 20, 2023, using a multispectral sensor (Altum-PT) mounted on a UAV (Matrice 300 RTK). After background removal using ENVI and QGIS based on a 0.52 cm GSD, the reflectance of each plant was extracted from the same circular area. Nine VIs were calculated for modeling after outlier removal. RR, LR, SVR, KNR, and RFR models were tested using calibration to validation splits of 6:4, 7:3, and 8:2 with stepwise feature selection except LR. The ability of each model was compared with  $R^2$ , RMSE, and MAPE.

## **RESULTS & DISCUSSION**

In the single-year models, the RFR model for August 2022 with 39 samples was the best at an 8:2 ratio with NDVI, DVI, OSAVI, and TCARI. Those were 0.801, 0.406 ea, and 9.997% for calibration, and 0.913, 0.116 ea, and 3.057% for validation, respectively. However, single-year models were limited by small sample size and low data diversity. Thus, monthly, yearly, and all-year combined models were developed. In the monthly combined models, the RFR model for August with 85 samples was the best at an 8:2 ratio with NDVI, RVI, NDRE, OSAVI, and TCARI. The model's ability was 0.855, 0.376 ea, and 8.519% for calibration, and 0.784, 0.407 ea, and 8.562% for validation, respectively. In the yearly combined models, the RFR model for 2023 with 93 samples was the best at 8:2 ratio with DVI and OSAVI. The model's ability was 0.801, 0.384 ea, and 7.398% for calibration, and 0.573, 0.406 ea, and 8.879% for validation, respectively. In the all combined models, the RFR model with 178 samples was the best at 8:2 ratio with NDVI, DVI, NDRE, and OSAVI. The model's ability was 0.833, 0.404 ea, and 8.817% for calibration, and 0.586, 0.551 ea, and 13.27% for validation, respectively. All combined models showed calibration  $R^2$  above 0.8. However, yearly and all-year models had validation  $R^2$  below 0.6. Therefore, the August model, with the best calibration and validation performance, was selected as optimal.

## **CONCLUSIONS**

In this study, machine learning regression models were developed to estimate soybean branch number using vegetation indices from UAV-based multispectral images, and their performances were comparatively analyzed. In the single-year models, the RFR model for August 2022 with 39 samples was the best at an 8:2 ratio. In the combined models, the RFR model for August with 85 samples was the best at an 8:2 ratio. It is expected that the model's stability and generalizability can be improved through additional time-series data collection and validation.

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