ABSTRACT

Leaf area index (LAI) is a dimensionless variable representing the total projected leaf area per unit of ground area. Direct measurements of LAI require destructive sampling as well as time-consuming and labor-intensive processing procedures. Therefore, significant research has focused on utilizing remote sensing to estimate LAI. Traditionally, multiple linear and nonlinear regression models have been used to estimate LAI using selected allometric plant features derived from spectral and LiDAR data. This study investigates the effectiveness of point-based deep learning models, which utilize geometric features at different scales, to estimate the LAI of maize using UAV-based light detection and ranging (LiDAR) data.

The experiment was planted in a modified randomized complete block design with two replicates of hybrid varieties and inbred varieties, located at the Agronomy Center for Research and Education (ACRE) at Purdue University, West Lafayette, Indiana, USA. Two different LiDAR units installed on different UAV platforms collected LiDAR data in 2021. A LiCOR LAI-2200 instrument was used to collect ground reference data. This study proposed a modification of PointNet++ to specifically incorporate the inbred and hybrid information from the varieties into the model. The estimated LAI values from the proposed model are compared to the results of PointNet++ and the results obtained by support vector regression (SVR) using manually selected features. Further, the impact of stratified sampling with and without considering the inbred and hybrid information was evaluated by comparing the performance of PointNet++ using two stratified cross-validation experiments. The impact of the scale of features used in the model was also evaluated by comparing the LAI estimated by PointNet++ and PointNet, which only utilizes global features.

While the quantity of the training data is small, the proposed model ($RMSE = 0.642$, $rRMSE = 0.141$, $MAPE = 0.138$) still outperformed both the SVR model $RMSE = 0.654$, $rRMSE = 0.141$, $MAPE = 0.142$ and PointNet++ ($RMSE = 0.657$, $rRMSE = 0.144$, $MAPE = 0.143$). The results for the experiments of stratified cross-validation show that the $RMSE$ was improved by 0.053 when considering the hybrid and inbred information in the stratified cross-validation. Finally, PointNet++ achieved better results compared to Pointnet ($RMSE = 0.913$), suggesting features in local scales are beneficial for LAI estimation.