Estimating Leaf Area Index From Terrestrial LiDAR and Satellite Based Vegetation Indices Using Bayesian Inference

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Abstract

Leaf area index (LAI) is an important indicator of ecosystem conditions, and can be estimated in the field using several methods. This study compared LAI estimates from two different sensors, a Leica ScanStation C 10 Terrestrial Laser Scanner (TLS) and a handheld Li-Cor LAI-2200 Plant Canopy Analyzer (PCA). Our study also evaluated the uncertainty of LAI estimates across space by using remotely sensed vegetation indices. The TLS-based LAI calculation involved separating green leaves from woody biomass based on distance and return intensity. The data were then used with circular and spherical point cloud slicing to calculate stereographically (G) and orthographically (O) projected LAI estimates. The LAI estimates from the TLS and PCA suggested that there is reasonable agreement (i.e., correlations r > 0.50) between the two sensors. Predicted LAI from LandSat TM-based vegetation indices were used to develop a Bayesian Linear Regression (BLR) approach to produce a continuous LAI for the Oak Openings Region in NW Ohio. The results from the BLR provide details about the parameter uncertainties and insight into the potential to estimate LAI using datasets with foliage only in comparison to datasets with foliage and woody biomass. For instance, the modeled residuals associated with the LAI estimates from the TLS-orthographic projection that considers only foliage had the lowest overall model uncertainty among all of the LAI estimates. In addition, comparisons between the deviations from the mean of the LAI estimates indicate that sparse and open areas were associated with the highest error.

Study Area

The ground data were collected from 30m radii plots, randomly selected across 30 sites of the Oak Openings Preserve Metro Park, Toledo, Ohio, a rare ecosystem with an approximate area of 15 km² in the Lake Erie watershed. Each site, 4 scans were acquired and co-registered into a single point cloud. The co-registered point clouds were clipped to a 30 m radius surface area. PCA data were collected from 9 positions from each site.

Materials and Methods

Terrestrial Laser Scanner C 10

LAI 2200 Plant Canopy Analyzer (PCA)

At each site, 4 scans were acquired and co-registered into a single point cloud. The co-registered point clouds were clipped to a 30 m radius surface area. PCA data were collected from 9 positions from each site.

Results

During pre-processing, the TLS return intensity and the distance to the target were identified using both leaf-on and leaf-off scans. Using these results, thresholds separating woody biomass from foliage were detected at 2m distance intervals.

Using thresholds, we prepared two sets of data: data with only foliage and data with foliage and woody biomass. We then calculated LAI from both data sets using stereographic and orthographic projections. To reduce the processing time, each data set was sliced into 25 cm thick slices.

Each 25 cm slice was projected into a 2D horizontal surface and rasterized into images to calculate Orthogonal LAI.

Conclusions

• Correlations among the six calculated LAI suggest that there is a strong agreement between the two sensors (TLS and LAI 2200/PCA).
• The BLR models suggest that the model complexity increases for LAI predictions of foliage compared to the prediction using both foliage and woody biomass.
• The Bayesian inference uncertainties and modeled residuals conclude that LAI estimates from the TLS-orthographic projection that consider only foliage had the lowest overall model uncertainty with lowest error and residual dispersion range among the six spatial LAI estimating models.
• TLS point cloud data can provide LAI estimates of foliage, potentially saving time and providing a more comprehensive dataset than other field-based methods.

References