Relationship between Leaf Area Index (LAI) Estimated By Terrestrial LiDAR and Remotely Sensed Vegetation Indices as a Proxy to Forest Carbon Sequestration

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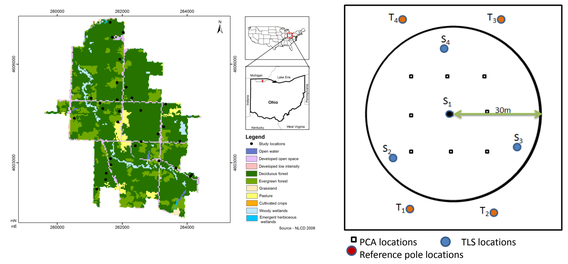
Abstract

Leaf Area Index (LAI) or the canopy foliage content is a key biophysical variable in calculation of Net Primary Productivity (NPP) which is considered as a major parameter in quantification of forest carbon stock. Hence, the accurate prediction of spatial distribution of LAI and associated uncertainty in the model development is essential. This research presents 1) a comparison between LAI ground-based measurements derived from LAI 2200 Plant Canopy Analyzer (PCA) and 3-D cloud data measurements from Terrestrial Laser Scanner (TLS) ; 2) the development of predictive LAI model that uses correlations between ground-based measurements and satellite derived indices including Normalized Difference Vegetation Index (NDVI), Perpendicular Vegetation Index (PVI), and Perpendicular Vegetation index 3 (PVI3) ; and 3) to quantify uncertainty in parameter estimates by coupling Bayesian Inference with MCMC simulation. The TLS based LAI calculation involves leaf-wood separation based on distance – return intensity relationship and circular and spherical point cloud slicing for 2D canopy image preparation to calculate stereographically (S) and orthographically (O) projected LAI calculations. PCA based LAI was directly calculated from the instrument and the vegetation data was derived from Landsat TM images of June 2011. The results display the correlations between ground based measurements, correlations of predicted and calculated LAIs and the overall uncertainty of the model with continuous LAI maps and residuals plots.

Study Area

The ground data was collected from 30 selected sites of the Oak Openings Preserve Metro Park, Toledo, a rare ecosystem with an approximate area of 15 km^2 in the Lake Erie watershed .

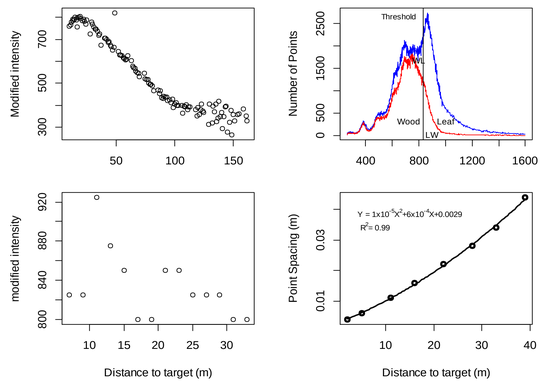


Materials and Methods

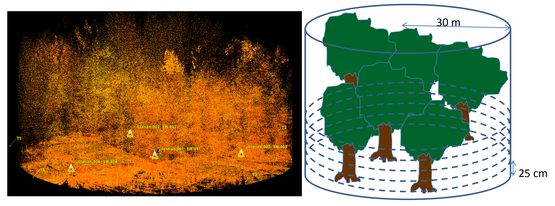
Terrestrial Laser Scanner C 10

LAI 2200 Plant Canopy Analyzer

The TLS return laser intensity was plotted as a function of distance for separating foliage from trunks and branches. Different, thresholds were generated for the LAI derivation.



At each plot, the TSL point cloud was generated from a total of four scans that were combined and clipped into 30 m radii cylinders. The photosynthetic components of the tree canopies were sliced into 25 cm cylinders parallel to the plane and converted from 3D real space into 2D model space.



Co-registered point cloud

Circular point cloud slicing

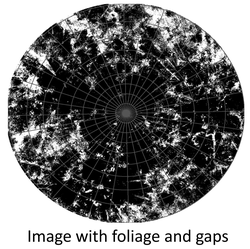
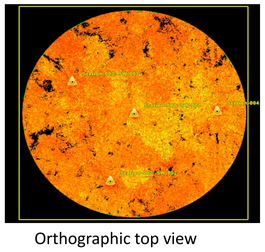
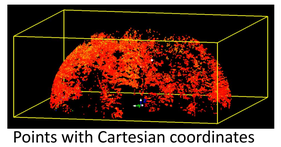


Image with foliage and gaps

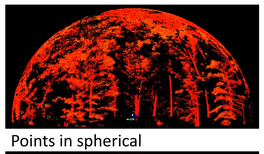


Orthographic top view

Stereographic LAI was calculated projecting points into a surface of a sphere and then to 2D images.

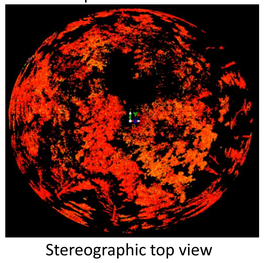


Points with Cartesian coordinates



Points in spherical

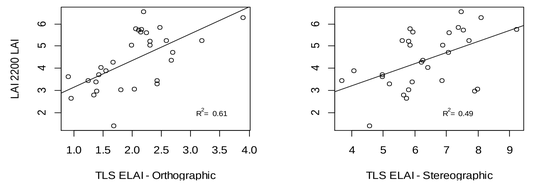
Image with foliage and gaps



Stereographic top view

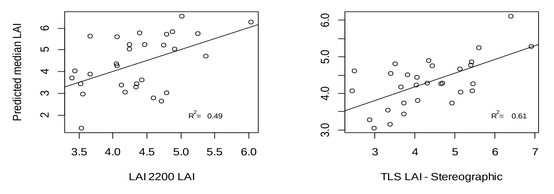
Results

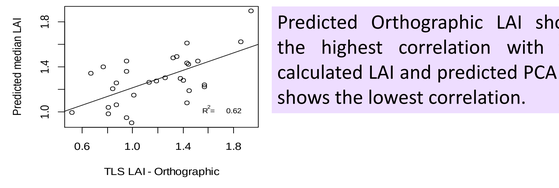
Both TLS based stereographic and orthographic LAIs showed a good correlation with PCA LAI (R^2>50).



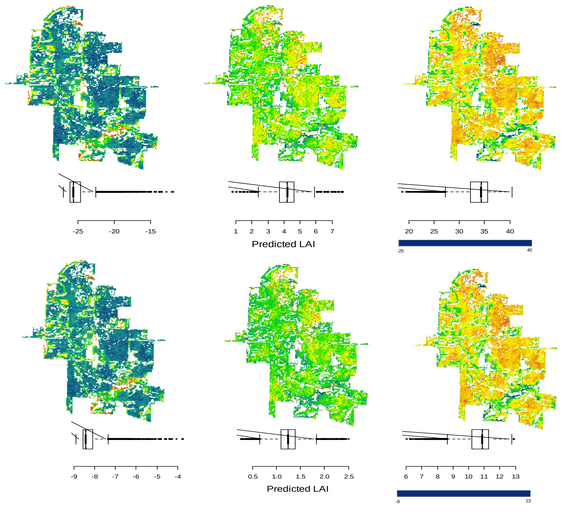
Median values of parameters estimated by Bayesian inference with MCMC and respective vegetation indices were used to develop the following prediction models of spatial LAI distribution.

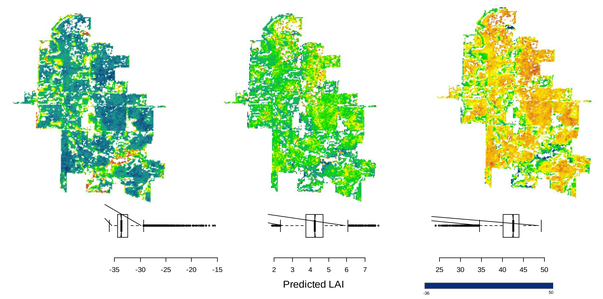
LAI (S) = -9.049 + 0.438 (PVI3) - 0.219 (NDVI) + 0.893 (PVI)
LAI (O) = -2.834 + 0.147 (PVI3) - 0.075 (NDVI) + 0.292 (PVI)
LAI (LAI 2200) = -6.059 + 0.392 (PVI3) - 0.202 (NDVI) + 1.013 (PVI)



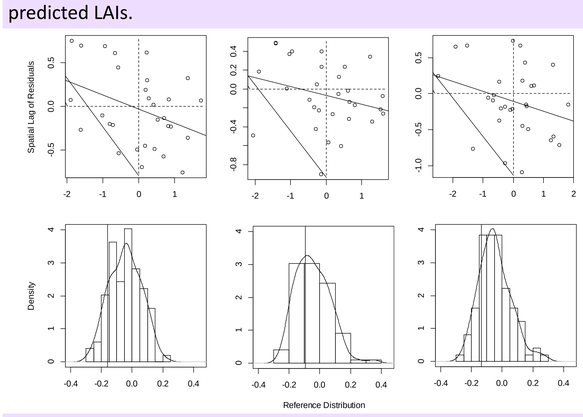


Predicted Orthographic LAI shows the highest correlation with the calculated LAI and predicted PCA LAI shows the lowest correlation.





The Maps display the predicted LAIs at 25th, 50th and 75th quartiles at 95% confidence level of stereographic LAI, orthographic LAI, and LAI 2200 LAI respectively. Orthographic LAI shows lowest deviation of predicted LAIs.



Plots display Moran's *I* test for assessing spatial autocorrelation of model residuals of PCA data (Morans's *I* = -0.1602), TLS-orthographic data (Morans's *I* = -0.0932), and TLS – stereographic data (Morans's *I* = -0.1369) respectively. The residuals has no spatial autocorrelation with each other. The respective density distribution pattern expresses that the orthographic data reveals the lowest overall uncertainty meaning the best predictive model.

References

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