TLS data to estimate aboveground biomass of open-grown urban and rural forest trees

Georgios Arseniou[1*], David W. MacFarlane[1], Kim Calders[2] and Matthew Baker[3]

[1]Department of Forestry, Michigan State University, East Lansing, Michigan, USA

[2]Computational & Applied Vegetation Ecology Laboratory, Department of Environment, Faculty of Bioscience Engineering, Ghent, University, Belgium

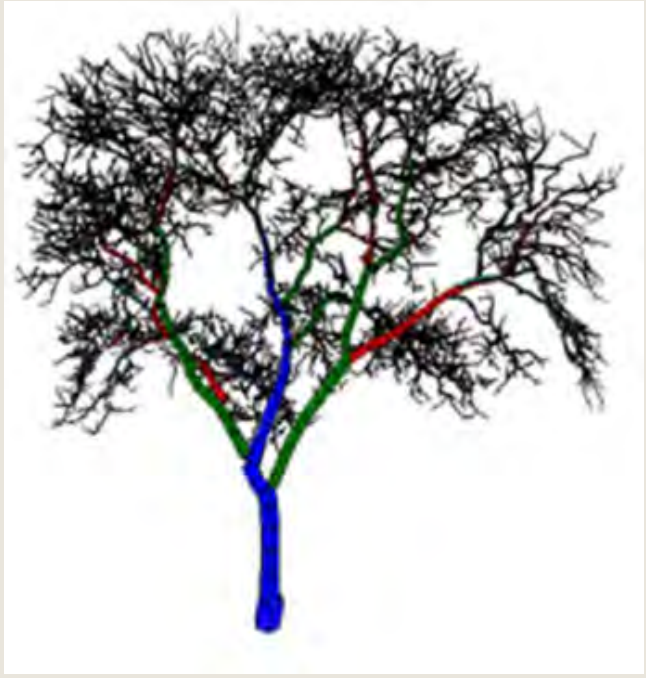
[3]Department of Geography and Environmental Systems, University of Maryland- Baltimore County, Baltimore, Maryland, USA

*presenter

2022 Operational Lidar Inventory (OLI) Meeting

Tree Architecture & Aboveground Biomass

- Allometric Growth
- Interaction of Genetic and Environmental Factors - Plasticity
- Branching Network
- Woody Biomass of Main Stem and Branches



The Tree of Life

Stoclet Frieze, 1905 by Gustav Klimt

Aboveground Biomass (AGB)

- Total dry mass (at 0% moisture content) allocated to the live and dead tissues and organs of the aboveground tree structure (Kükenbrink et al. 2021, Burt et al. 2021)
- Approximately 45-50% of live plant biomass is carbon content (Burt et al. 2021)
- Urban and rural forest trees store large amounts of carbon in their aboveground biomass (McPherson 1998)
- Uncertainty for forest carbon stocks at different spatial scales: dearth of accurate and detailed tree biomass data
- More uncertainty for urban forests carbon offsets (Tigges and Lakes 2017)

McPherson 1998, Nowak and Crane 2002, Casalegno et al. 2017

Urban Forest AGB→ Benefits Optimization

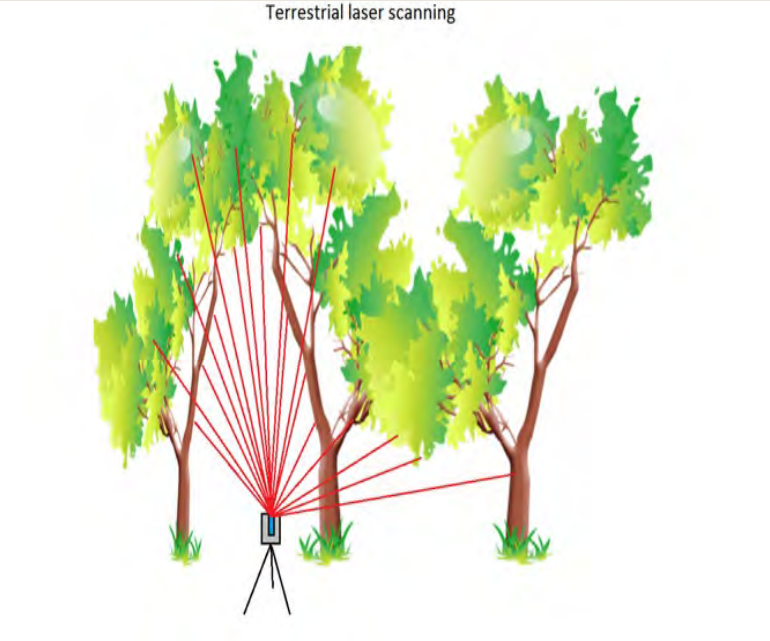
Data to Quantify Tree AGB

Destructive Sampling/ Standing Tree Measurements

Terrestrial Laser Scanning (TLS)

Terrestrial Laser Scanning (TLS)

- Active remote sensing
- Emission of laser pulses (tens to hundreds of thousands per second)
- Returned energy : function of time (time-of-flight systems) or shift in the phase of the light wave of the emitted laser beam (phase-shift technology)
- Detailed reconstruction of tree architecture & structural complexity



Calders et al. 2015, Liang et al. 2016 , Malhi et al. 2018

Terrestrial Laser Scanner

- FARO Focus^{3D} X330
- Laser light: 1550 nm wavelength
- Typical beam divergence: 0.19 mrad
- Range: 0.6–330 m

Methods – TLS Data

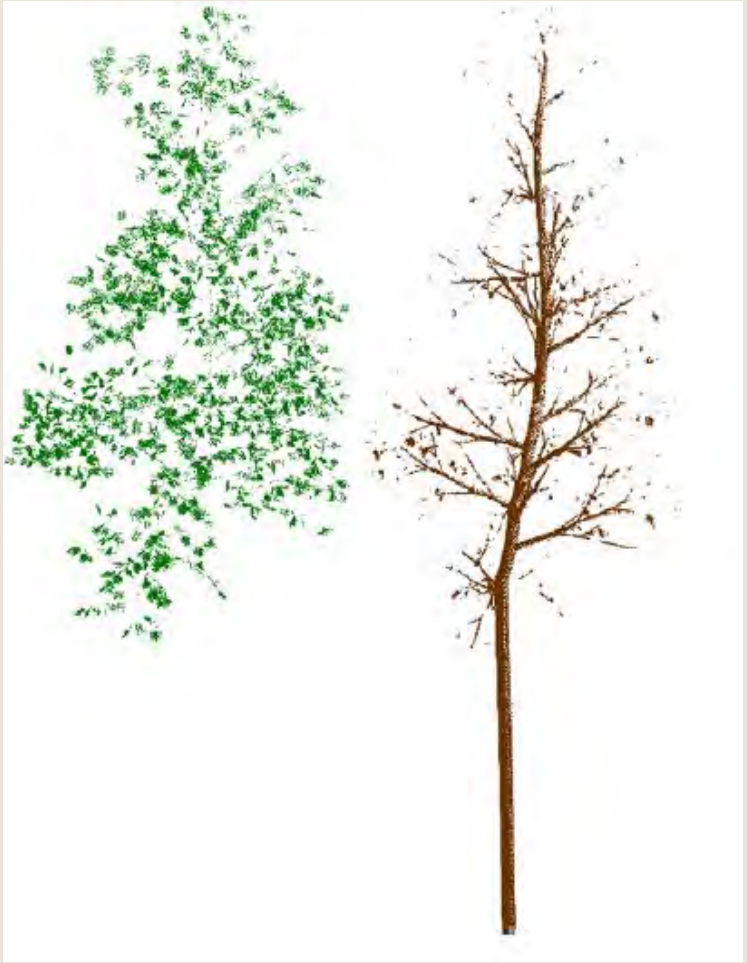
10 Urban Trees- MSU (*A. rubrum, A. saccharum, G. triacathos, P. nigra)*

- FARO Focus^{3D} X330
- Leaves-on scans only for *G. triacanthos* and *P. nigra* trees
- Scans of Individual trees

20 Harvard Forest Trees (*Q. rubra, A. rubrum*, *T. canadensis*, *P. strobus)*

- Riegl VZ-400
- Leaves-off scans except evergreen trees
- 48 scans in 50m x 50m Main plot (16 trees)
- 9 scans in 20m x 20m North plot (4 trees)

Methods - Leaf and Wood Classification of the Point Clouds



- *TLSeparation* algorithm
- Unsupervised classification of geometric features
- "Shortest-path" analysis

Vicari et al. 2019

Methods- Quantitative Structure Models (QSMs)

- QSMs: three-dimensional architecture of trees by fitting cylinders to a tree's laser point cloud (leaf-off)
- Branch and stem topology are preserved
- Stem & branches of different branching orders
- Information about the size, the location, the hierarchy and the orientation of the branching network
- TreeQSM v.2.3.0 (Copyright (C) 2013-2017 Pasi Raumonen)

Raumonen et al. 2013, Hackenberg et al. 2015, Disney et al. 2018

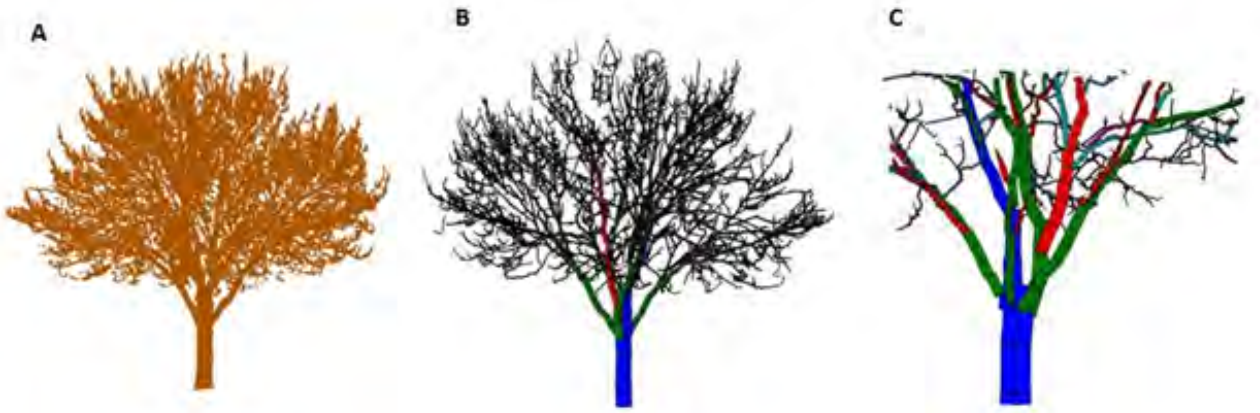
Methods- Woody Biomass Estimation from QSMs

- Total woody volume: the total volume of the cylinders that were fitted to the leaf-off point cloud of each tree
- Stem woody volume vs Branches woody volume

<u>Woody Volume to Mass</u>

- Reference basic density values of the main stem and branches
- Published values of basic density at species level (Miles and Smith 2009)

Methods- Quantitative Structure Models (QSMs)

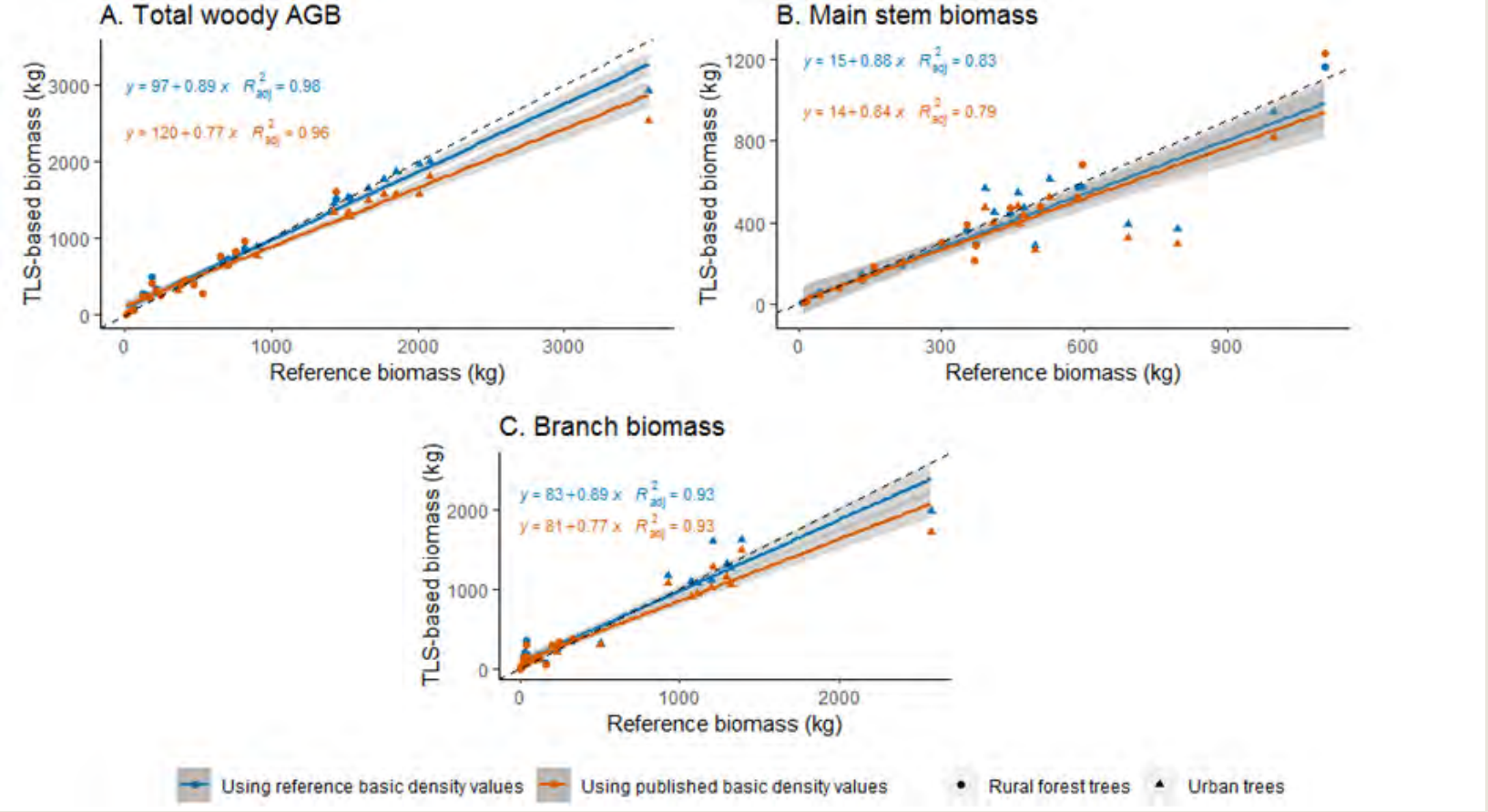


(A) The leaf-off point cloud of an urban *A. rubrum* tree. (B) The generated QSM of the tree. (C) A close-up picture of the generated QSM, consisted from several cylinders fitted to the point cloud of the tree. The colors denote the different branching orders i.e. the main stem is colored blue, the 1st order branches are colored green, the 2nd order branches are colored red etc. Four facets have been used to visualize the QSM cylinders.

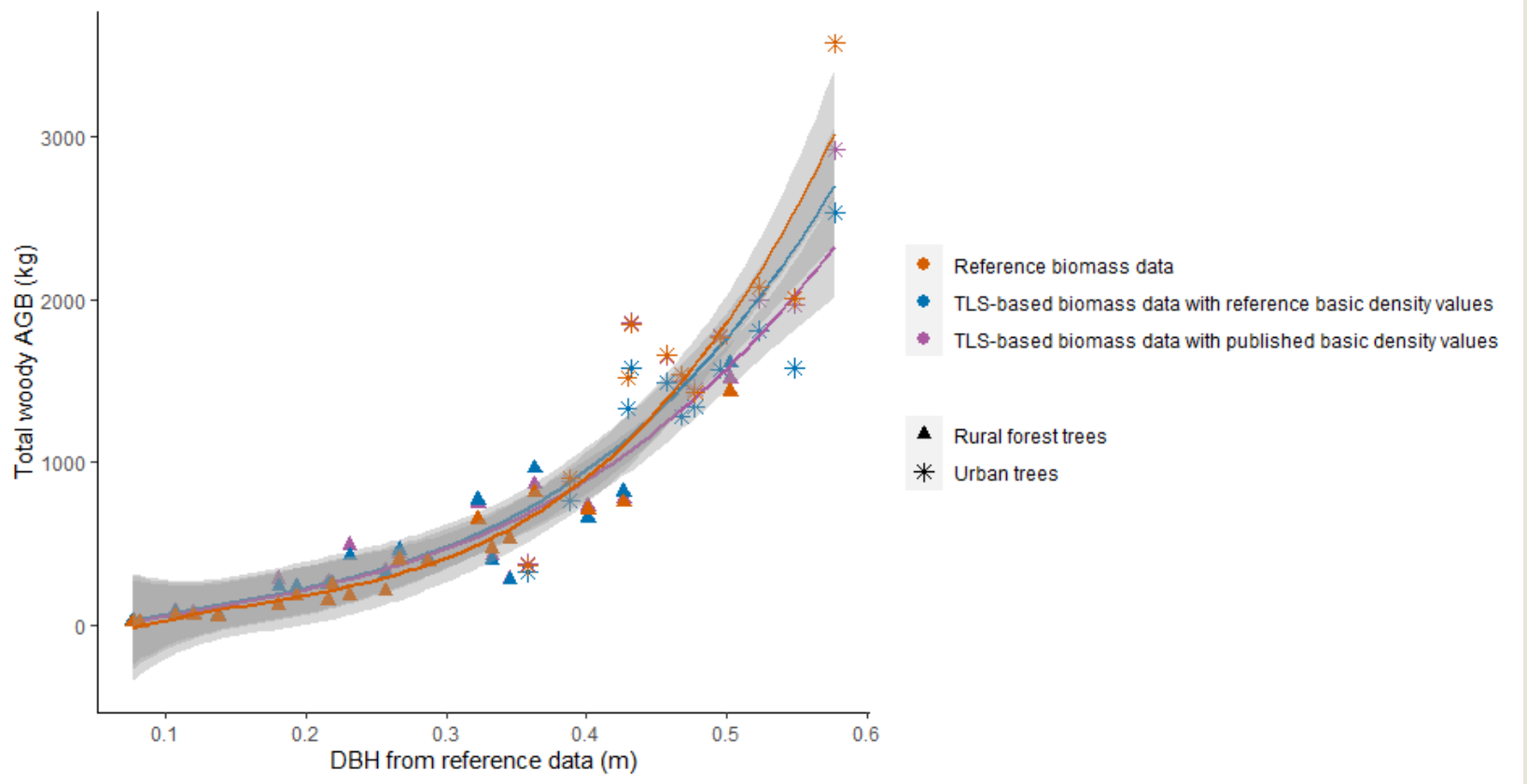
Methods – Reference Tree Data

- Standing Tree Measurements
- Green Weights
- Dry Weights (in lab)

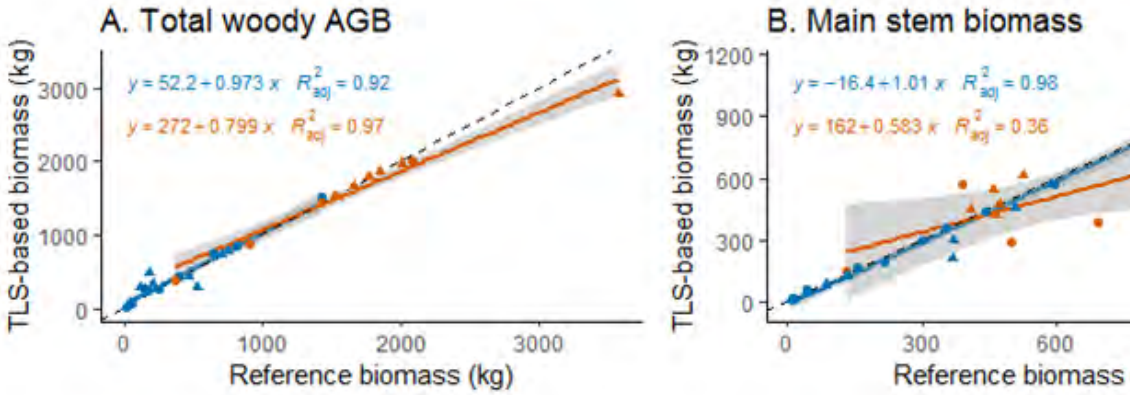
Results- AGB and components biomass across all study trees

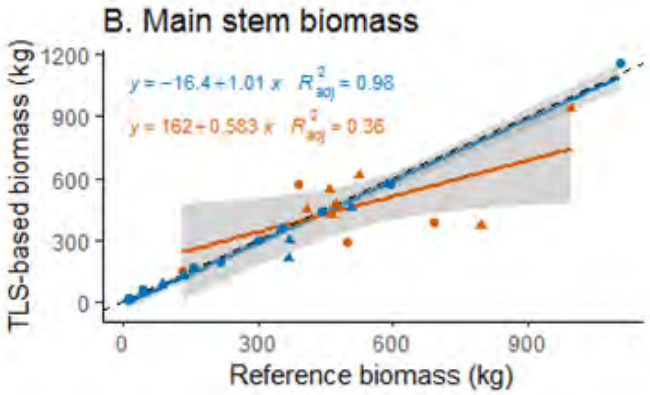


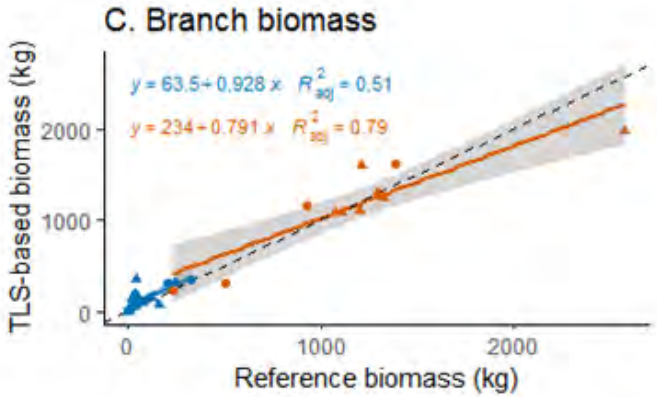
Results- AGB and components biomass across all study trees



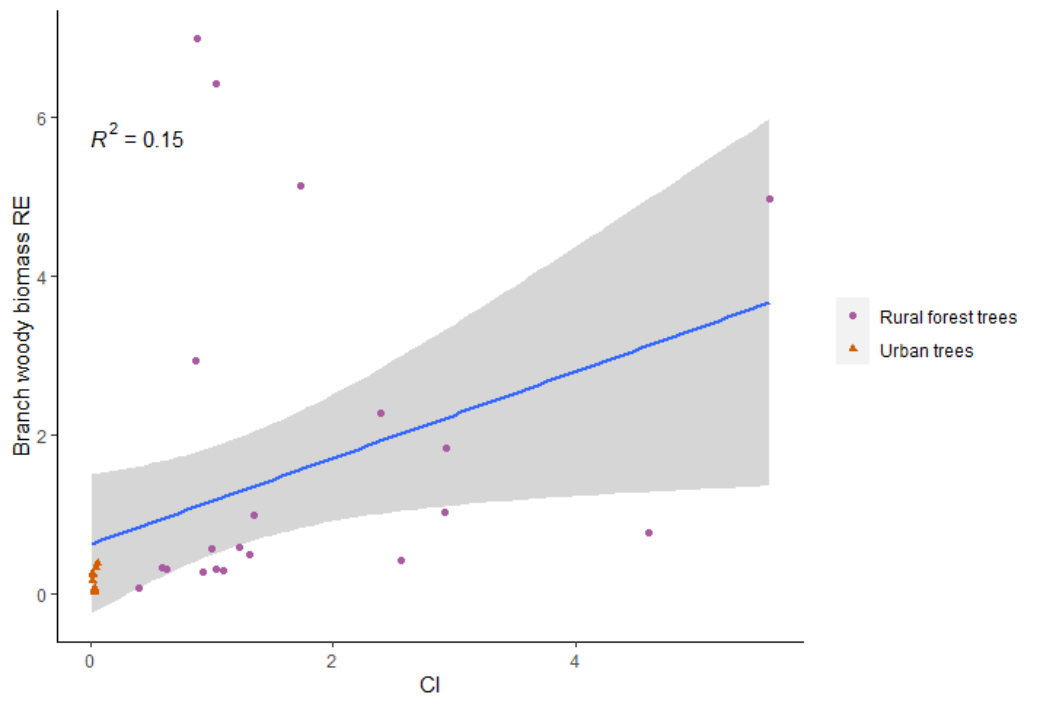
Results- AGB and components biomass for urban and rural forest trees



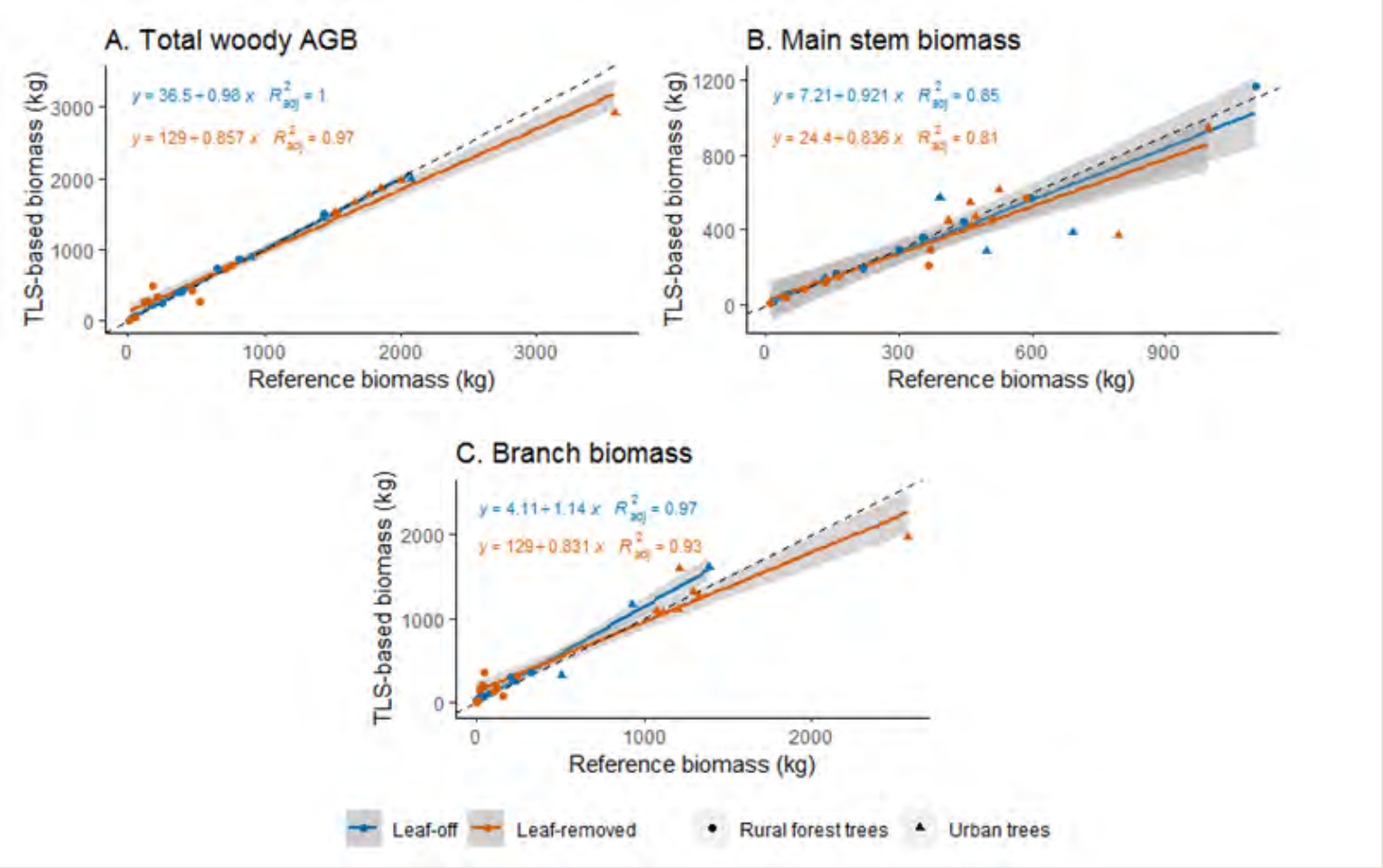




Results- AGB and components biomass for urban and rural forest trees



Results- AGB and components biomass of leaf-off and leaf-removed tree point clouds



Conclusions

- TLS produces novel data of tree architecture: volume estimates that can be converted to biomass
- TLS could provide comparable data for calibrating tree biomass equations, without the need for destructive sampling
- Basic density values, growing environment, and leaf conditions can affect TLS-based estimates quality
- **Ecological Implications**: modeling carbon stocks of trees and forest carbon dynamics in different spatial and temporal scales

Acknowledgements

- Dr. David W. MacFarlane, Dr. Kim Calders, Dr. Matthew Baker
- MSU W.J. Beal Botanical Gardens and Campus Arboretum
- MSU Department of Infrastructure, Planning and Facilities
- UNAVCO U-061 (Dr. Alan Strahler)
- Research staff of Harvard Forest (Dr. David Orwig, Dr. Audrey Barker Plotkin)
- Bouyoukos Fellowship
- USDA National Institute of Food and Agriculture
- USDA Forest Service, FIA Northern Region
- NSF grant DEB no. 1637661 and DEB no. 1855277

Thank you for your attention!

Georgios Arseniou, PhD

Research Associate
Forestry Department
E: arseniou@msu.edu

https://www.researchgate.net/profile/Georgios-Arseniou-2