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Forestry Systems (CAFS)

City of Olympia



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Remote
Sensing &
Geospatial
Analysis
Laboratory

Dr. L. Monika Moskal

*Assistant Professor of Remote Sensing & Biospatial Analysis
School of Forest Resources, University of Washington*

LiDAR-based metrics for solar energy attenuation and large woody supply potential in riparian forests



EEON
Evergreen Ecological Observation Network



UNIVERSITY OF WASHINGTON
Precision Forestry Cooperative

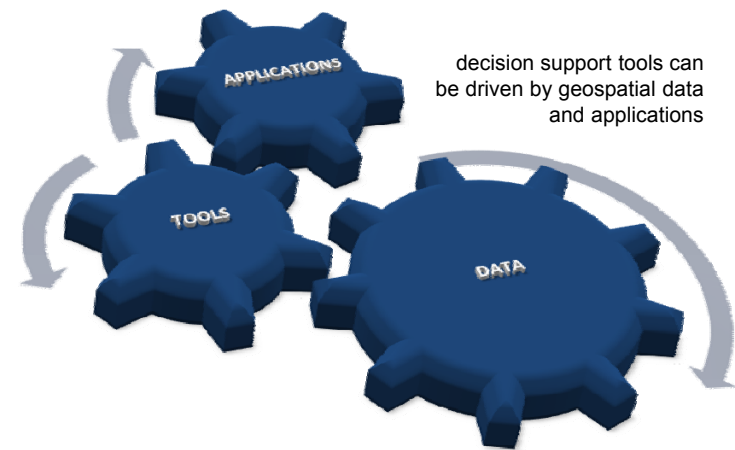


EVERGREEN
THE EVERGREEN STATE COLLEGE
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Outline

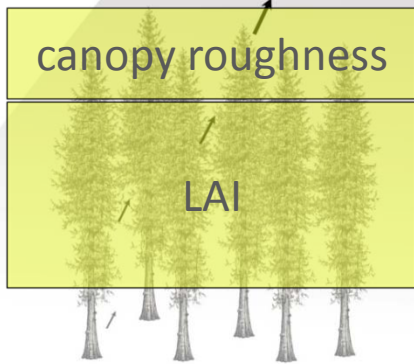
- Background
- LiDAR based forest inventory and LAI (leaf area index)
 - Large woody supply potential
 - Solar energy attenuation
- Future work

Background

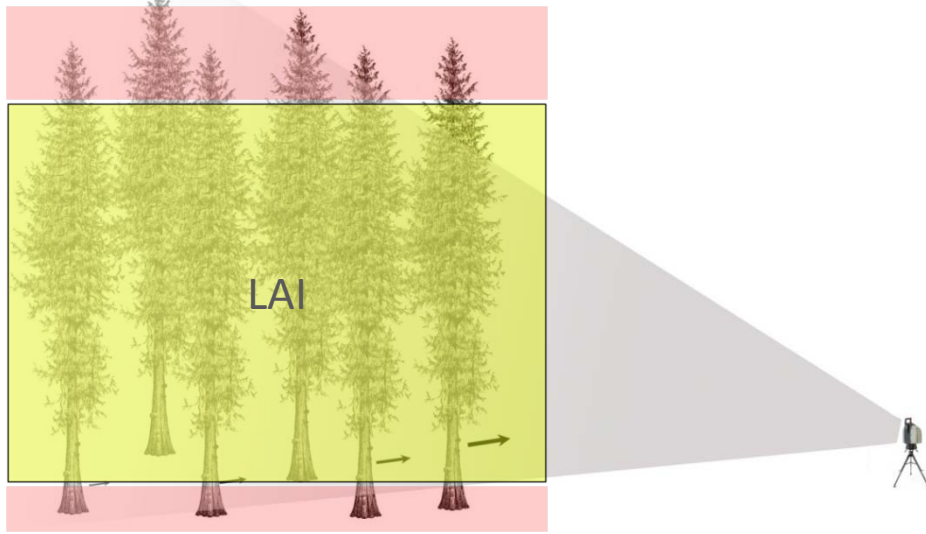
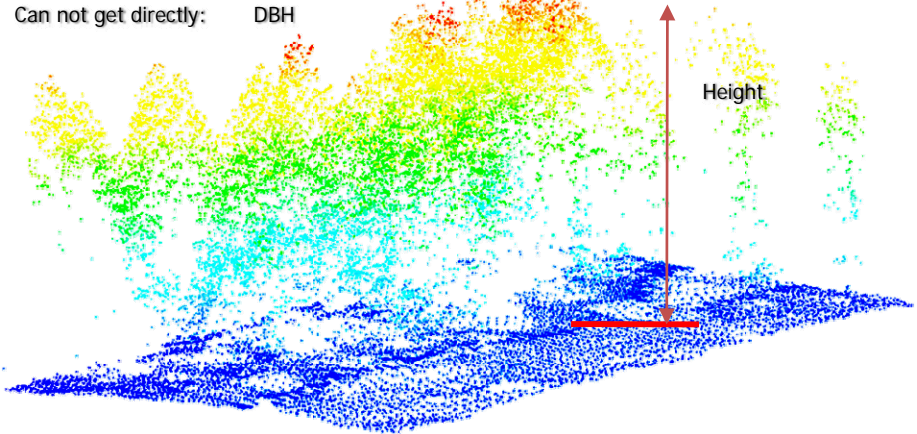


- Solar energy attenuation (thermal loading) and large woody supply potential are two ways of describing the ecosystems function of riparian forests
 - Thermal loading is the relative potential for stream warming; not stream temperatures (would need site specific calibration)
- Field studies represent only a snapshot in the spatiotemporal continuum, remote sensing can assist with spatially explicit modeling at a site, watershed and landscape levels
- Understanding the riparian function supports watershed restoration and conservation

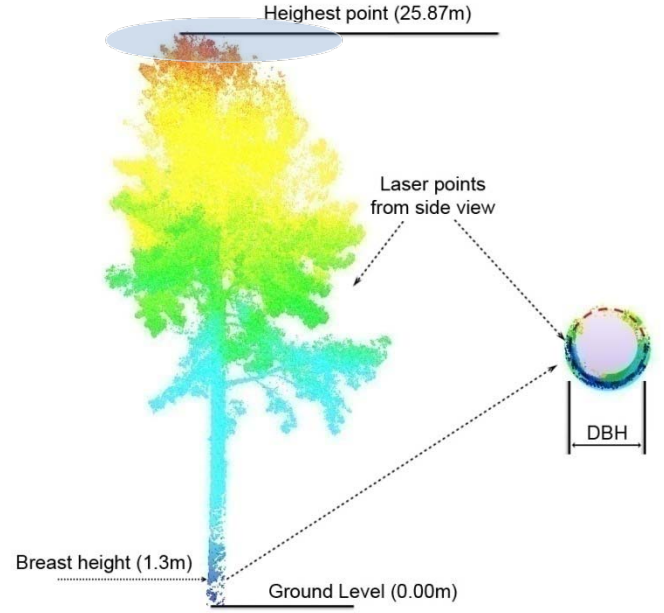
Airborne LiDAR

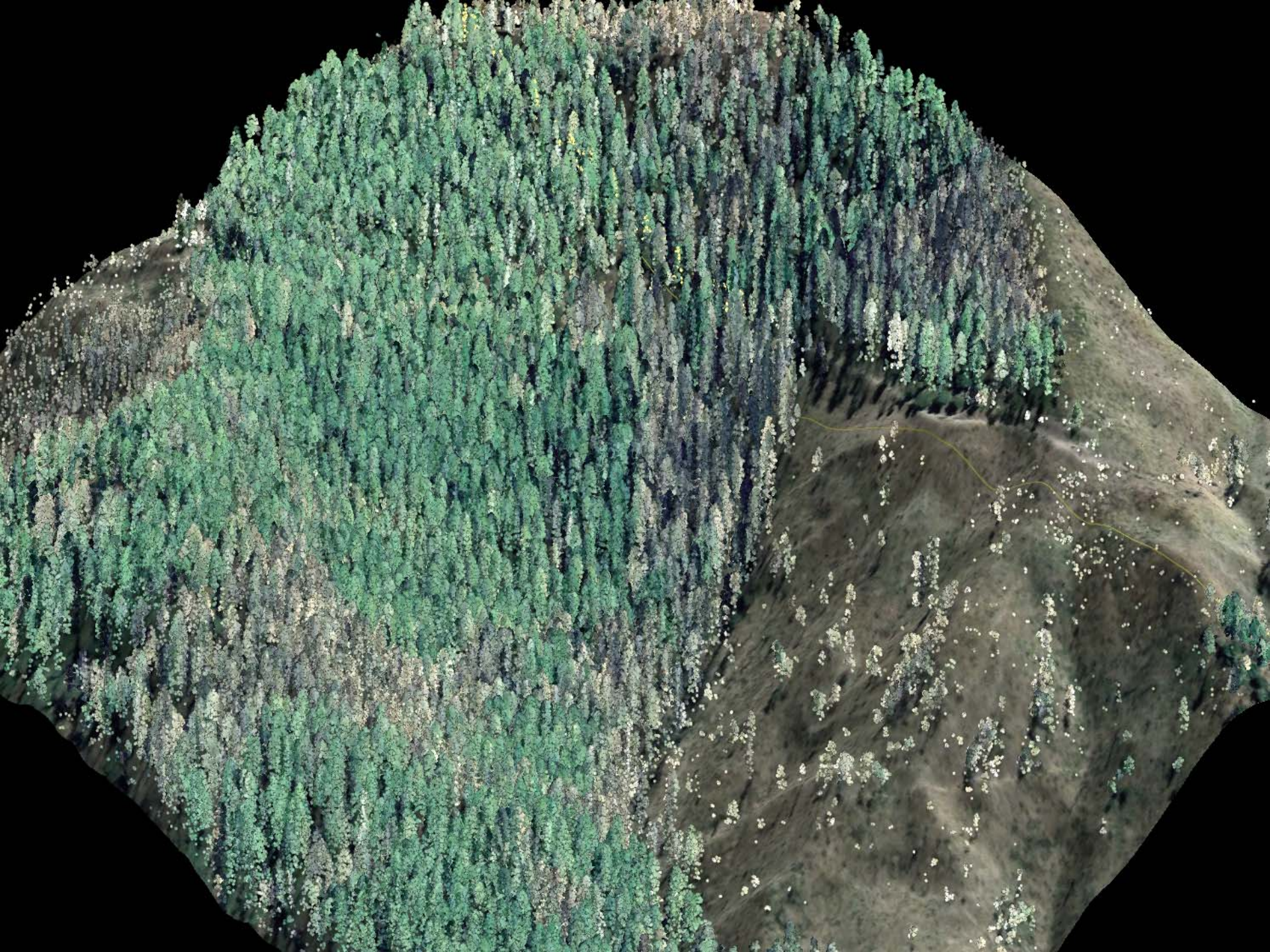


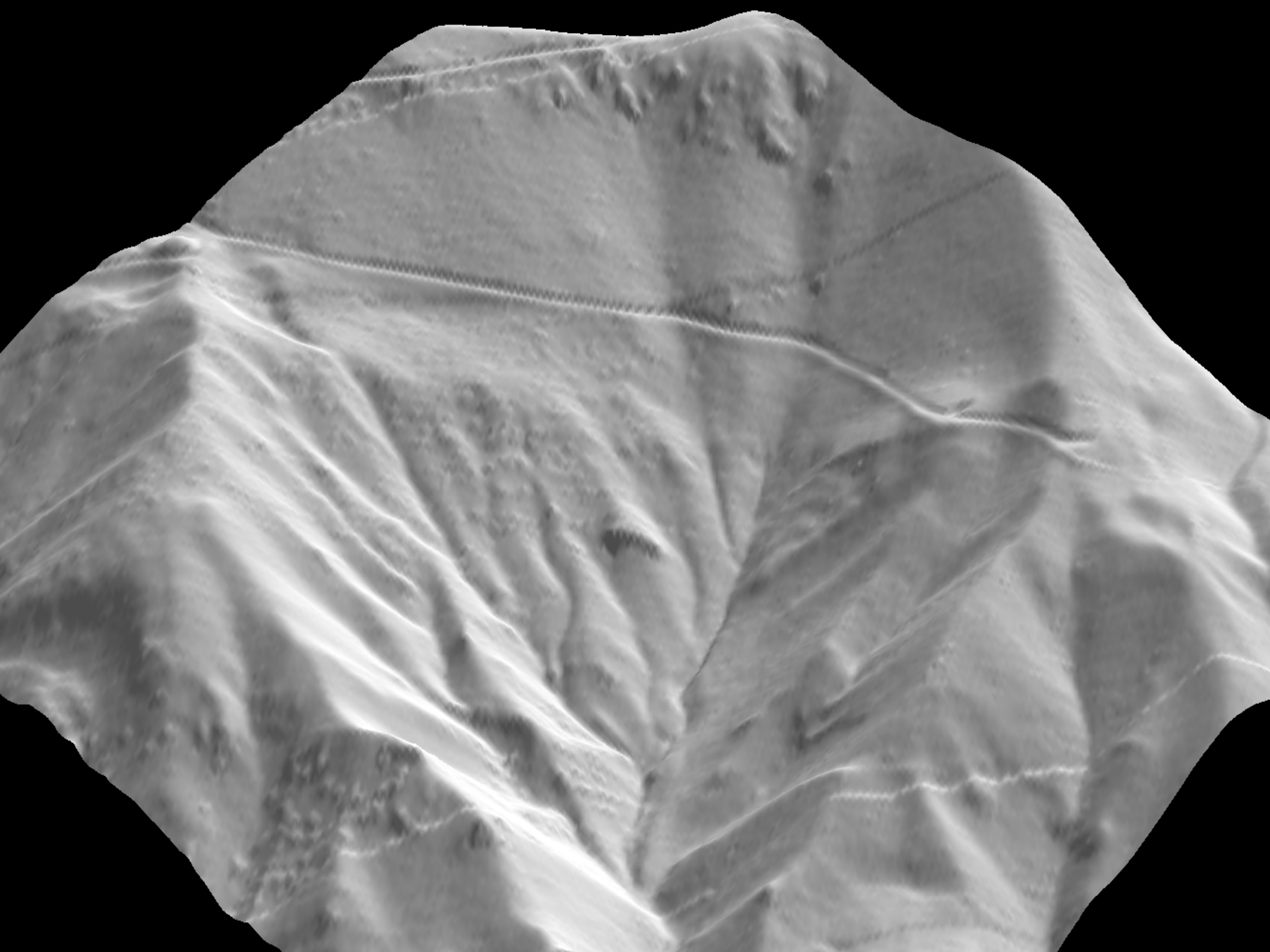
- Easy to get: Stem location
Height
Density
- Harder to get: Species
Crown diameter
Height to crown

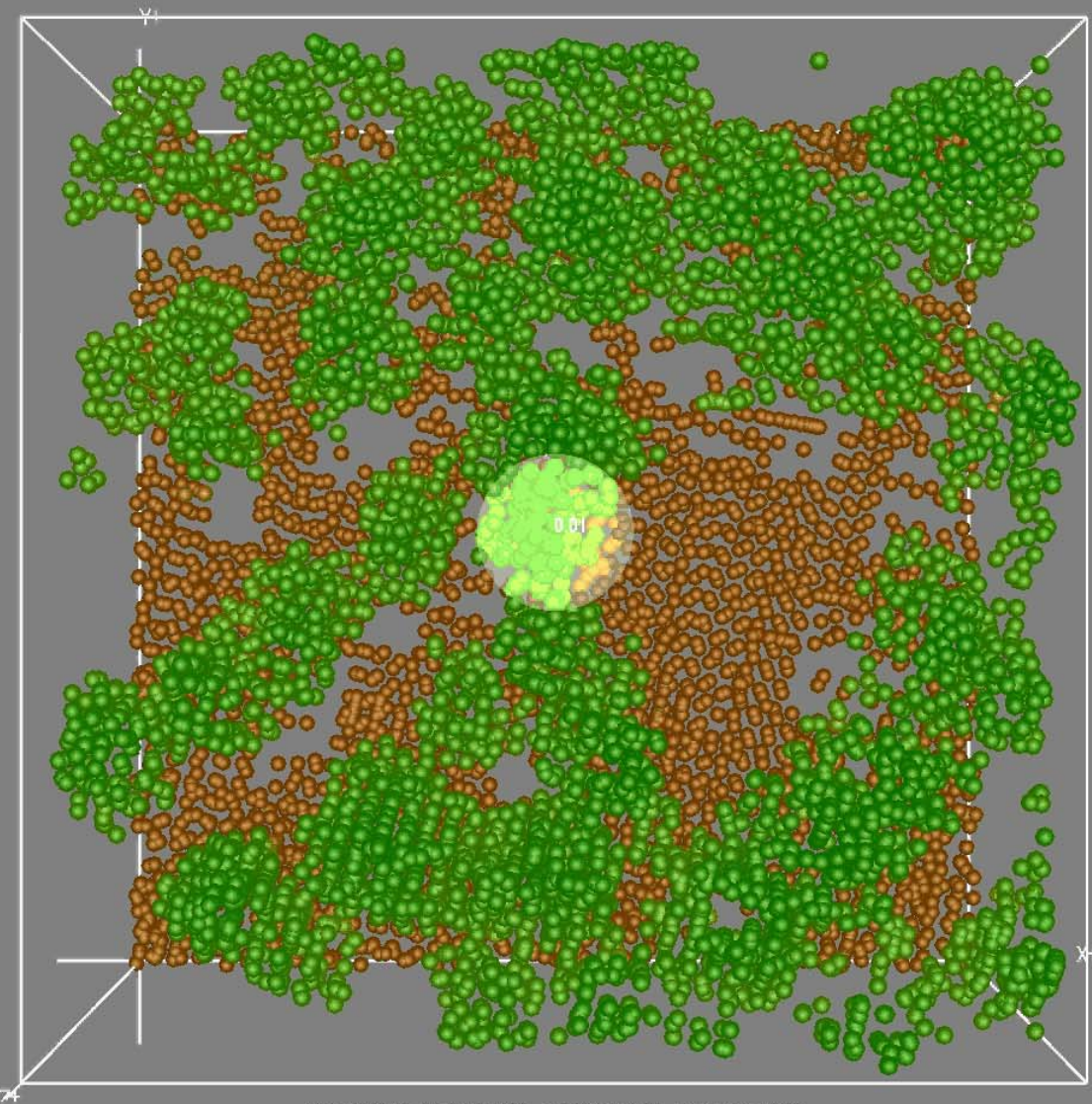
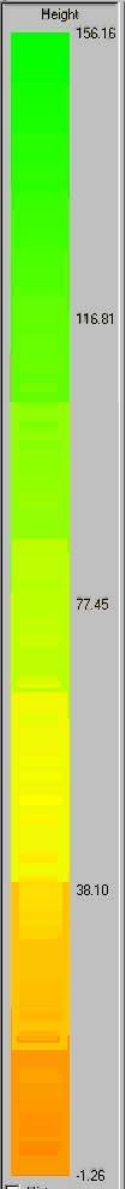
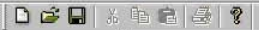


Ground-based LiDAR





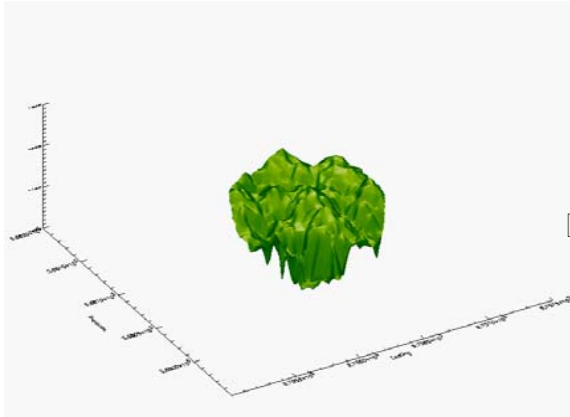




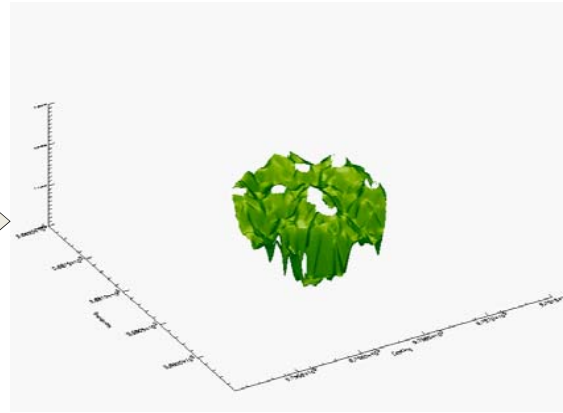
X: 974870.27 Y: 566376.11 Elevation: 0.01 Diameter: 25.20

About LDV

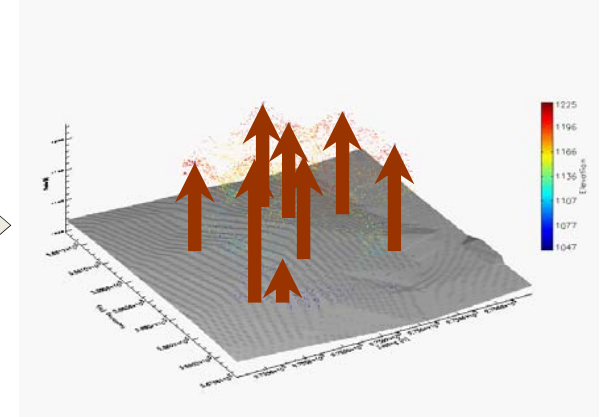
LiDAR based forest inventory



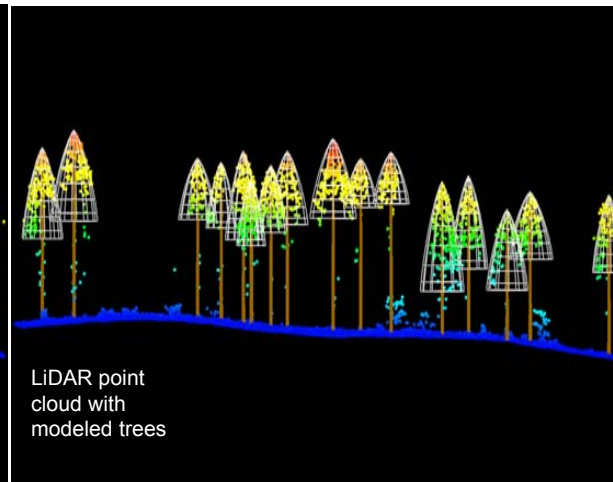
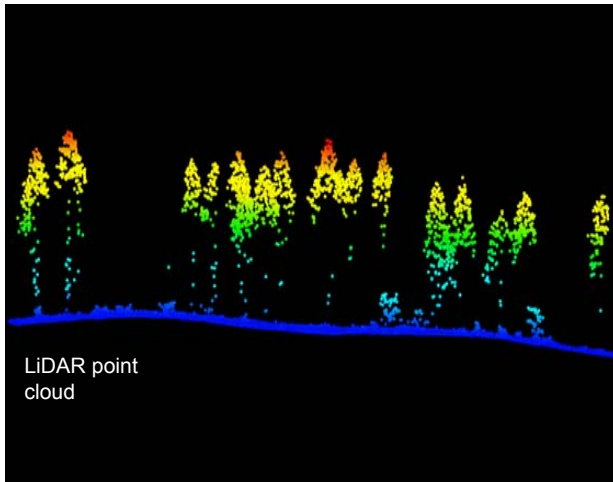
LIDAR Canopy Surface Model for 1/5th-acre Plot



Tree Crown Apexes Located through Morphological Analysis



Individual Tree Stem Locations and Heights
(vertical brown arrows)

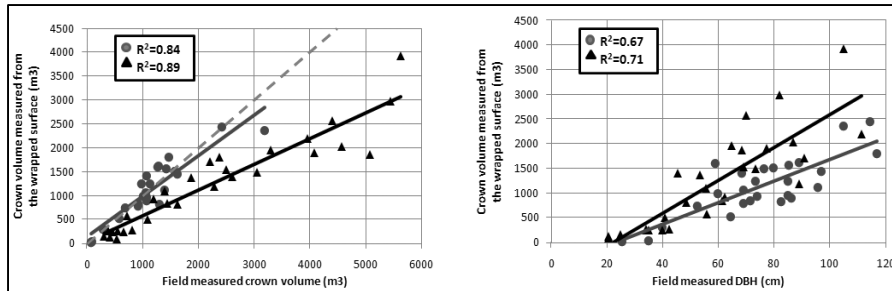
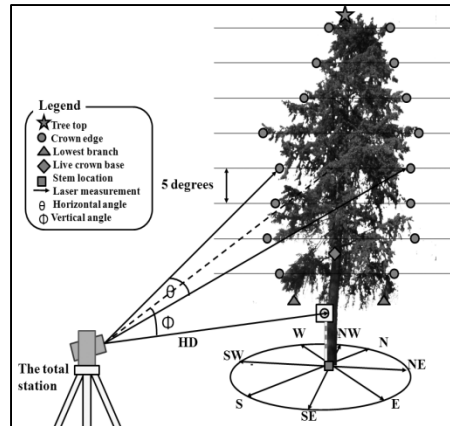


Many inventory metrics have been developed over the last 10 years (most are data quality specific)

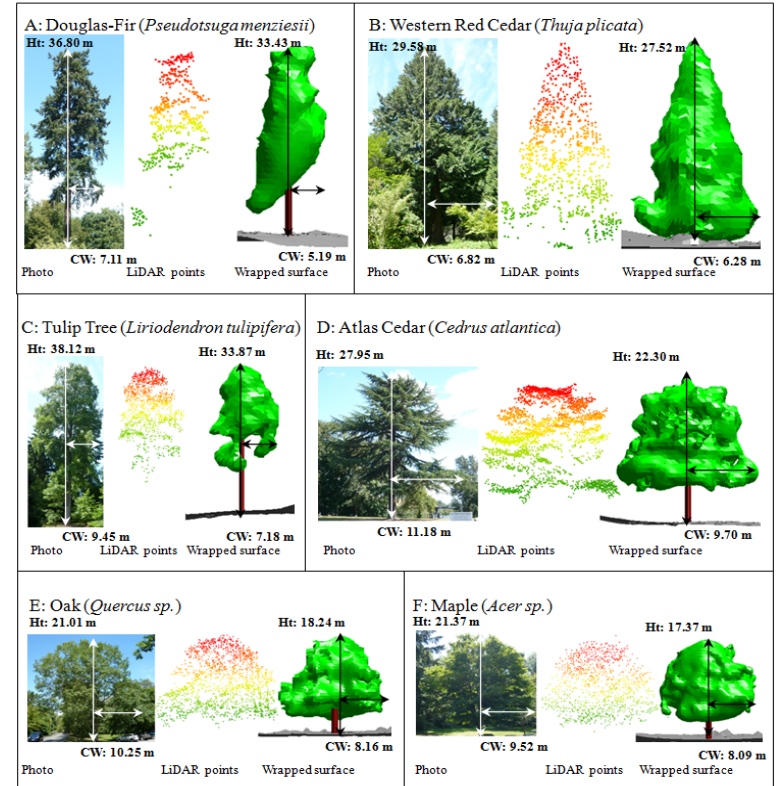
LiDAR based tree crown surface reconstruction

Can we develop a universal approach to derive LiDAR based tree parameters?

- Multitemporal approach through x, y z Cartesian matrix algebra can identify where in the crown the change has occurred

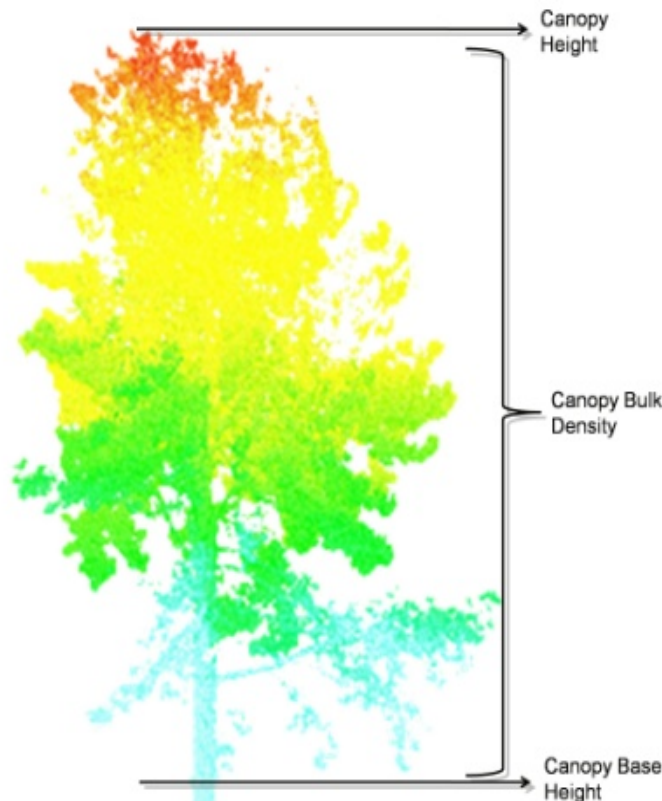


Correlation of crown volume estimation between field and wrapped surface measurement (left) and crown volume derived from the wrapped surface and field measured DBH (right). Grey circles and line represent coniferous trees and black triangles and line represent deciduous trees. Dashed line represents one-to-one correlation; p-values are 0.00 ($\alpha = 0.05$).

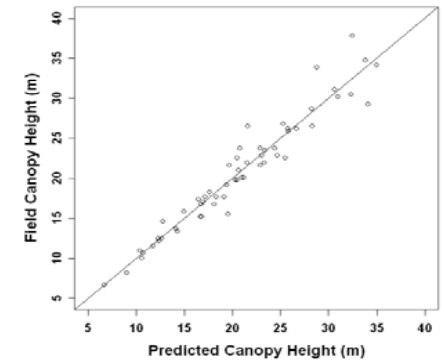


Visualization of the wrapped surface reconstruction. Shown are Douglas-fir (A), western red cedar (B), tulip-tree (C), atlas cedar (D), oak (E), and maple (F). Ht: Tree Height, C W: Crown width.

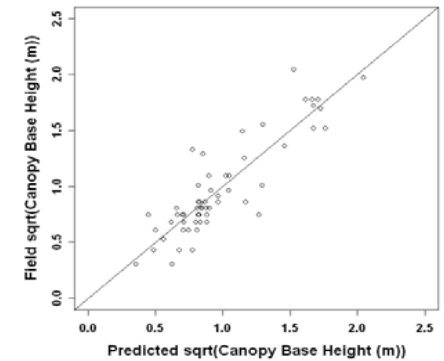
Beyond inventory: fuel metrics



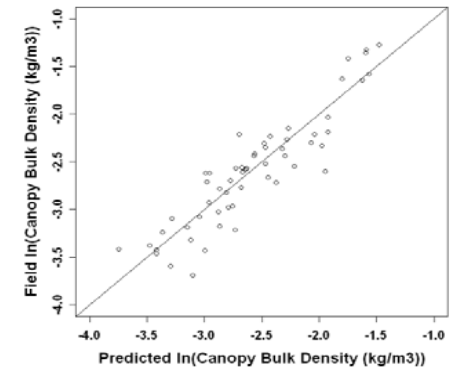
Above: Examples of canopy fuel metrics
Below: Sample of a LiDAR point cloud representing a field plot



Predicted versus Field-measured canopy height ($R^2=0.94$, P-value <0.0001)



Predicted versus Field-measured (square-root transformed) canopy base height ($R^2=0.78$, P-value <0.0001)



Predicted versus Field-measured (log-transformed) canopy bulk density ($R^2=0.83$, P-value <0.0001)

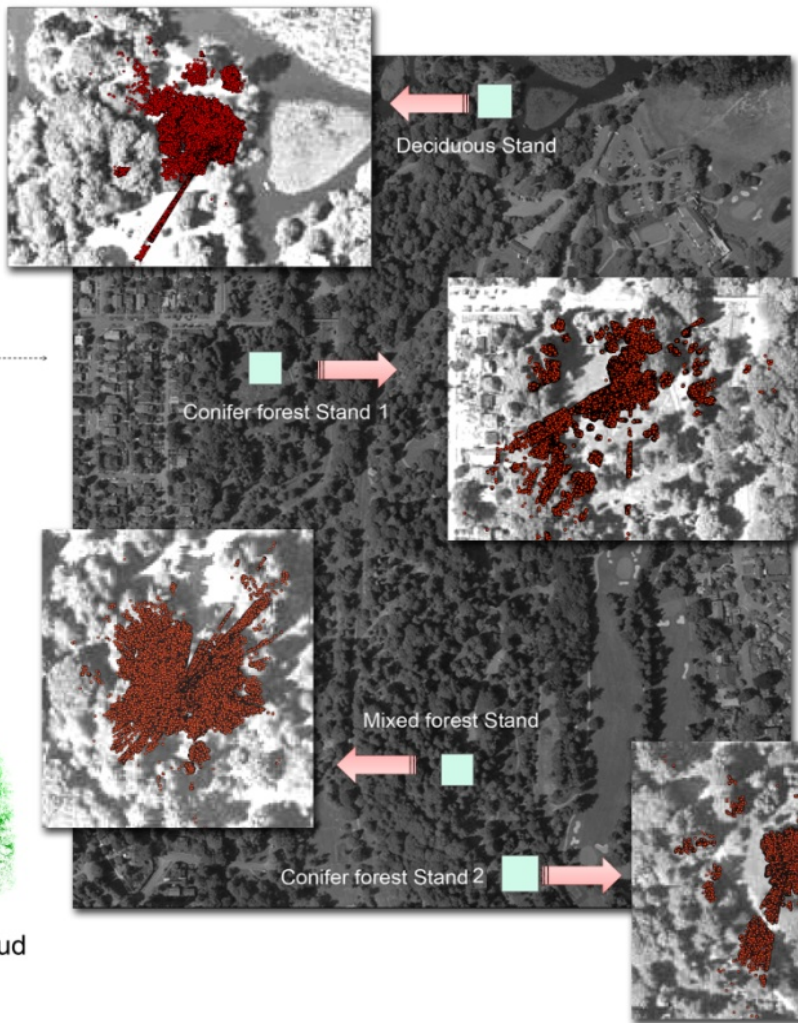
Forest inventory characterization from ground-based LiDAR



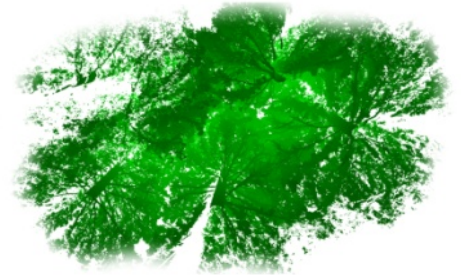
3-D perspective view of point cloud data for deciduous forest stand



3-D perspective view of point cloud data for mixed forest stand

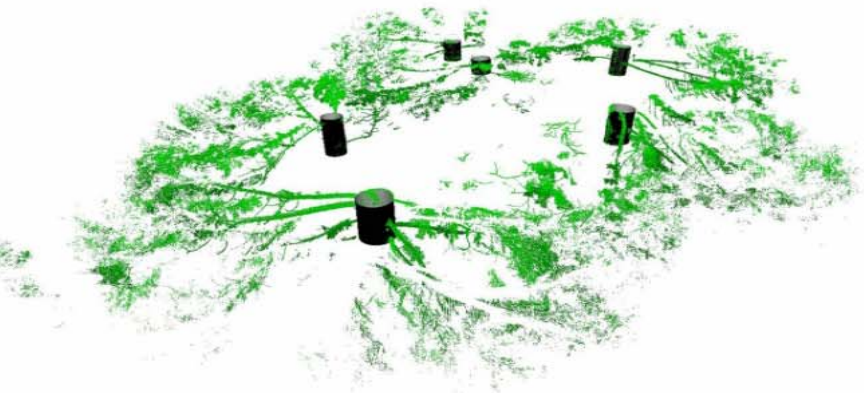


3-D perspective view of point cloud data for conifer1 forest stand

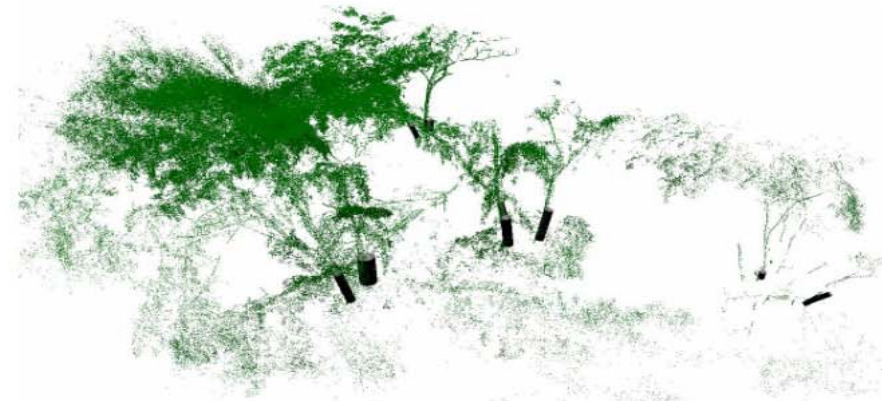


3-D perspective view of point cloud data for conifer2 forest stand

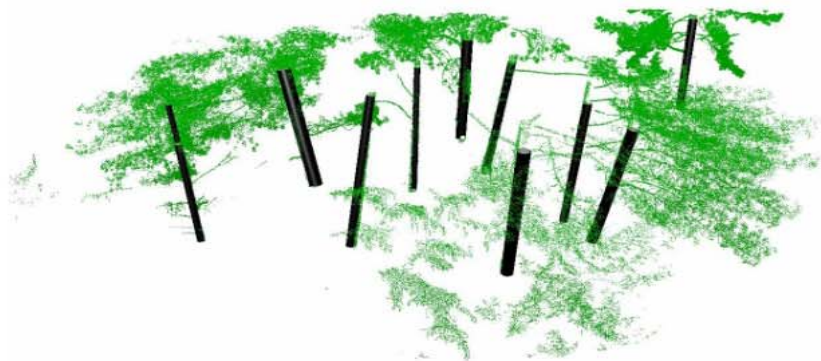
Forest inventory (dbh)



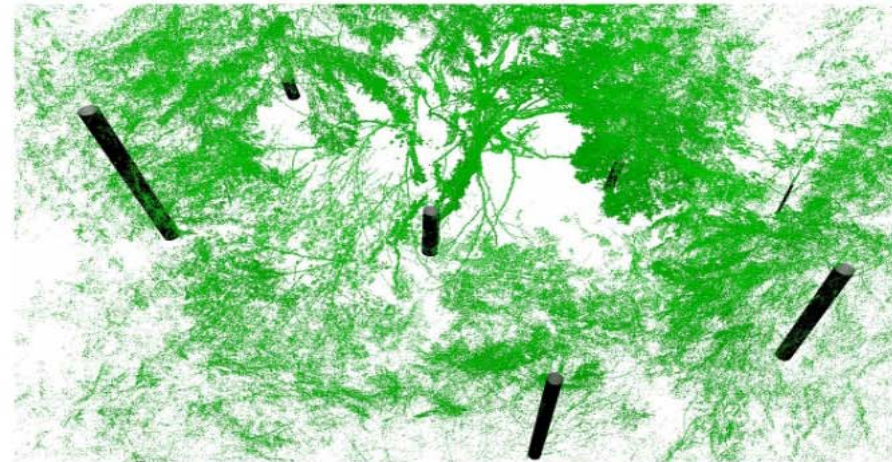
(a)



(b)

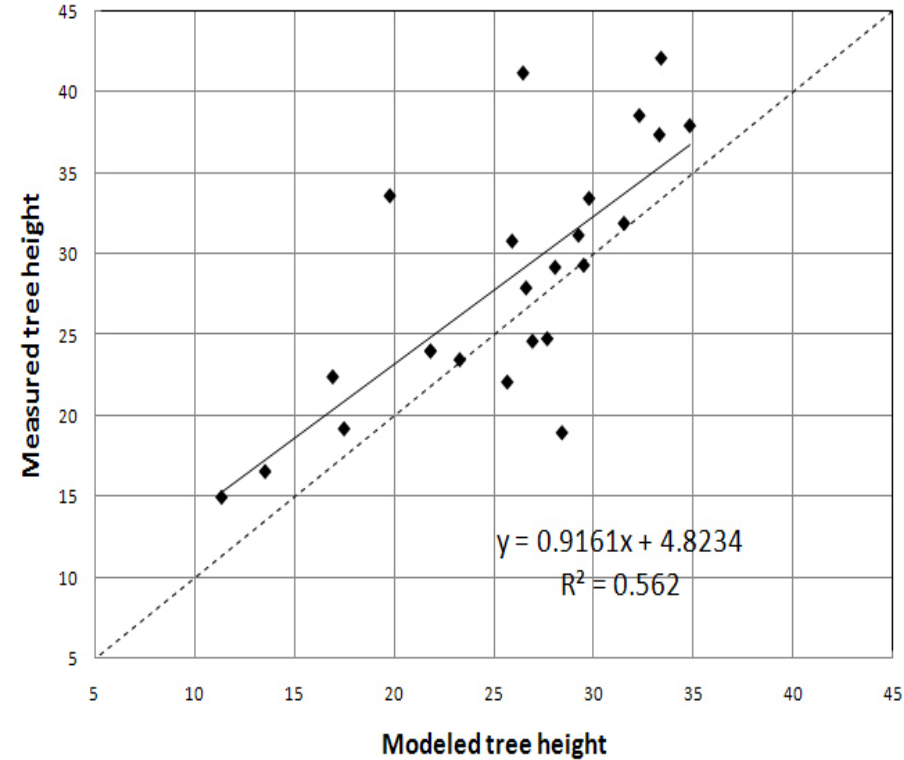
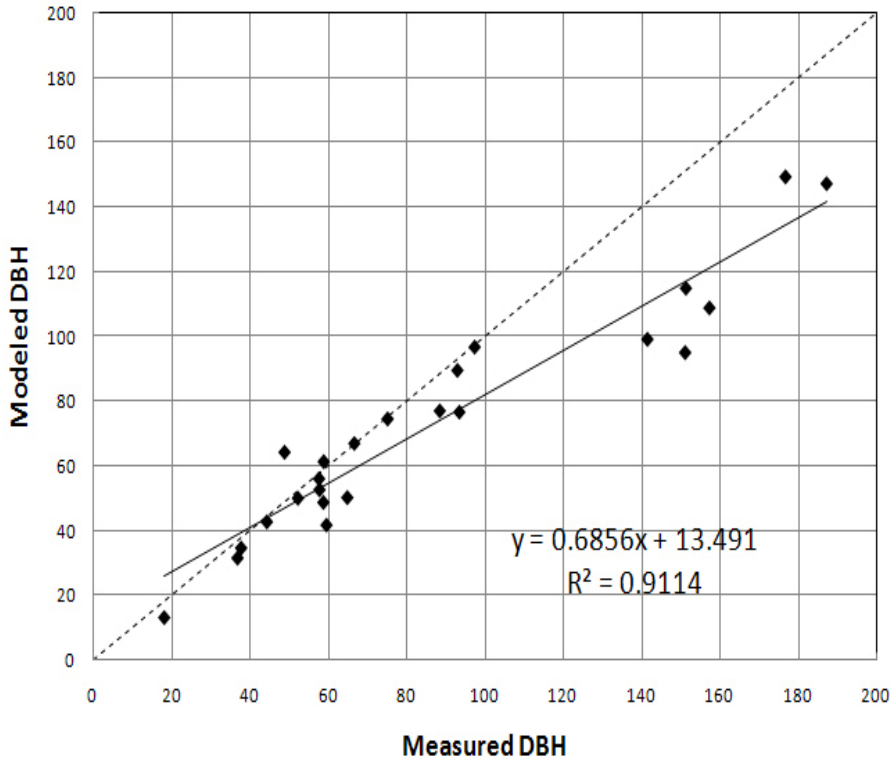


(c)



(d)

Forest inventory characterization from ground-based LiDAR (dbh, height)

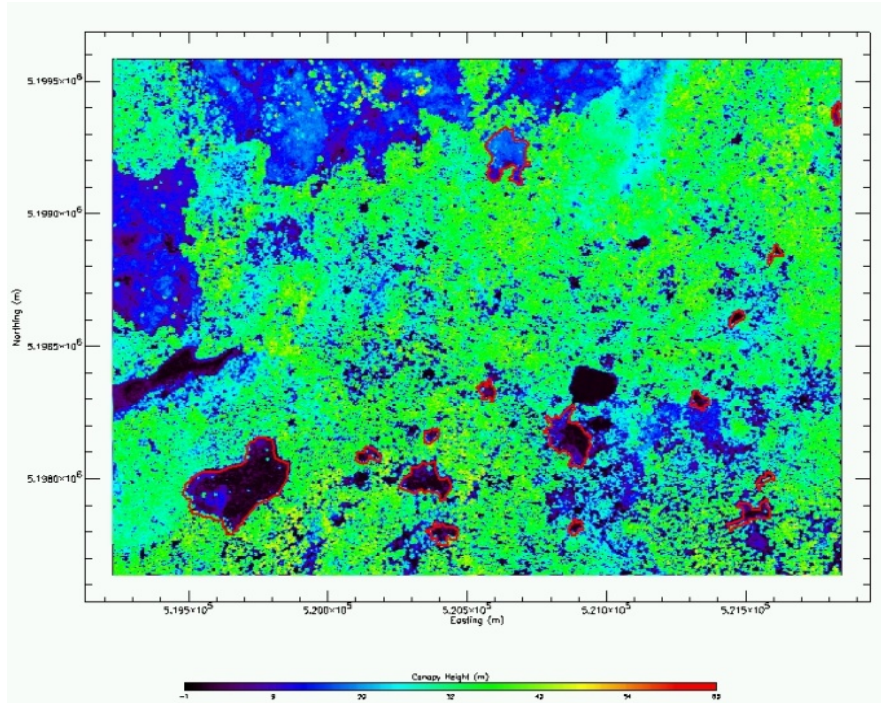


Large woody supply potential

- Theoretical steps to estimate development
 - Produce a LiDAR based terrain model
 - Generate streams
 - Buffer streams
 - Identify unstable slopes
 - Produce canopy models for areas with unstable slopes
 - Identify large trees (health?)
 - Assess woody supply potential

Remote sensing of canopy gaps

LIDAR Canopy Height Map



LIDAR Gap Map

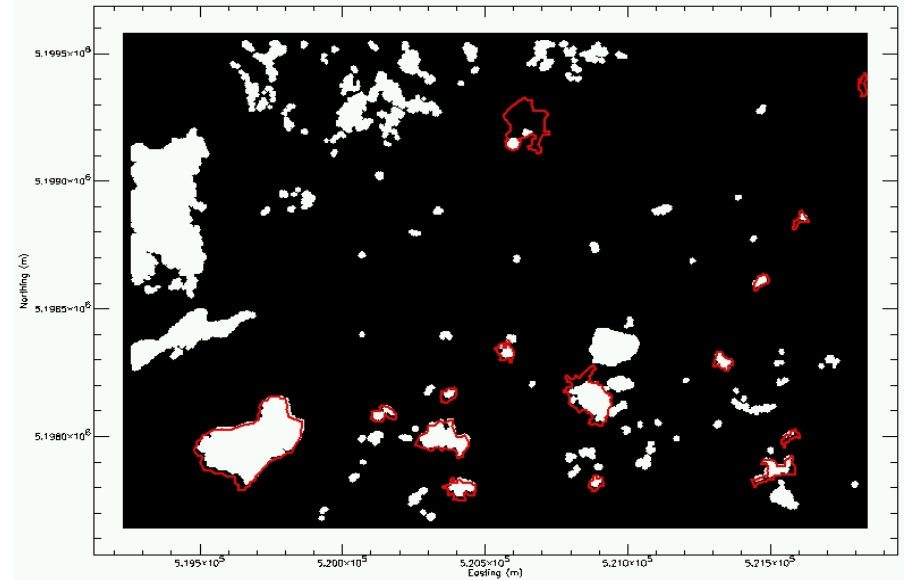
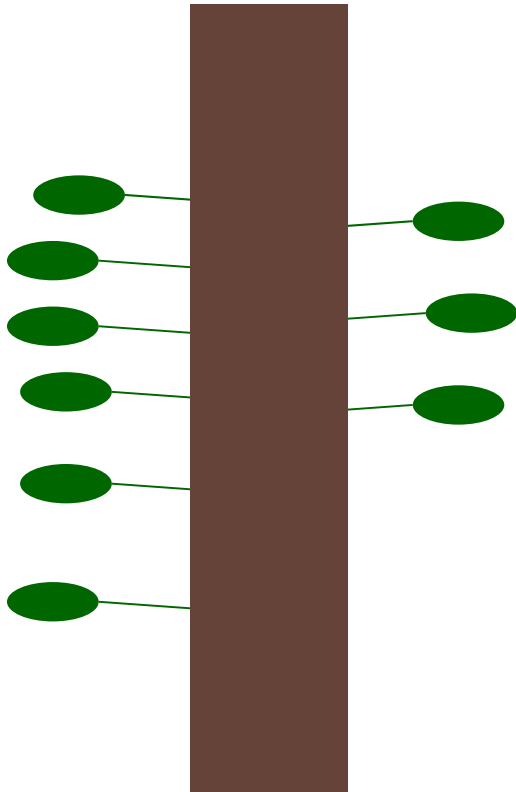


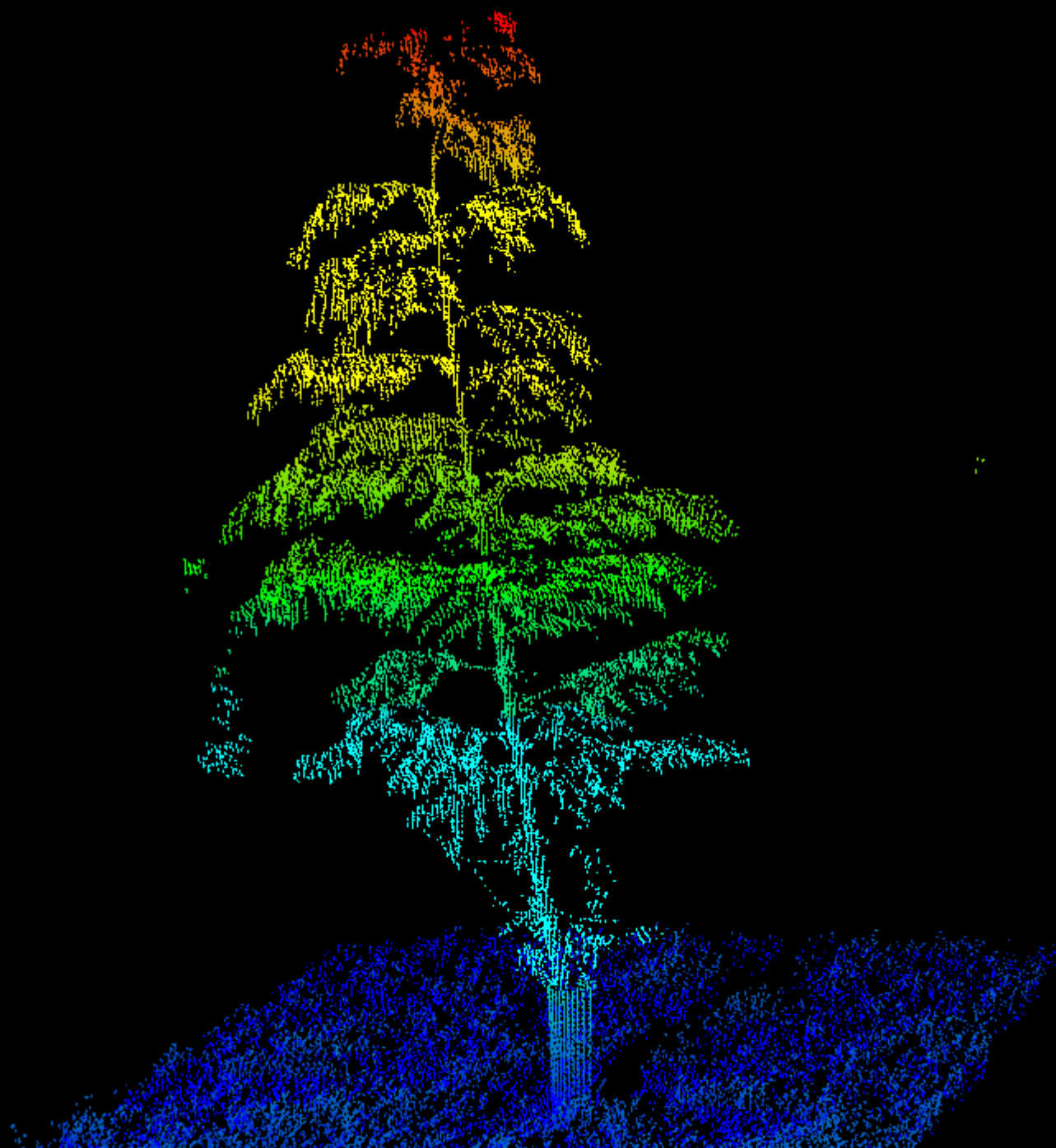
photo measured gaps in red

Solar energy attenuation based on LiDAR derived LAI (leaf area index)

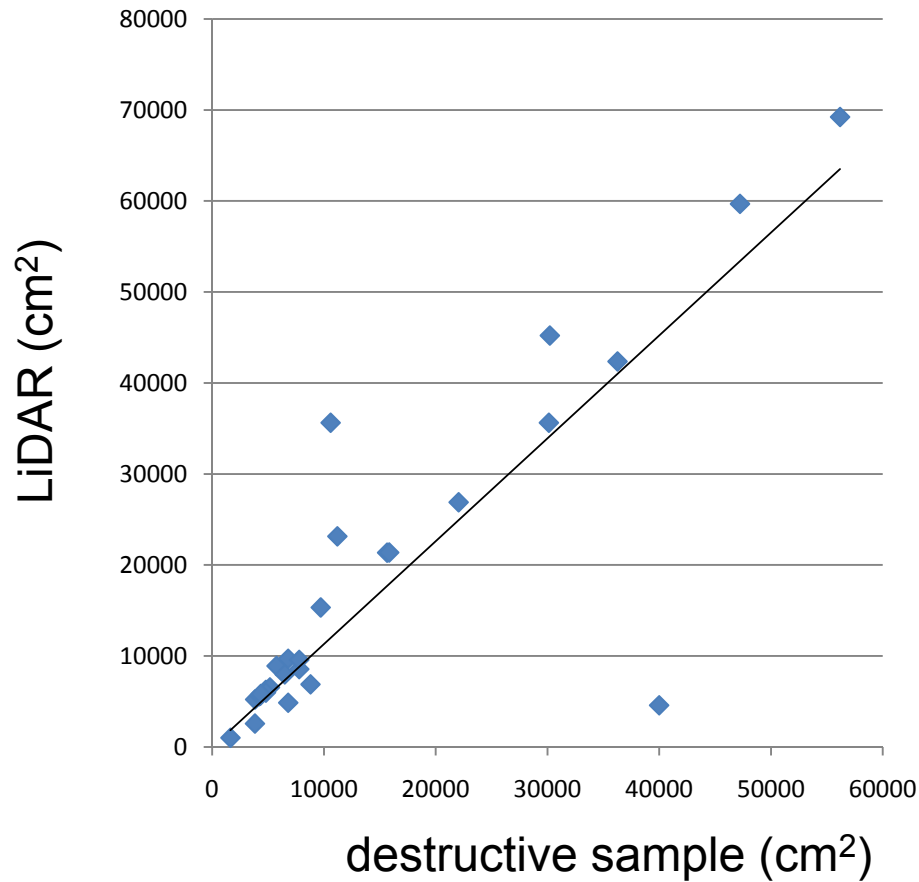


Leaf Area Index (LAI) is the ratio of total upper leaf surface of vegetation divided by the surface area of the land on which the vegetation grows. LAI is highly correlated to:

- Net Primary Productivity (NPP)
- Rainfall interception
- Carbon sequestration
- **Process-based Ecological Models**

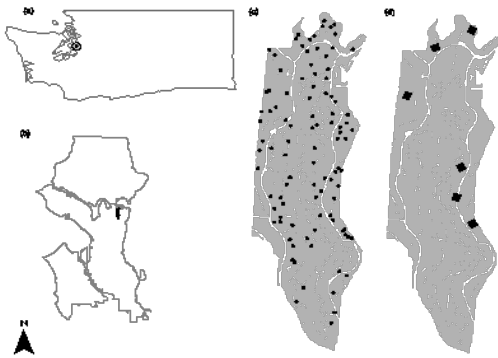


Relationship between LAI and LiDAR pPAI (projected plant area index)

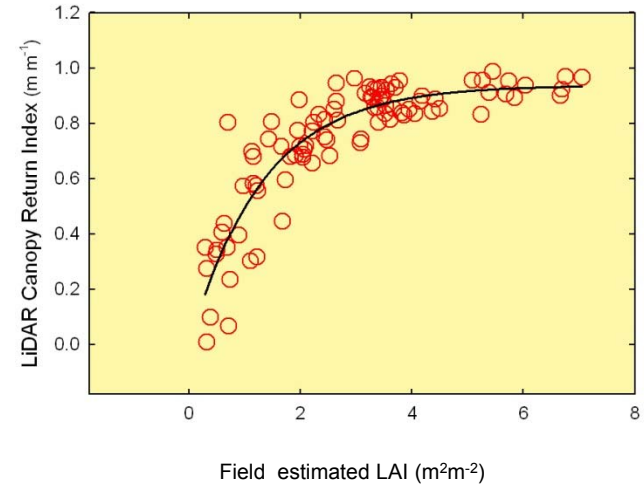
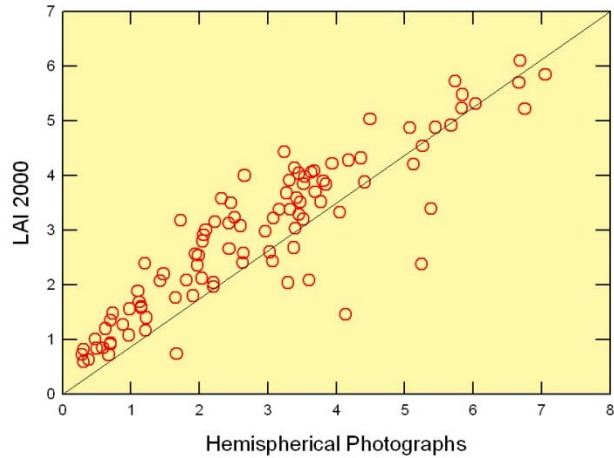


LAI in heterogeneous (urban) forest: UW Arboretum

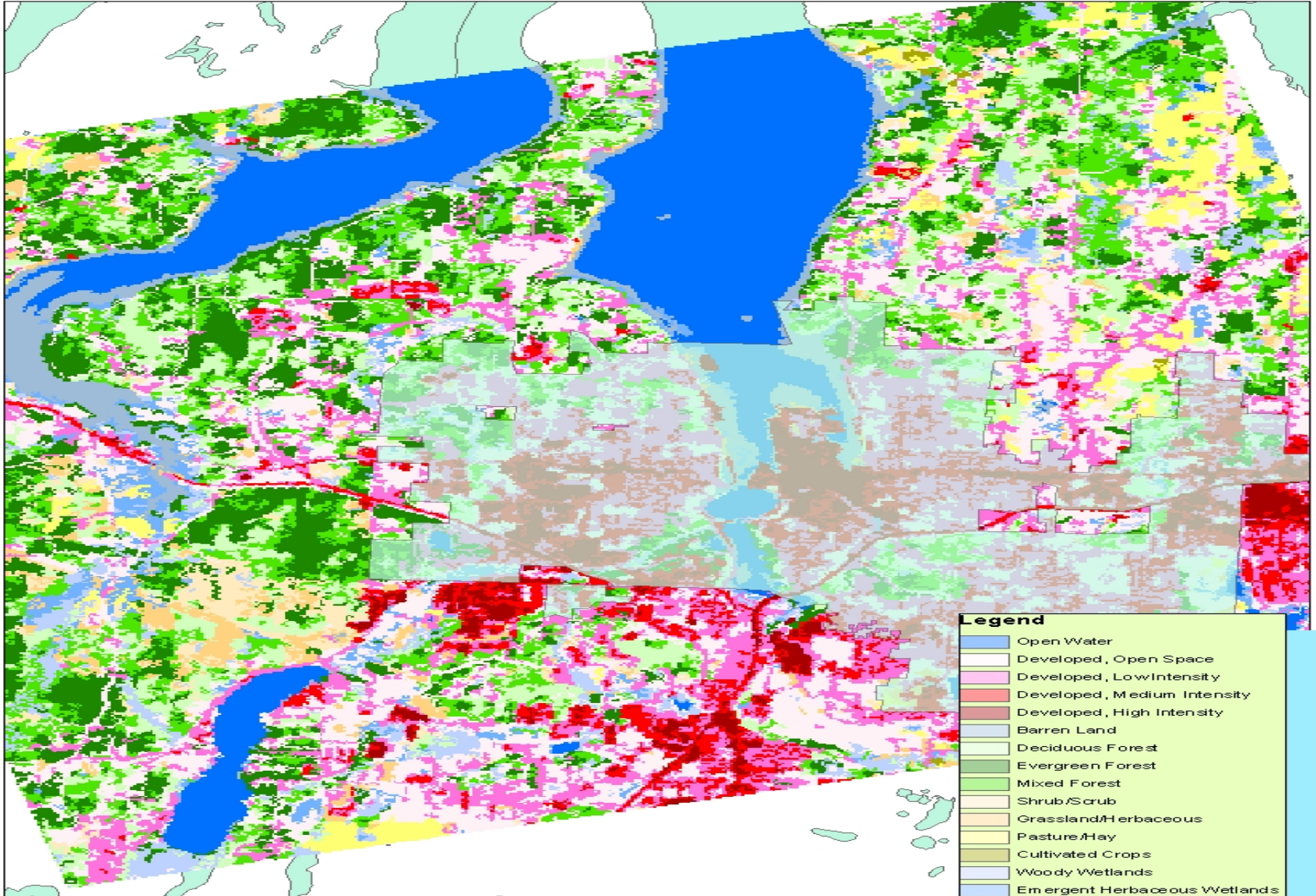
The most simple metric, the ratio of all canopy returns to the number of ground first returns (LiDAR Canopy Return Index), is well correlated to ground LiDAR, but suffers from a tendency to saturate at LAI larger than 3

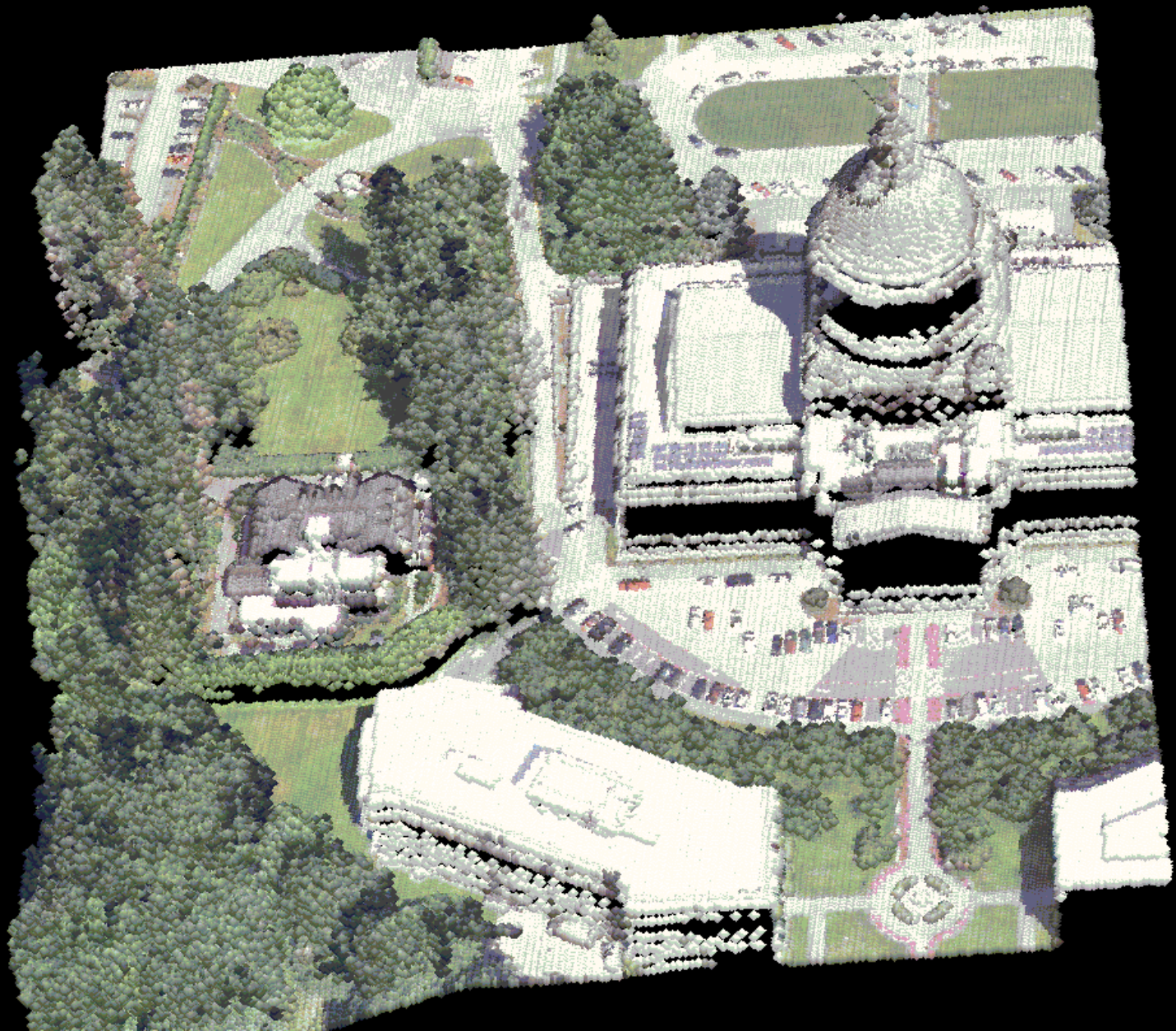


Comparison of Ground Estimates of LAI

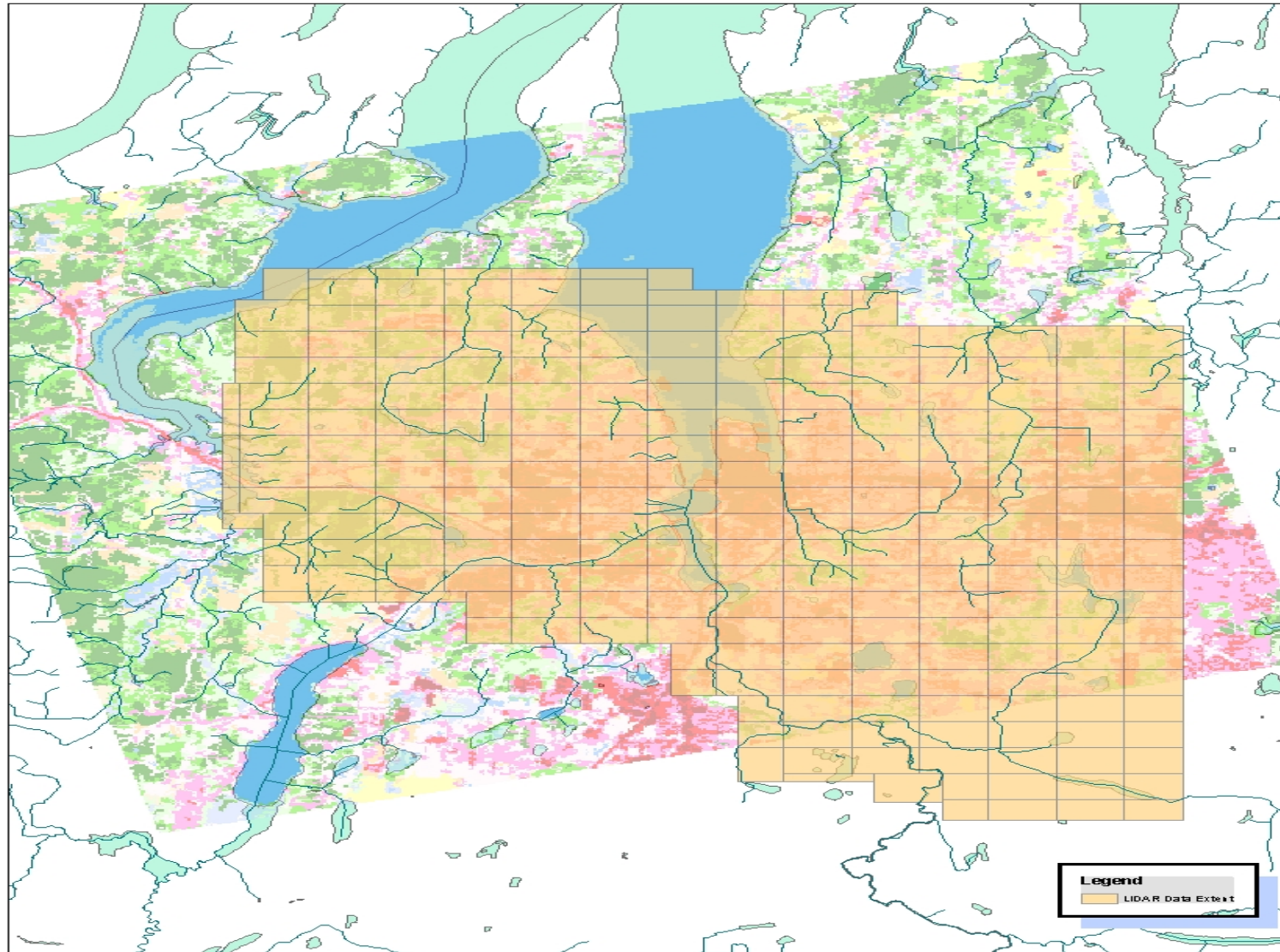


LULC and Olympia city boundary

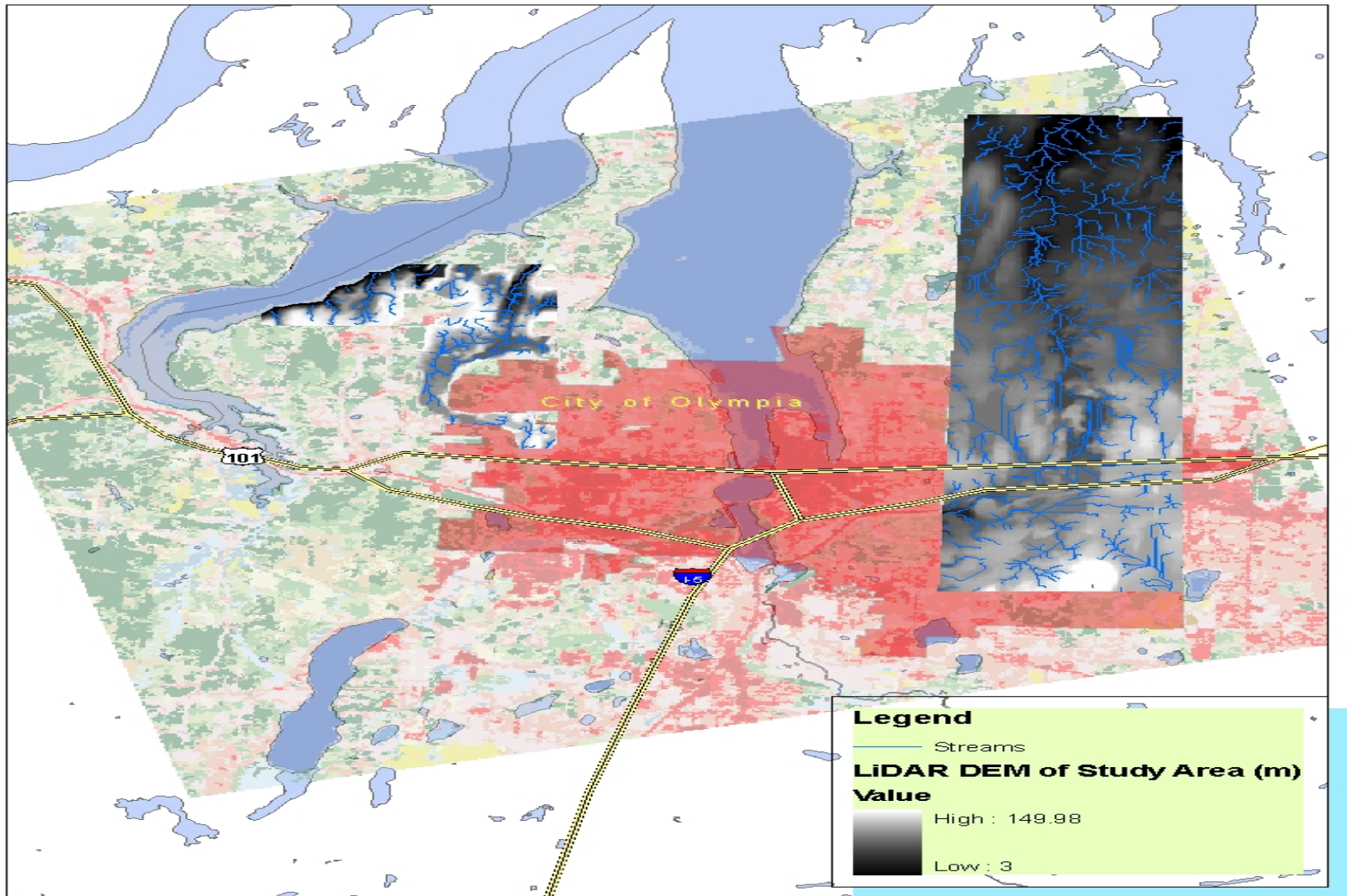




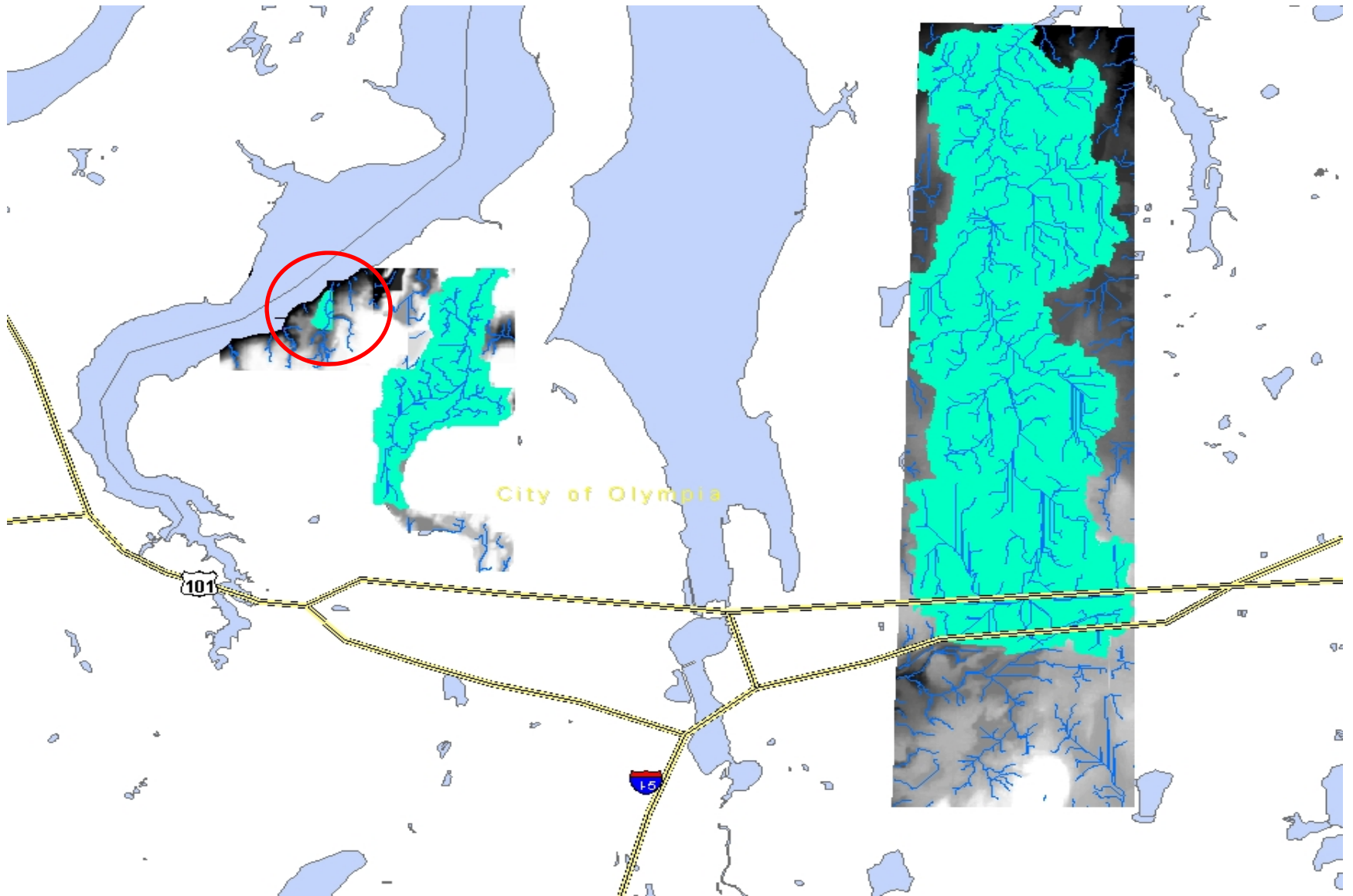
LiDAR coverage



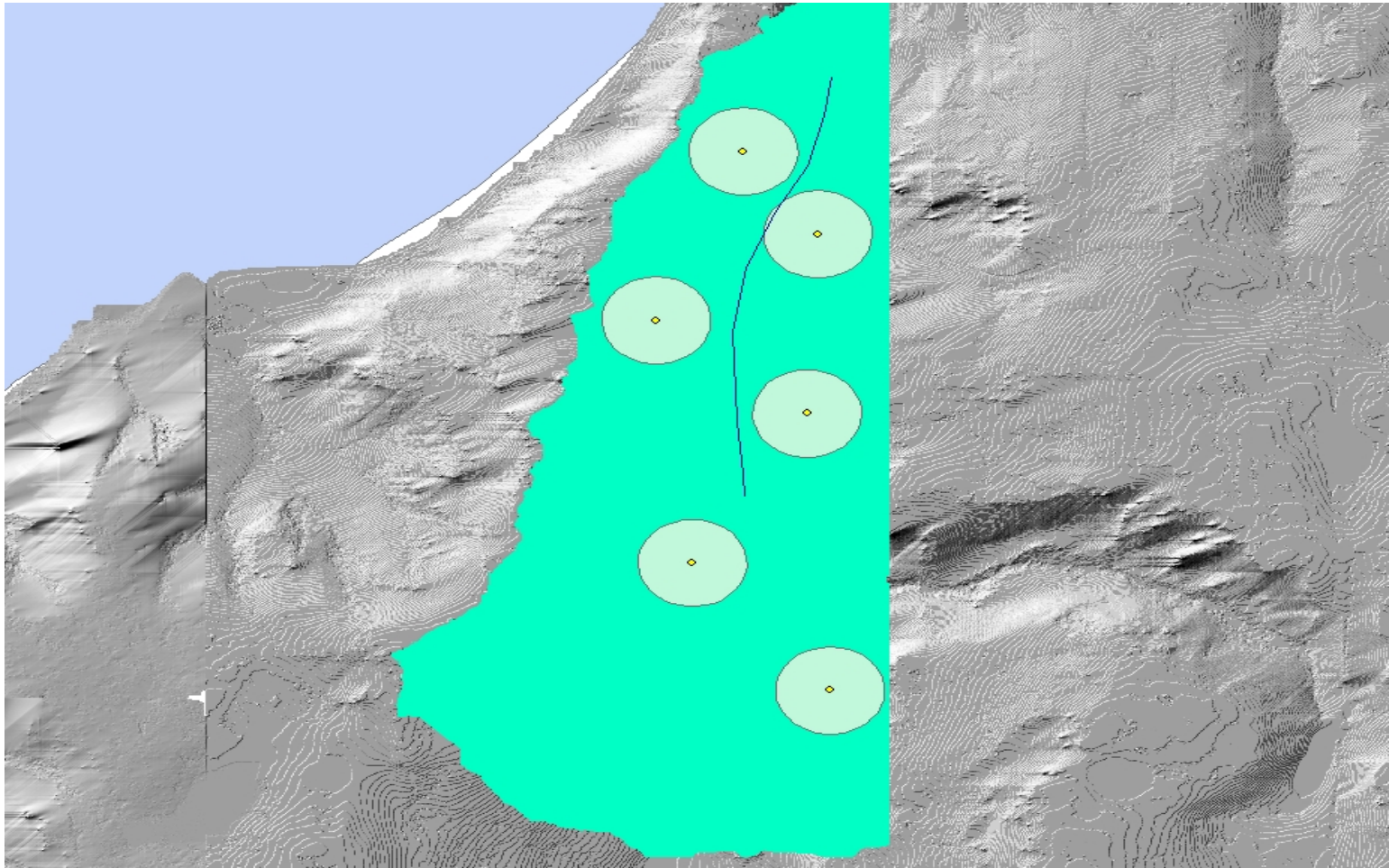
Pilot study sites

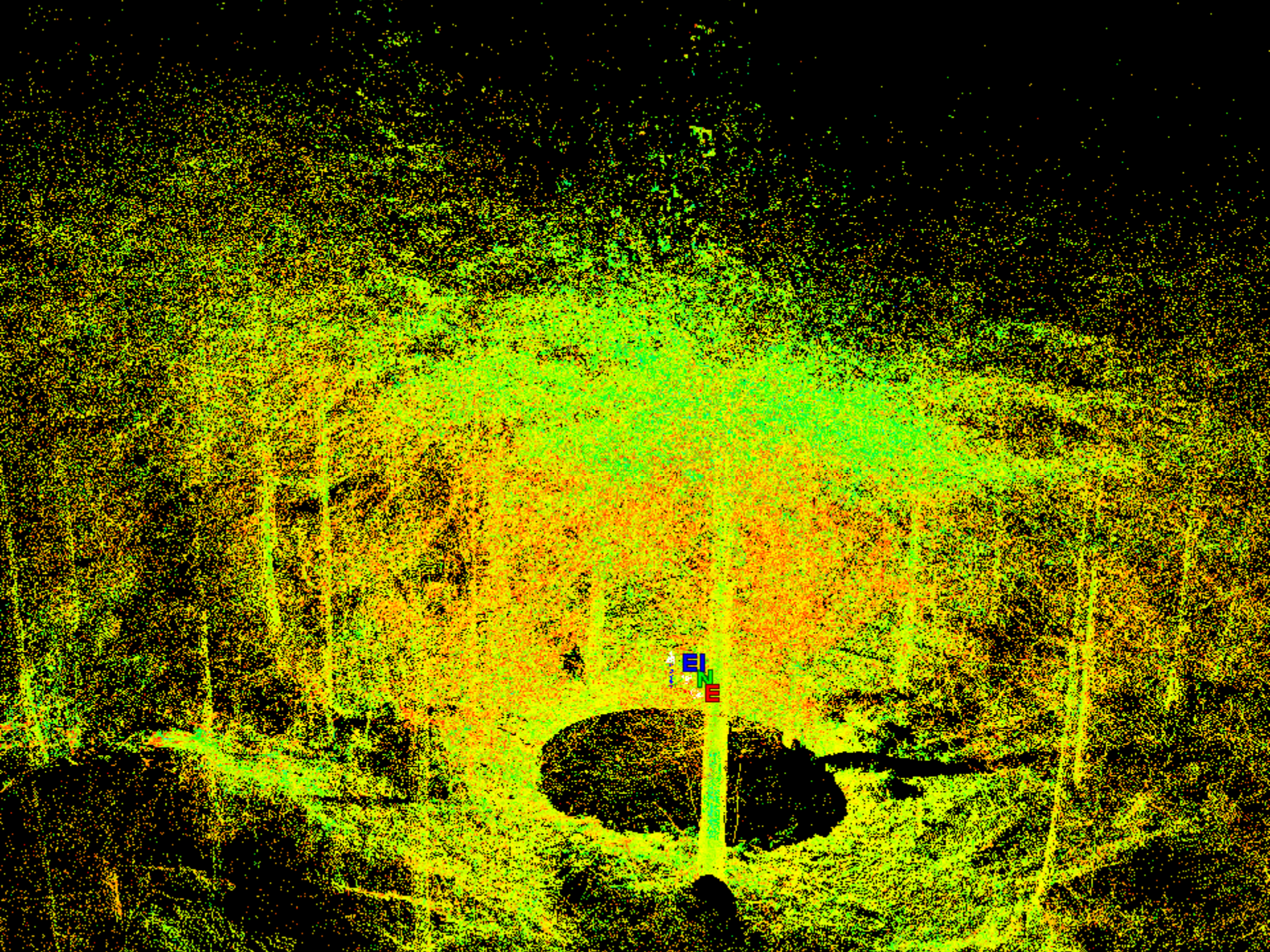


Watershed outlines

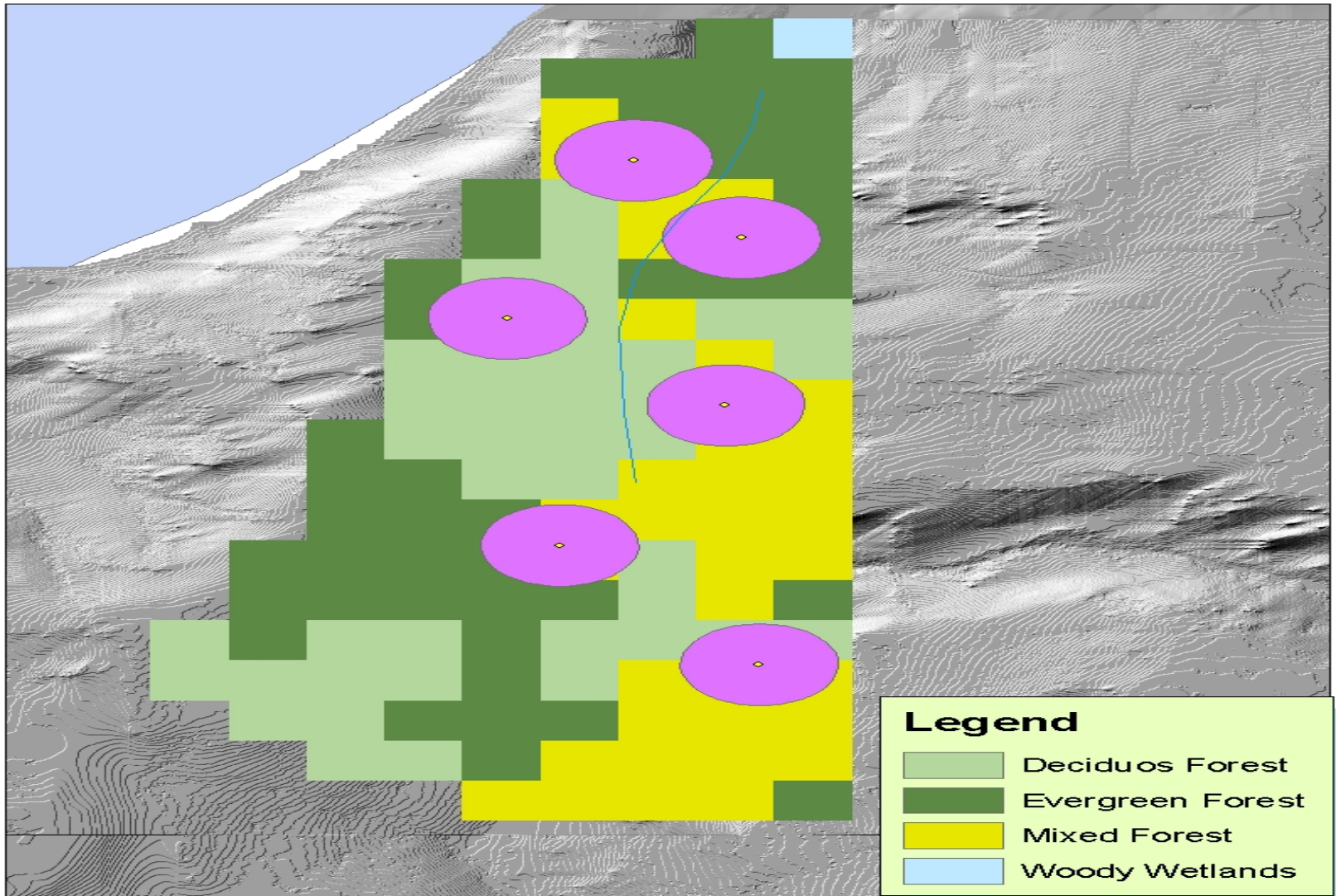


Watershed area 1 with terrestrial LiDAR plots





LULC of watershed area 1



Simplified LiDAR Based Thermal Loading Model



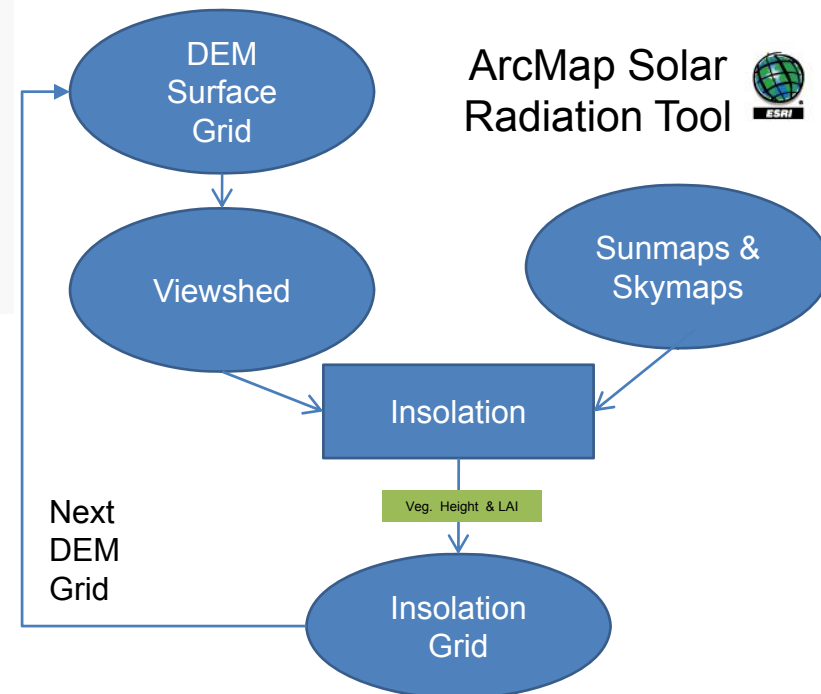
Schematic for obtaining solar energy attenuation from LiDAR. The LiDAR-based terrain model is used in conjunction with canopy density metrics to model solar conditions for 365 days out of the year. The 365 models are combined to produce a thermal loading potential surface. The same technique can be applied on spatial explicit watershed coverage provided by aerial LiDAR and to calibration sites from terrestrial LiDAR.

Source: Moskal and Park 2010

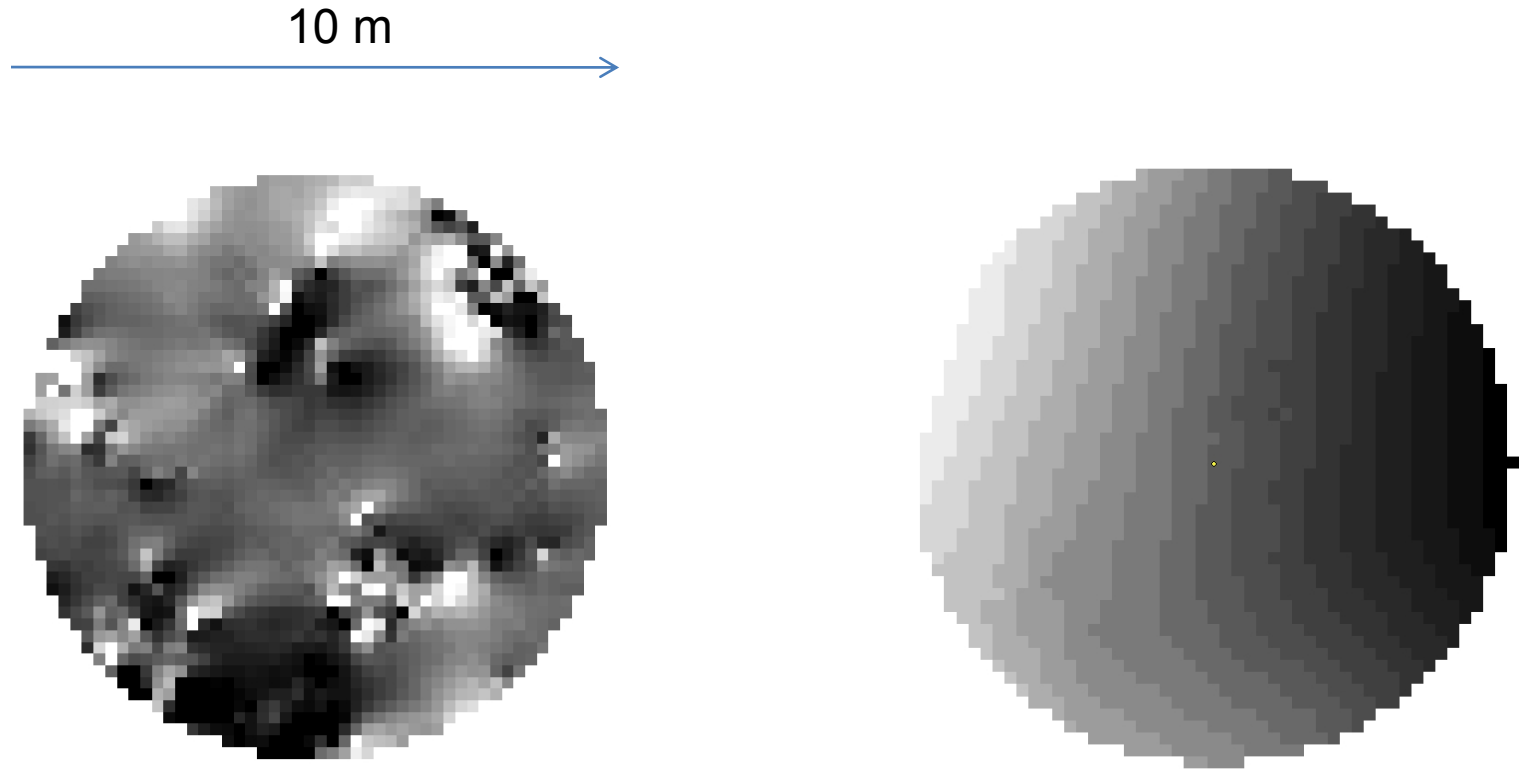
Solar Radiation Model Parameters:

- LiDAR topographic shading
- LiDAR aspect
- LiDAR Vegetation height/canopy density (LAI)
- geographic location (latitude)
- resolution (data dependent)

Model output (watt/m²) is spatially continuous but can be buffered for streams and other features

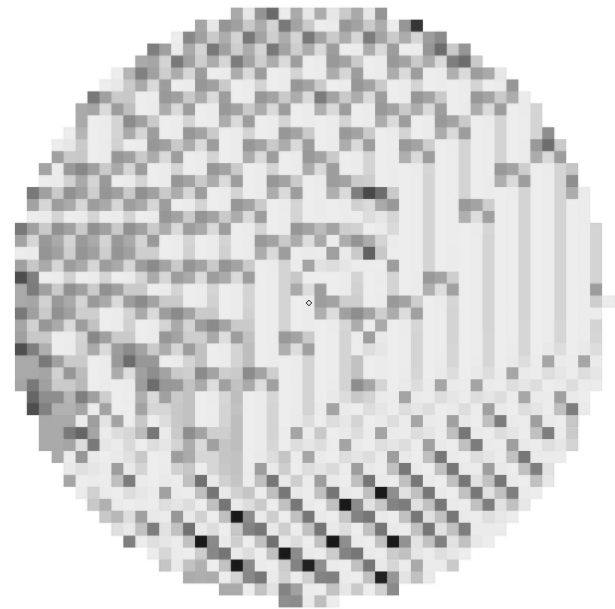
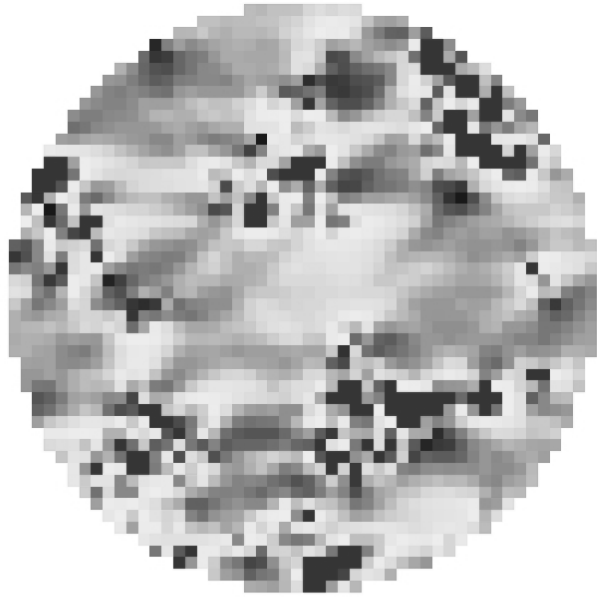


Ground vs. Aerial DEM Surface

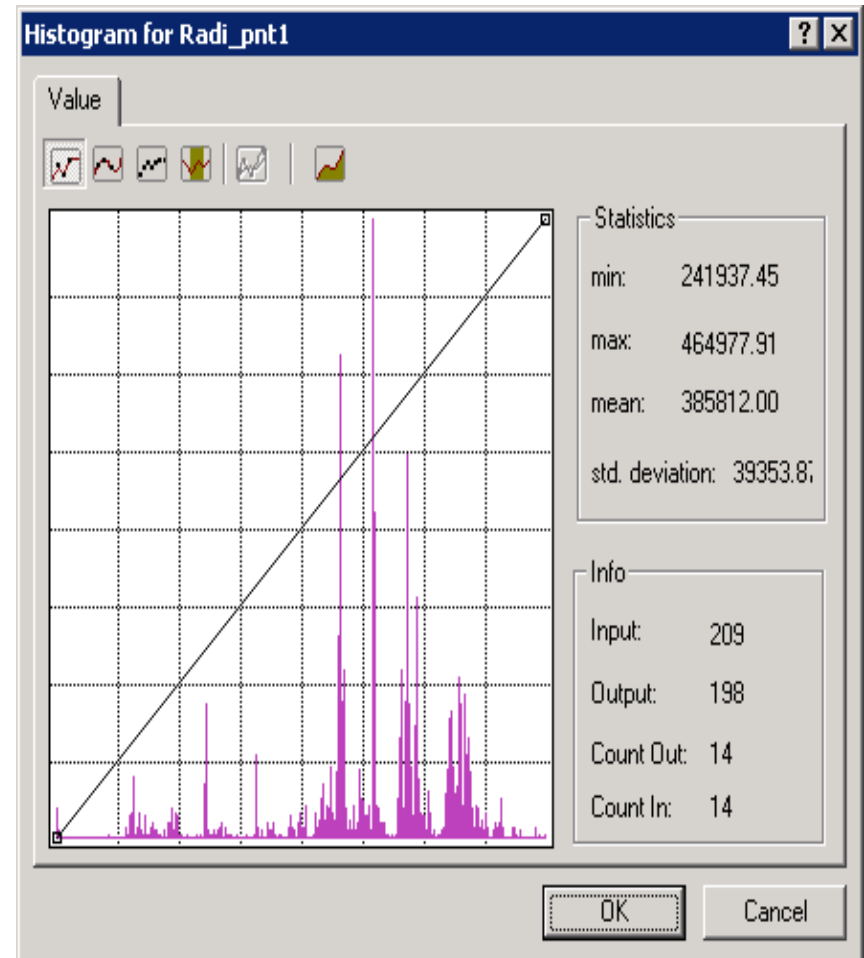
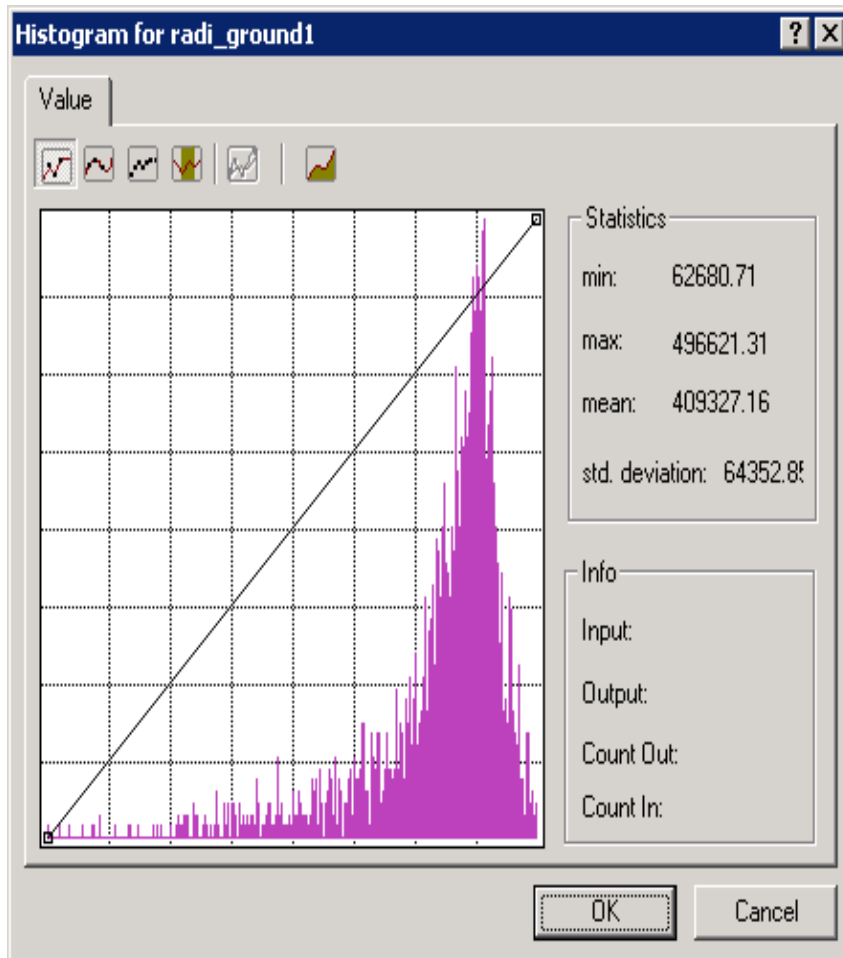


USGS DEMs will only have one value for the whole plot

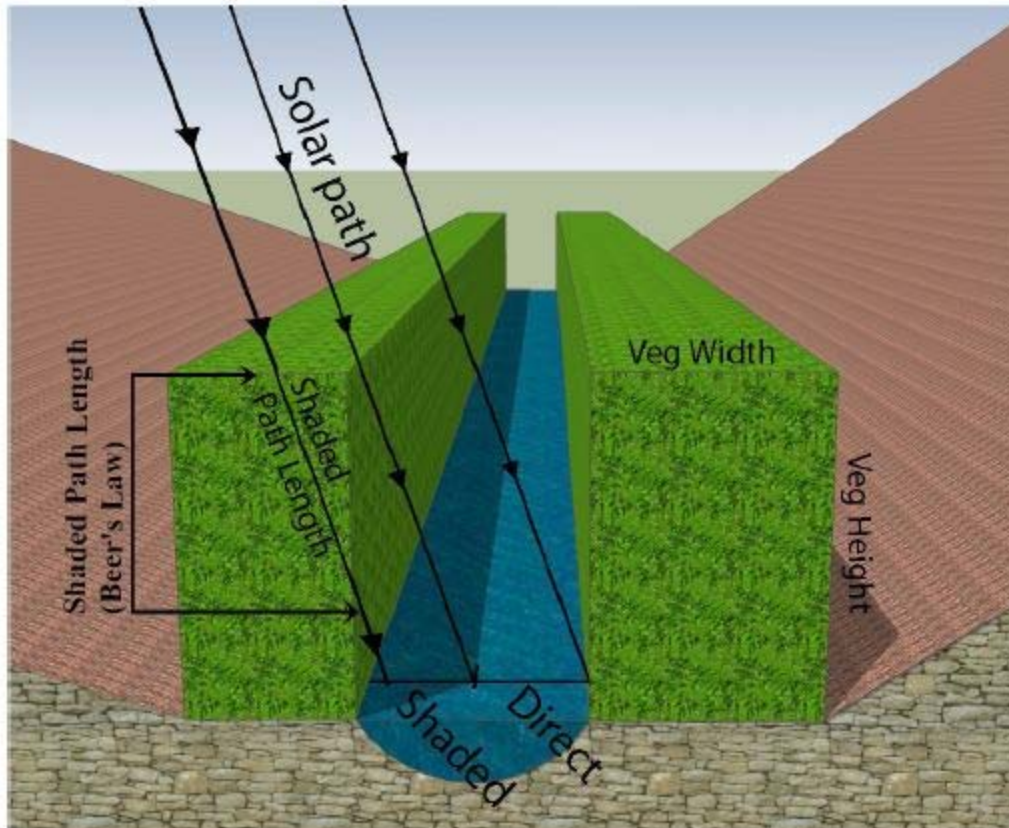
Ground vs. Aerial Radiation



Ground vs. Aerial Radiation



Next Step



Integrate LiDAR derived metrics with Earth Systems Institute's NetMap Tool

Figure 2-60. NetMap's thermal tool assumes streamside vegetation is rectangular in shape with a height, width and vegetation density. Sunlight passing through streamside vegetation is attenuated by Beer's Law.

Future LiDAR Based Work

- Refine solar energy attenuation (implement canopy roughness into models)
- Test model in riparian zones adjacent to a wide range of LULC (will need better/newer LULC maps)
- Continue work on large woody supply potential estimation
- Sediment loading estimation

Collaborators

- **Joowon Park**, PhD Candidate, UW Remote Sensing and Geospatial Analysis Laboratory
- **Dr. Dylan Fisher**, Evergreen Ecological Observation Network and Field Ecology Lab, The Evergreen State College
- **Dr. Carri LeRoy**, Aquatic Ecology Lab, The Evergreen State College
- **David Kuhn**, City of Olympia
- **USDA FS PNW** (Bob McGaughey for some of the LiDAR animations)
- **Field Assistants:** Meghan Halabisky, Ryan Leon, Justin Kirsh, Alexandra Kozakova, Jeff Richardson, Guang Zheng

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Understanding multiscale dynamics of landscape change through the application of remote sensing & GIS

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- CFR facilities and maps
- LiDAR view of CFR buildings

If you are visiting RSGAL and would like to park in LotC10 please contact Dr. Hoesli for a parking permit.

Directions to UW

RSGAL is located in the College of the Environment, School of Forest Resources at the main Seattle campus of the University of Washington (UW).

Driving directions to UW from IS north or southbound:

From I-5 southbound, take the NE 45th Street exit (#160). Turn left onto NE 45th Street. Continue east about one quarter mile to 15th Avenue NE and turn right. Head south on 15th Avenue three blocks to NE 41st Street. Turn left at Gate #1 into the Central Plaza Garage. Stop at the gatehouse inside the garage for directions to Anderson Hall and a parking permit. RSGAL is located on the 3rd floor of Anderson Hall.

Driving directions to UW from the east, via SR 520:

Coming from the east use State Route 520. Take the Montlake Boulevard exit. Continue north on Montlake Blvd. and cross the drawbridge. At the first traffic light after the bridge, turn left onto NE Pacific Street. Proceed west on NE Pacific to 15th Avenue NE. Turn right and head north on 15th Avenue to NE 41st Street where Gate #1 is located. Turn right into the Central Plaza Garage. Stop at the gatehouse inside the garage for directions to Anderson Hall and a parking permit. RSGAL is located on the 3rd floor of Anderson Hall.

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RSGAL Monthly Journal Club

University of Washington
College of the Environment, School of Forest Resources
Anderson Hall 200, Box 352100
Seattle, WA 98195-2100

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<http://depts.washington.edu/rsgal/>