Factsheet # 2

Leaf Area Index (LAI) from Aerial & Terrestrial LiDAR

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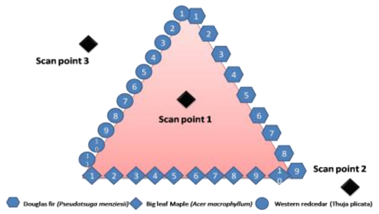
In this work, the well-known and popular light extinction model was used to calculate the LAI, which is similar to the Beer's Law to characterize the light attenuation through the canopy.

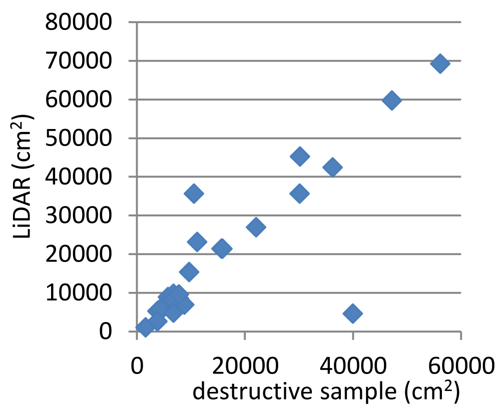
$$P(\theta) = \exp(-G(\theta, \alpha)\, L / \cos(\theta))$$

where θ is the zenith angle of view , α is the leaf angle, $P(\theta)$ is the gap fraction or the probability of non-interception in the direction of laser come through or view direction, L is the leaf area index and $G(\theta, \alpha)$ is named the G-function and corresponds to the fraction of foliage projected on the plane normal to the zenith direction. $G(\theta, \alpha)$ depends on leaf-angle distribution α. In this work, the gap fraction was measured with height step for a certain height slice plane, allowing a calculation of the LAI for each specific height slice plane.

The schematic below shows the geometrical relationship between projection area of leaf in the plane normal to incident solar direct beam. In the spherical coordination system, the incident solar direct beam (0, cos β, sin β), and the azimuth angle is θ, and the inclination angle is α, so the leaf can be denoted as (cos α cos θ, -cos α sin θ, sin α), the vector normal to the leaf plane can be expressed as (-sin α cos θ, cos α sin θ, cos α). So the projection area of leaf on the plane is | cos β cos α sin θ + sin β cos α|. Because the leaf azimuth angle could be 0 ~360 degrees, the mean projection of leaf on the plane normal to the solar beam should be obtained by calculating the integration for all possible azimuth angle and inclination angle (0 ~90 degrees).

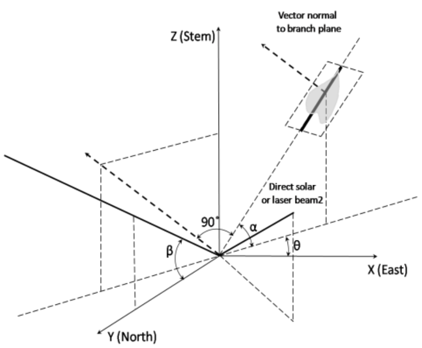


Above: Sample design
Below: Point cloud of Douglas Fir



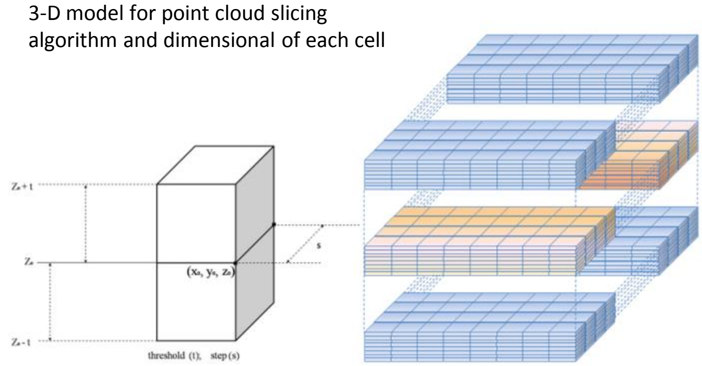
Relationship between LiDAR destructive sample

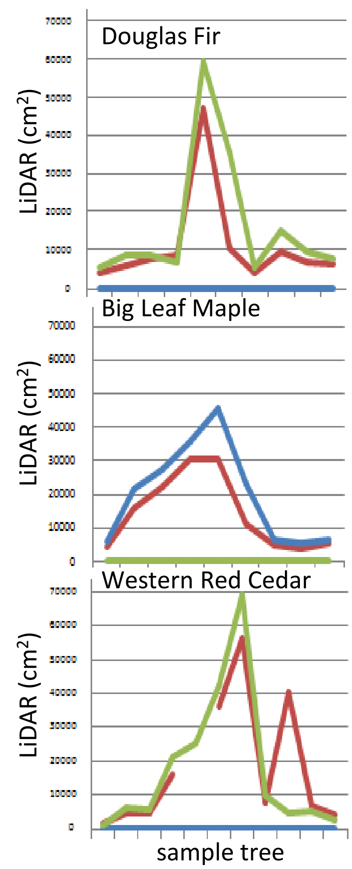
By counting the non-zero points in each slice plane, the plant area has been achieved by multiplying the numbers of points by top-side area, which is the product of threshold and step. Our analysis shows that the PAI is usually larger than the destructive LAI due to the contribution of tree trunk or branches. In addition, we can see from the below graphs that results for the different species vary due to the foliage structure.



Geometrical relationship between the leaf and its projection on the plane normal to direct solar beam

3-D model for point cloud slicing algorithm and dimensional of each cell





Below is a short sample of the record table of destructive LAI scanning for single trees in triangle plot

	Douglas fir		Big leaf maple		Western red cedar
No.	Needle + branch (cm2)	Needle alone (left over) (cm2)	Total Area (cm2)	Leaves No.	Total Area (cm2)
1	4215.7	400.2	4272.1	28	1629.7
2	15647	1670	5758	31	4805.8
3	22047.6	5343.3	7783.4	48	4352.8
4	30214.5	1678	8795.6	55	15834.5

Based on the point cloud slicing algorithm (PCS), in each slice plane, the dimension of each cell, which is a 3-D rectangular object, can be determined by the step (s) and threshold (t). After successfully slicing the point cloud data, we can convert the 3-D real space into the 2-D model space, each cube is coded with 1 if there is at least one point in the cube and 0 if there is nothing in the cube, we regard it as a gap between leaves. In this work, the area of one side of rectangular cell is used to represent the area of partial leaf or plant surface area within the cube of intersected slice plane.

THE ISSUE: Leaf Area Index (LAI) is undisputedly important biophysical parameter quantifying the amount of foliage in the canopy of a live tree per unit surface area. LAI is defined as the one half of the total area of light intercepted leaves per unit horizontal ground surface area. Theoretically, the most accurate way to measure LAI is the destructive way, however, such approach is labor and time consuming, terrestrial laser scanning is a promising new techniques allowing us to measure LAI at multiple intervals without destroying the sample.

THE KEY QUESTIONS:
How can we obtain Leaf Area Index (LAI) form terrestrial LiDAR?

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