USDA United States Department of Agriculture

NCSS National Cooperative Soil Survey

12-GRR/FLI - Utility of LiDAR in Ecological Site Descriptions

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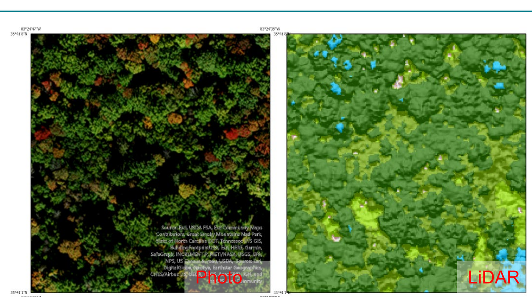
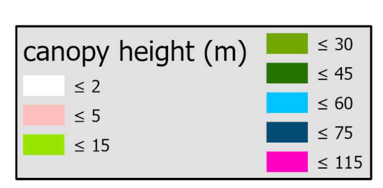
Soil scientists increasingly use bare-earth LiDAR derived digital elevation models for their extreme level of accuracy and precision for soil mapping, but less attention within the Soil and Plant Science Division is paid to other LiDAR derived products that focus on above surface features. There is enormous potential for LiDAR to assist ecologists in their vegetation inventories through canopy height models (CHM). In addition to commonly recorded canopy closure, and maximum canopy height, the spatial variability in height may be just as informative in characterizing communities that have acquired old-growth characteristics. We are working with the USFS to acquire a state-wide coverage CHM to screen potential sites for field inventory based on resemblance to old-growth reference conditions. In stands of the same age, composition, and soils, CHM can also reveal previously undocumented strong canopy height relationships to hillslope position and aspect, which may justify phasing map units in the future. The geographically continuous nature of CHMs makes prevailing canopy height more readily available and more interpretable than other productivity and biomass indicators such as site index. We are exploring potential vertical and horizonal vegetation structural indices to attribute to community phase descriptions and wildlife interpretations.

Old-growth vs. second growth

>200-year-old mesic forest, Warren Woods, Michigan



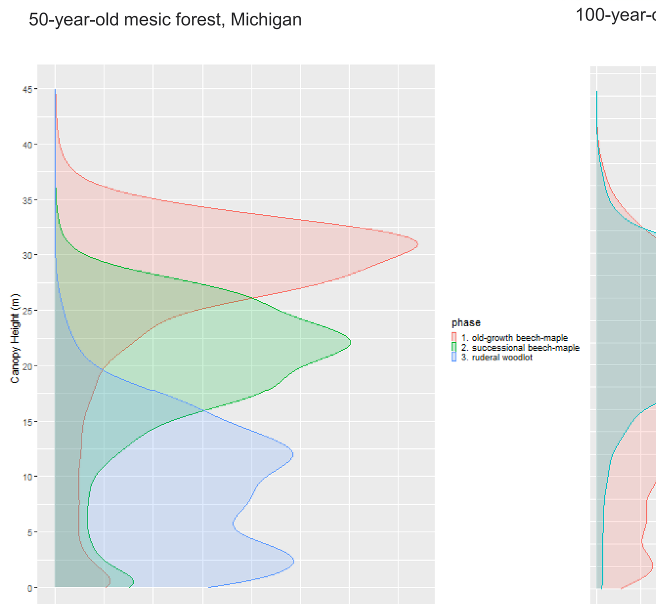
>200-year-old mesic forest, Tennessee



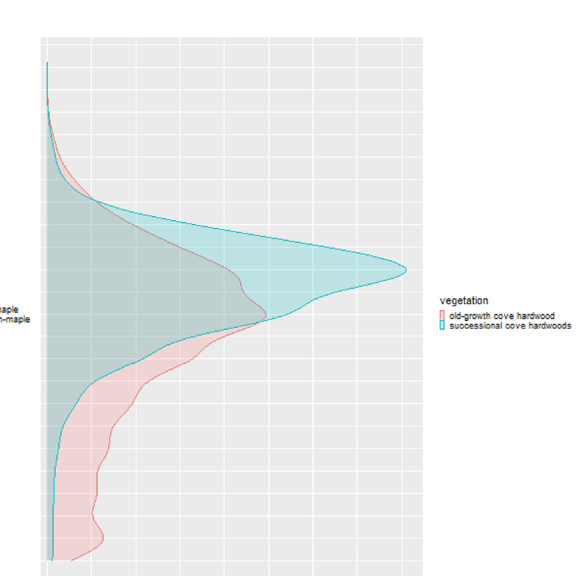
Each area on the left covers exactly 4 ha

50-year-old mesic forest, Michigan

100-year-old mesic forest, Tennessee



Canopy height profile of old-growth forest (>200 y), second growth forest (50-100 y), and ruderal woodland (<50y) among mesic sites in Michigan

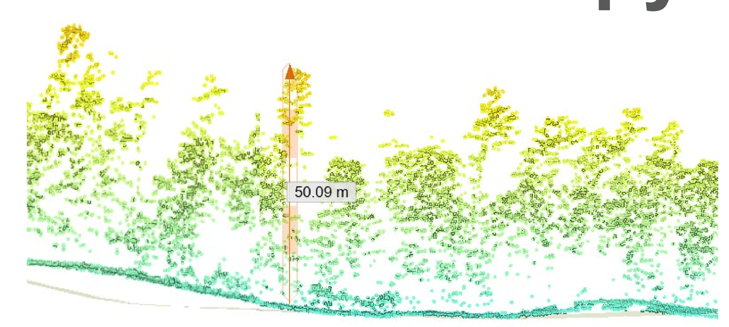


Canopy height profile of old-growth (>200 y), second growth (100 y), among mesic sites in Tennessee

Young and old forests can be distinguishing by:

- Michigan example: immature forest shorter than old growth forest.
- Tennessee example: young mature forest taller more uniform in height (dominated by *Liriodendron*), while old-growth is more variable in height due to canopy gaps.

Metrics: Canopy vs. Crown Height Distribution



While the canopy height model is derived from subtracting the ground returns from the top returns, a 2-dimensional vertical slice of a LiDAR point cloud reveals information about the understory structure.

Prevailing height is surprisingly difficult to find from most vegetation descriptions, yet vertical structure is potentially relevant in characterizing habitat suitability for songbirds (Lesak et al, 2011; Goetz et al, 2007), and can be a key proxy to ecosystem productivity and biomass potential (Pan et al, 2013; Shaoa et al, 2017). Few attempts have been made in deriving vegetation height reference values by plant community. Global analyses on vegetation heights attempt base-line reference for forest height by latitude (Lefsky, 2010; Simard et al., 2011), but even considering the poor resolution the product it conflicts with known local data.

I have explored the range of LiDAR tools in both ArcGIS Pro and RStudio and settled upon the RStudio and the lidR package to automate the point cloud download, surface rendering, and subsequent analysis of canopy height models. The USGS National Map provided all point cloud data for sites within the United State, while opentopography.org provided data for sites outside the United States.

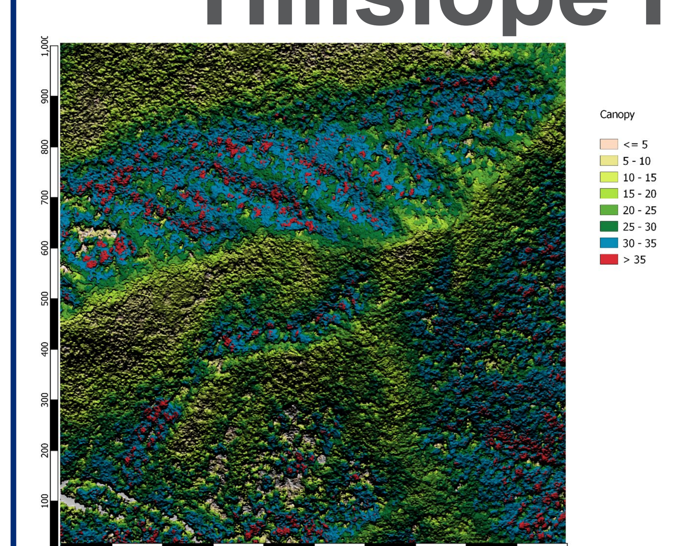
Canopy height distributions allow for a quantitative comparison of different stands not easily seen from casual ground observations or aerial imagery. However, metrics derived from the canopy height models are not directly comparable to ground-based measurements since canopy heights in the field are typically maximum height by crown. The relationship between canopy and maximum crown height distribution is complicated by the vagaries of crown shape and diameter. Crown height distributions, therefore, should be estimated by segmenting the portion of the canopy exceeding tree height (> 5 m). Generally, median canopy height is about 70-90% of area-weighted median crown height.

Variability in crown height can be appreciated from calculating percentiles, but horizonal scale should also be considered. A single 0.04-ha (20 by 20 m) vegetation plot, is only the width of one or two large overstory trees. Some forests may be characterized by a contiguous lower canopy interrupted by one or two emergent crowns per hectare. Therefore, several small plots or a single large plot would be necessary to capture an adequate range in tree heights found in a stand. While LiDAR would allow an appreciation of the scale of this vertical structure, it is still no substitute for ground-level observations which still needed to assess the understory strata and species composition.

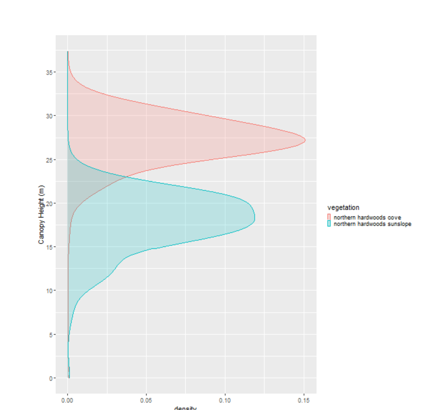
Reference Vegetation	Median Crown Width	Median Tree Canopy Height	25th Percentile Crown Height	Median Crown Height	75th Percentile Crown Height	Tallest Tree per 0.04 Hectare	Tallest Tree per 1 Hectare	Tallest Tree
Coast Redwood Forest, California	27.0	70.1	82.5	88.0	93.6	85.9	96.3	105.2
Sitka Spruce Forest, Washington	21.9	40.7	46.9	60.0	73.6	63.4	80.0	90.2
White Pine Forest, Michigan	21.3	31.4	40.7	43.8	45.9	43.6	47.5	50.2
Tropical Rainforest, Costa Rica	25.6	28.4	31.6	36.1	40.6	37.7	47.6	61.7
Tropical Rainforest, Puerto Rico	23.0	23.9	26.4	29.7	33.4	31.1	38.0	49.6
Tropical Dry Forest, Puerto Rico	10.7	6.8	7.6	8.8	10.2	9.9	12.7	14.6
Cove Hardwood Forest, Tennessee	22.1	30.0	33.9	37.6	41.9	38.9	46.0	55.5
Beech-Magnolia Forest, Florida	21.1	26.8	29.6	33.6	37.1	34.2	39.3	46.7
Beech-Maple Forest, Michigan	22.9	29.2	32.0	33.5	35.3	34.1	38.1	43.1
Northern Hardwoods Forest, Michigan	20.8	27.4	29.0	30.4	31.7	30.7	33.5	37.3
Oak-Chestnut Forest, Tennessee	16.2	18.6	18.0	22.9	26.2	23.3	29.3	38.5
Sweetgum-Loblolly Pine Bottomland, South Carolina	20.7	23.7	24.6	31.0	35.2	34.0	43.0	50.5
Bald-cypress-Tupelo Swamp, South Carolina	21.8	29.8	31.8	33.6	35.4	34.0	37.0	41.5
Oak-Pine Barrens, Michigan	14.1	13.7	14.3	17.7	20.0	17.4	21.6	27.5
Longleaf Pine Woodlands, Georgia	14.6	23.6	25.5	27.8	30.2	27.8	31.8	36.3
Subalpine Forest, Colorado	10.7	13.3	16.6	18.4	20.8	20.8	26.4	36.4
Boreal Forest, Alaska	6.9	6.4	7.5	8.5	9.9	9.6	15.8	16.9
Jack Pine Barrens, Michigan	7.7	6.6	7.6	8.2	8.8	7.6	8.9	14.5
Heath Bald, Tennessee	7.4	5.8	6.5	7.4	8.6	7.8	19.9	12.9
Joshua Tree Desert, California	5.1	6.2	6.5	7.6	9.0	6.9	8.6	17.0

Reference Vegetation	Canopy Cover 0-2 m	Canopy Cover 2-5 m	Canopy Cover 5-15 m	Canopy Cover 15-30 m	Canopy Cover 30-45 m	Canopy Cover 45-60 m	Canopy Cover 60+ m	Total Tree Cover	Crown Cover 5-15 m	Crown Cover 15-30 m	Crown Cover 30-45 m	Crown Cover 45-60 m	Crown Cover 60+ m
Coast Redwood Forest, California	0.8	0.5	3.4	10.6	11.6	17.6	55.5	98.7		0.1	1.5	1.3	95.7
Sitka Spruce Forest, Washington	12.6	4.8	10.0	22.8	26.6	13.8	9.5	82.6	0.5	1.6	15.1	24.1	41.4
White Pine Forest, Michigan	0.9	0.4	2.2	44.1	50.9	1.5		98.7		0.9	62.1	35.7	
Tropical Rainforest, Costa Rica	1.6	1.9	10.4	51.7	32.4	1.9		96.5	0.8	16.5	69.3	9.8	0.1
Tropical Rainforest, Puerto Rico	0.0	0.0	3.8	83.9	12.3			100.0		52.2	47.5	0.2	
Tropical Dry Forest, Puerto Rico	5.2	36.3	58.4					58.4	58.4				
Cove Hardwood Forest, Tennessee	2.0	3.0	11.5	43.6	38.8	1.2		95.0	0.8	7.8	74.1	12.4	
Beech-Magnolia Forest, Florida	0.4	0.7	10.0	61.4	27.5			98.9	0.3	26.7	71.6	0.3	
Beech-Maple Forest, Michigan	1.8	1.2	5.8	53.6	37.5			97.0		7.4	89.6		
Northern Hardwoods Forest, Michigan	0.3	0.1	0.3	84.8	14.6			99.6		41.6	58.0		
Oak-Chestnut Forest, Tennessee	0.2	1.0	31.5	66.3	1.0			98.8	13.1	78.9	6.8		
Sweetgum-Loblolly Pine Bottomland, South Carolina	0.9	1.9	29.6	52.0	15.2	0.5		97.2	5.5	38.8	48.7	4.2	
Bald-cypress-Tupelo Swamp, South Carolina	0.1	0.1	2.3	50.5	46.9			99.7		9.0	90.7		
Oak-Pine Barrens, Michigan	31.0	6.7	41.6	20.7				62.3	18.7	43.6			
Longleaf Pine Woodlands, Georgia	39.6	4.5	11.1	42.4	2.4			55.9	1.4	39.6	15.0		
Subalpine Forest, Colorado	19.9	8.3	52.5	19.1	0.1			71.8	8.7	62.1	1.0		
Boreal Forest, Alaska	26.8	33.1	40.1					40.1	40.0	0.1			
Jack Pine Barrens, Michigan	43.9	50.8	5.4					5.4	5.4				
Heath Bald, Tennessee	27.7	58.9	13.4					13.4	13.4				
Joshua Tree Desert, California	79.8	18.0	2.3					2.2	2.2				

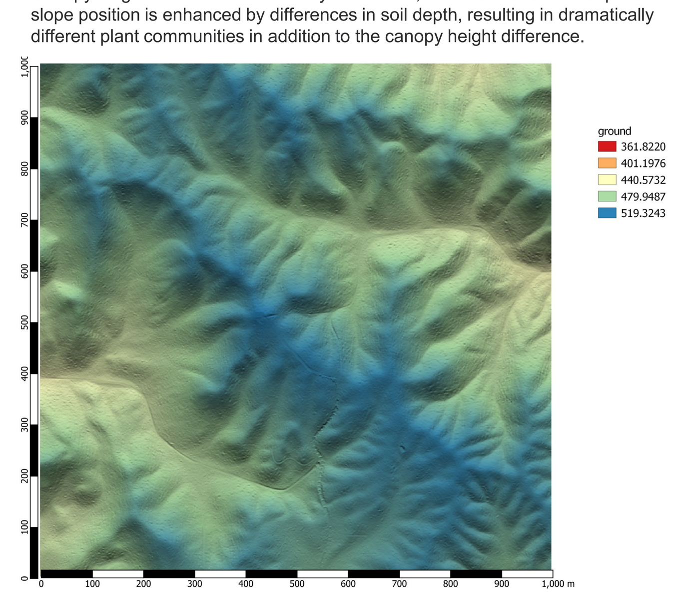
Hillslope Position



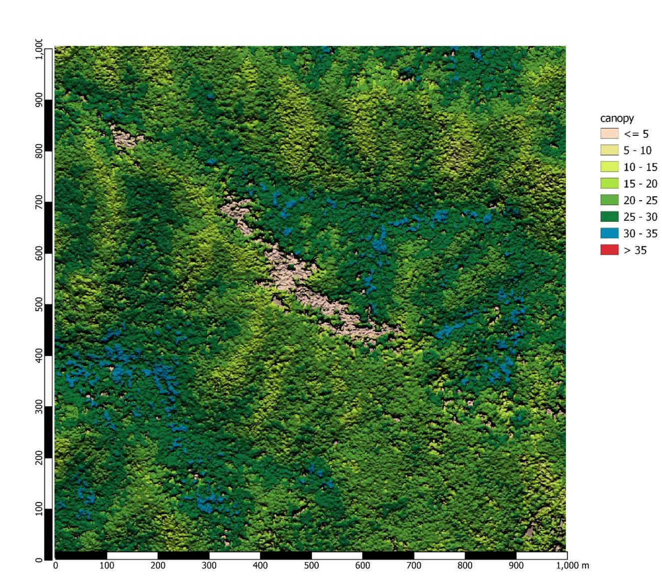
Canopy height model in Great Smoky Mountains, where the effects of aspect and slope position is enhanced by differences in soil depth, resulting in dramatically different plant communities in addition to the canopy height difference.



Comparison of canopy height profiles of an upper-slope, southwestern-aspect stand, and a lower-slope, northeastern-aspect stand in the Briar Hills, MI. Stand age, species, and soils are not known to vary according to stand and soil map unit records.



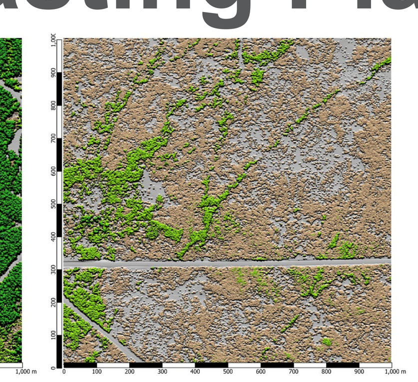
Shaded relief elevation map of Briar Hills, Michigan

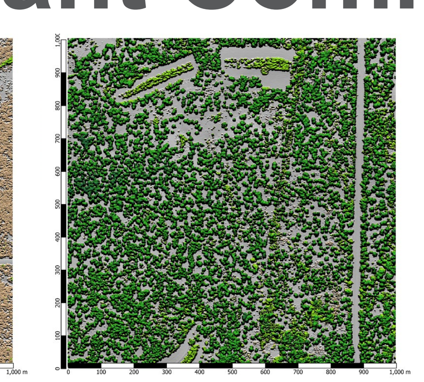


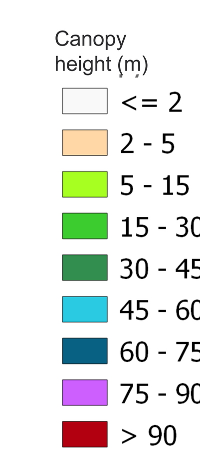
Canopy height model of Briar Hills, Michigan

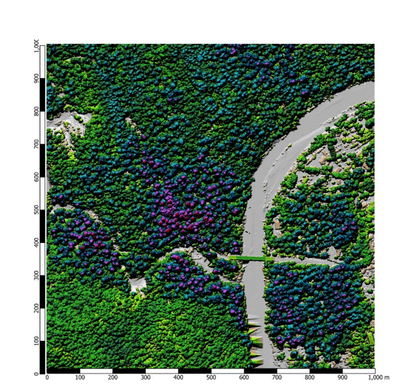
Contrasting Plant Communities

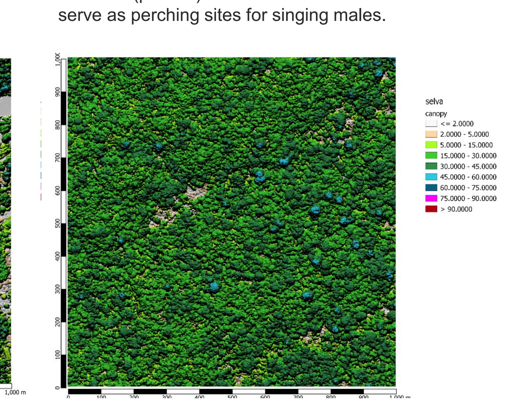

Hartwick Pines, known to have the 50-meter white pines (Pinus strobus), tallest tree in Michigan


Fire created jack pine barrens in northern Michigan with peak occupancy by Kirtland's Warbler (*Setophaga kirtlandii*) at the 2-5 m height class, along with scattered herbaceous/low shrub openings < 2 m. Residual (pre-fire) lines of trees 5-15 m tall serve as perching sites for singing males.


Old-growth longleaf pine woodland characterize by canopy closure of only 60%, with a rich sun-loving grass and forb understory.




Grove of the world's tallest trees, the coast redwoods (*Sequoia sempervirens*), here reaching 105 m tall.



La Selva NP, in Costa Rica showing a 15-30 m canopy with a dispersed pattern of emergent canopy 45-60 m tall.

References

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