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NCSS National Cooperative Soil Survey

Utility of LiDAR in Ecological Site Descriptions

2021 National Cooperative Soil Survey (NCSS)
National Conference ● June 8-10, 2021

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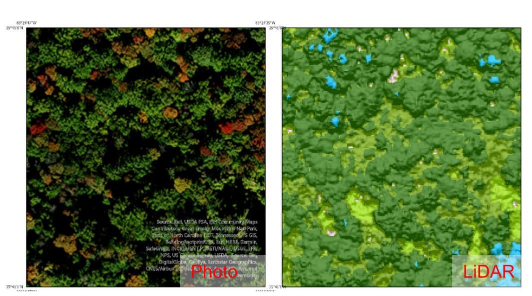
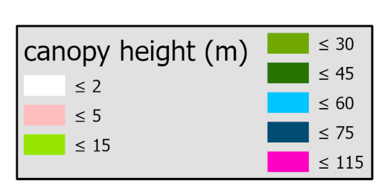
Soil scientists increasingly use bare-earth LiDAR derived digital elevation models for their extreme level of accuracy and precision for soil mapping, but less attention within the Soil and Plant Science Division is paid to other LiDAR derived products that focus on above surface features. There is enormous 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

Mesic forest, 200+ years old, Warren Woods State Park, Michigan



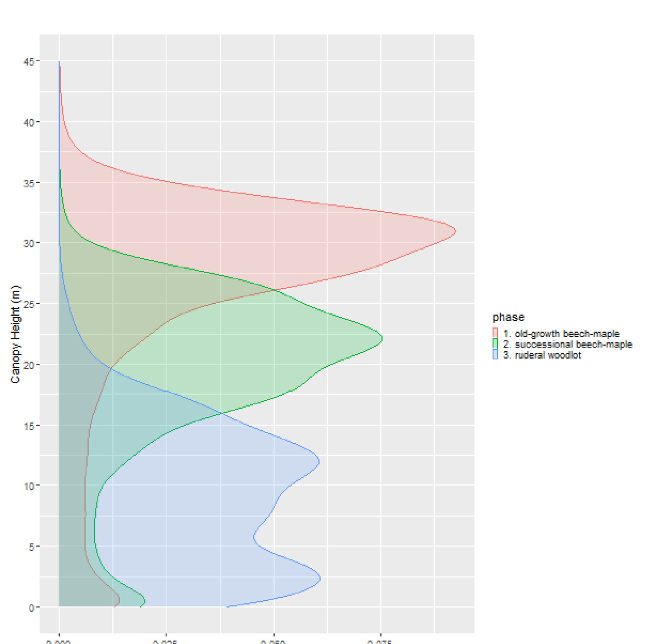
Mesic forest, 200+ years old, Great Smoky Mountains, Tennessee.



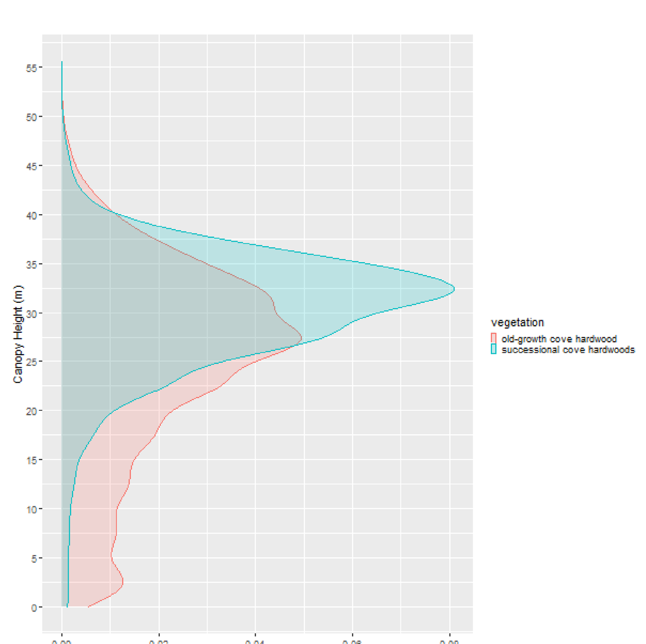
Mesic forest, 50 years old, Clinton County, Michigan

Mesic forest, 100 years old, Great Smoky Mountains, Tennessee.

Each map on the left consists of alternating aerial photos and LiDAR canopy height models, of old-growth and newer growth mesic forests. Each map covers exactly 4 hectares.



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

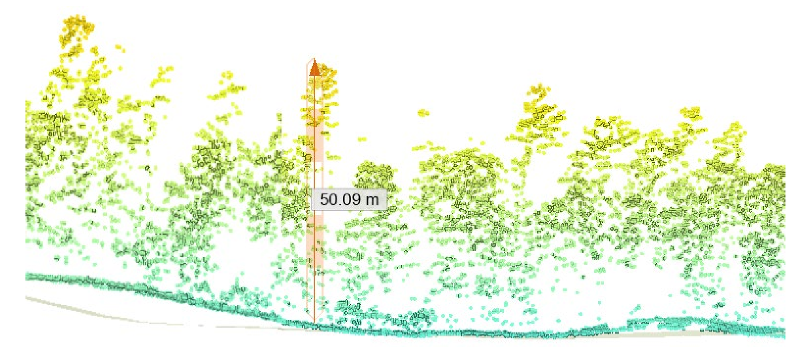


Canopy height profile of old-growth (>200 y), second growth (100 y), among mesic sites in Tennessee

Young and old forests can be distinguishing by:

- Michigan example: immature forest shorter than old growth forest.
- Tennessee example: young mature forest is on average taller and more uniform in height (dominated by *Liriodendron*), while old-growth is more variable in height due to single tree canopy gaps and slightly more frequent large emergent crowns.

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.

Possible improvement to ESDs:

- Revised crown height distribution break points to represent full range of forest types across the US, and to help distinguish community phases differing mainly in structural maturity.
- Display key structural indices like median crown height and total tree or shrub cover more prominently on the State and Transition Model.

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 for 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 of canopy height attempt base-line references by biome (Lefsky, 2010; Simard et al., 2011); however, this dataset is at a resolution too low to assess crown cover distribution and is unclear how its modal height metrics are supposed to relate to height metrics of local data, other than it being inconsistent.

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 (USGS, 2021) provided all point cloud data for sites within the United States, while OpenTopography (2021) provided data for sites outside the United States.

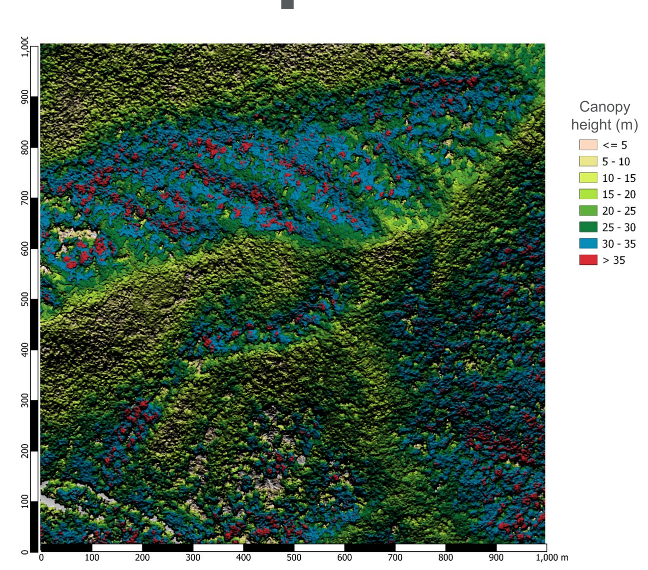
Canopy height distributions allow for a quantitative comparison of different stands not easily seen from casual ground observations or aerial imagery. However, metrics derived from the canopy height models are not directly comparable to ground-based measurements since canopy heights in the field are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

Variability in crown height can be documented 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 relatively 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 are still needed to assess the understory strata and species composition.

CROWN HEIGHT METRICS FOR SELECTED PLANT COMMUNITIES 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, Humboldt Redwoods State Park, California	29.7	81.0	94.9	98.5	102.2	96.9	105.7	112.7
Sitka Spruce Forest, Olympic National Park, Washington	21.9	40.7	46.9	60.0	73.6	63.2	80.2	90.2
White Pine Forest, Hartwick State Park, Michigan	21.3	31.4	40.7	43.8	45.9	43.6	47.5	50.2
Tropical Rainforest, La Selva Biological Station, Costa Rica	25.6	28.4	31.6	36.1	40.6	37.7	47.8	61.7
Tropical Rainforest, El Yunque National Forest, Puerto Rico	23.0	23.9	26.4	29.7	33.4	31.0	37.9	49.6
Tropical Dry Forest, Guánica State Forest, Puerto Rico	10.7	6.8	7.6	8.8	10.2	9.8	12.7	14.6
Cove Hardwood Forest, Great Smoky Mountains, Tennessee	22.1	30.0	33.9	37.6	41.9	38.8	45.9	55.5
Beech-Magnolia Forest, Torreya State Park, Florida	21.1	26.8	29.6	33.6	37.1	34.1	39.3	46.7
Beech-Maple Forest, Warren Woods State Park, Michigan	22.9	29.2	32.0	33.5	35.3	34.1	38.2	43.1
Northern Hardwoods Forest, Manistee National Forest, Michigan	20.8	27.4	29.0	30.4	31.7	30.7	33.5	37.3
Broadleaf Evergreen Forest, San Gabriel Mountains, California	19.5	19.0	19.9	25.4	33.1	30.5	41.7	50.5
Oak-Chestnut Forest, Great Smoky Mountains, Tennessee	16.2	18.6	18.0	22.9	26.2	23.3	29.1	38.5
Sweetgum-Loblolly Pine Bottomland, Congaree National Park, South Carolina	20.7	23.7	24.6	31.0	35.2	34.0	42.9	50.5
Bald-cypress-Tupelo Swamp, Congaree National Park, South Carolina	21.8	29.8	31.8	33.6	35.4	34.0	36.9	41.5
Longleaf Pine Woodlands, Thomas County, Georgia	14.6	23.6	25.5	27.8	30.2	27.9	31.9	36.3
Oak-Pine Barrens, Allegan State Game Area, Michigan	14.1	13.7	14.3	17.7	20.0	17.5	21.6	27.5
Ponderosa Pine Woodland, Grand Canyon National Park, Arizona	9.9	8.1	9.4	11.1	14.6	15.3	20.8	25.9
Pinyon-Juniper Woodland, Grand Canyon National Park, Arizona	7.0	6.3	6.9	7.8	9.0	8.5	11.7	17.2
Subalpine Forest, Front Range, Colorado	10.7	13.3	16.6	18.4	20.8	20.8	26.2	36.4
Boreal Forest, Fairbanks, Alaska	6.9	6.4	7.5	8.5	9.9	9.7	15.8	16.9
Jack Pine Barrens, Huron National Forest, Michigan	7.7	6.6	7.6	8.2	8.8	8.1	8.9	14.5
Heath Bald, Great Smoky Mountains, Tennessee	7.3	6.7	7.8	10.2	16.5	13.7	36.4	20.3
Mesic Chaparral, San Gabriel Mountains, California	8.7	6.1	6.5	7.8	10.5	8.0	12.7	20.2
Joshua Tree Desert, Joshua Tree National Park, California	5.1	6.2	6.5	7.6	9.0	7.5	8.8	17.0

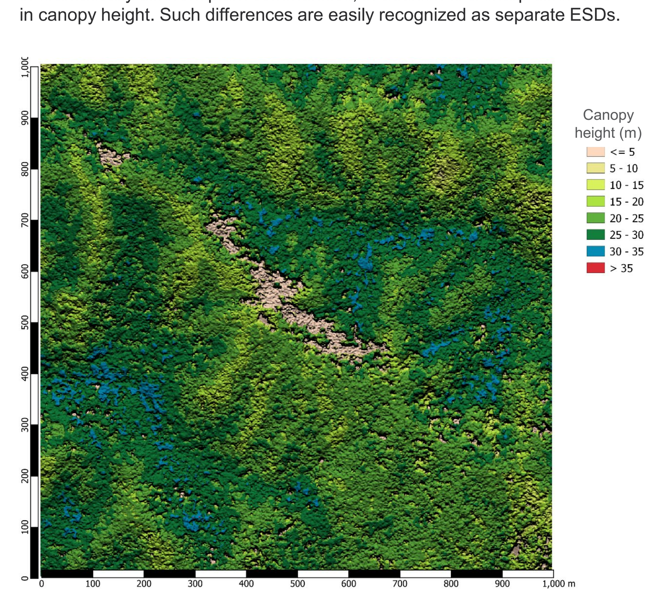
CANOPY vs CROWN COVER BY COMMON STRATUM CLASSES FOR SELECTED PLANT COOMUNITIES Reference Vegetation	Canopy Cover 0-2 m	Canopy Cover 2-5 m	Canopy Cover 5-15 m	Canopy Cover 15-30 m	Canopy Cover 30-45 m	Canopy Cover 45-60 m	Canopy Cover 60+ m	Total Tree Cover	Crown Cover 5-15 m	Crown Cover 15-30 m	Crown Cover 30-45 m	Crown Cover 45-60 m	Crown Cover 60+ m
Coast Redwood Forest, California	0.8	0.6	1.6	3.5	4.5	8.6	80.4	98.6				0.1	98.5
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	0.0		100.0	0.0	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	0.0		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	0.0	7.4	89.6		
Northern Hardwoods Forest, Michigan	0.3	0.1	0.3	84.8	14.6			99.6		41.6	58.0		
Broadleaf Evergreen Forest, California	1.1	1.4	29.7	58.5	9.2	0.2		97.5	8.5	57.3	28.1	3.7	
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		
Longleaf Pine Woodlands, Georgia	39.6	4.5	11.1	42.4	2.4			55.9	1.4	39.6	15.0		
Oak-Pine Barrens, Michigan	31.0	6.7	41.6	20.7				62.3	18.7	43.6			
Ponderosa Pine Woodland, Arizona	19.9	14.6	61.0	4.5				65.5	50.7	14.8			
Pinyon-Juniper Woodland, Arizona	38.3	33.0	28.7	0.0				28.7	28.6	0.1			
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	5.1	86.6	7.6	0.7				8.3	5.9	2.5			
Mesic Chaparral, California	41.2	50.0	8.5	0.2				8.8	7.7	1.1			
Joshua Tree Desert, California	79.8	18.0	2.3					2.2	2.2	0.0			

Hillslope Position

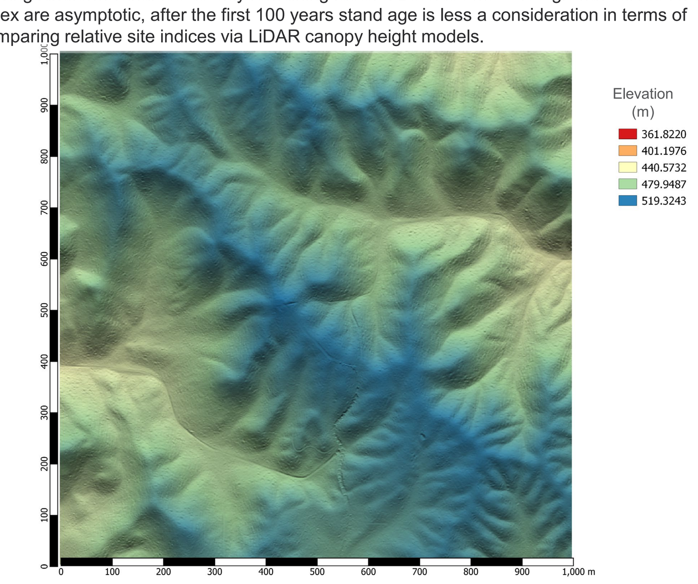


Canopy height model in the Great Smoky Mountains, where the effects of aspect and slope position is enhanced by differences in soil depth, resulting in dramatically different plant communities, in addition to a sharp difference in canopy height. Such differences are easily recognized as separate ESDs.

Comparison of canopy height profiles of an upper-slope, southwestern-aspect "sunslope" stand, and a lower-slope, northeastern-aspect "cove" stand in the Briar Hills, Michigan. Based on stand and soil map unit records, stand age, species, and soils does not significantly vary, leaving landform variables as only remaining factors. Because most tree growth curves for site index are asymptotic, after the first 100 years stand age is less a consideration in terms of comparing relative site indices via LiDAR canopy height models.



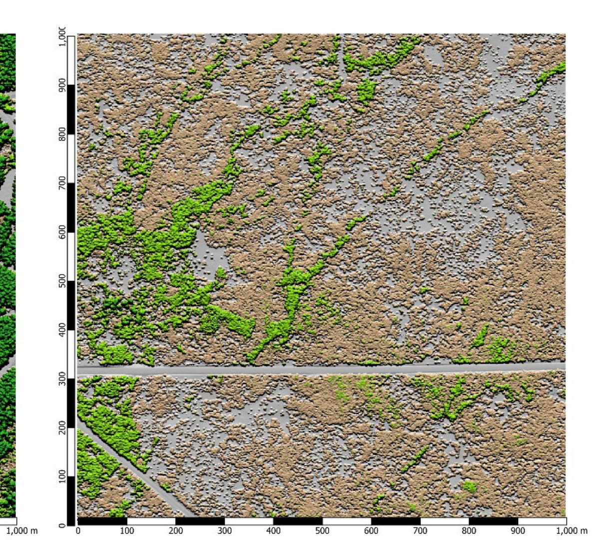
Canopy height model of Briar Hills, Michigan, showing a more subtle but consistent difference in canopy height where soils and tree species remain relatively uniform. This variability is currently treated provisionally as the same ecological site, but potentially can be subdivided into a high and low productivity phases.

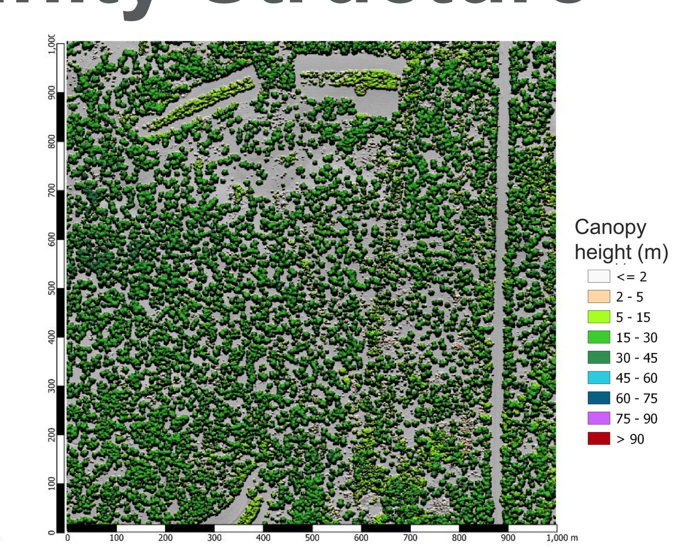


Shaded relief elevation map of Briar Hills, Michigan, for comparison to canopy height map on the left.

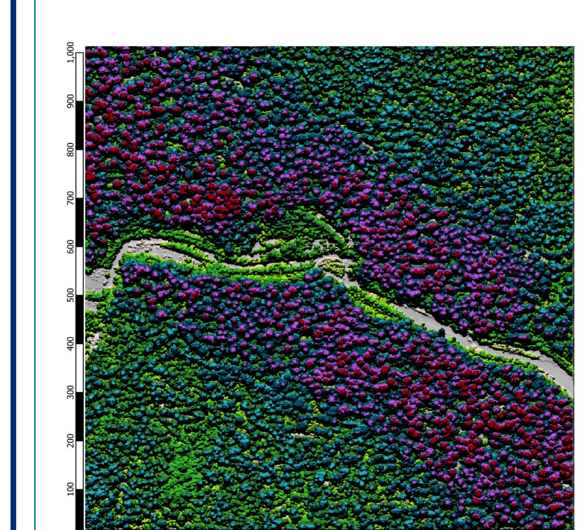
Contrasting Plant Community Structure

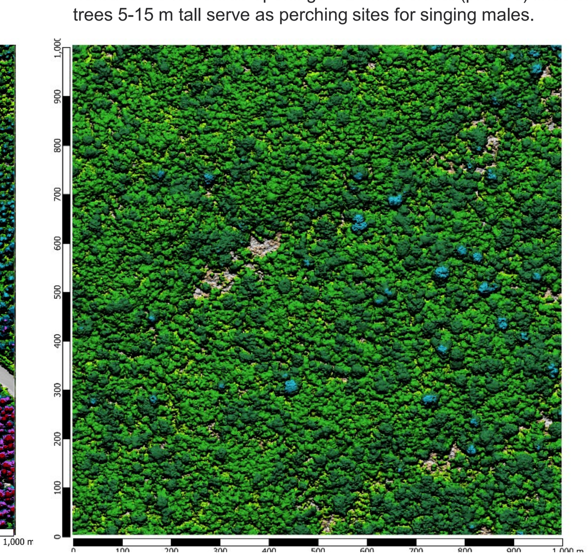

A grove of old-growth pines and hemlock, in Hartwick Pines State Park, MI, known for having the tallest tree in Michigan, a white pine (*Pinus strobus*) at 50 m tall.


Fire-created jack pine barrens (19 years old) in northern Michigan (Huron National Forest) 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, Thomas County, Georgia, characterized 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*), in Humboldt Redwoods State Park, CA, several here exceeding 100 m tall.


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

References

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