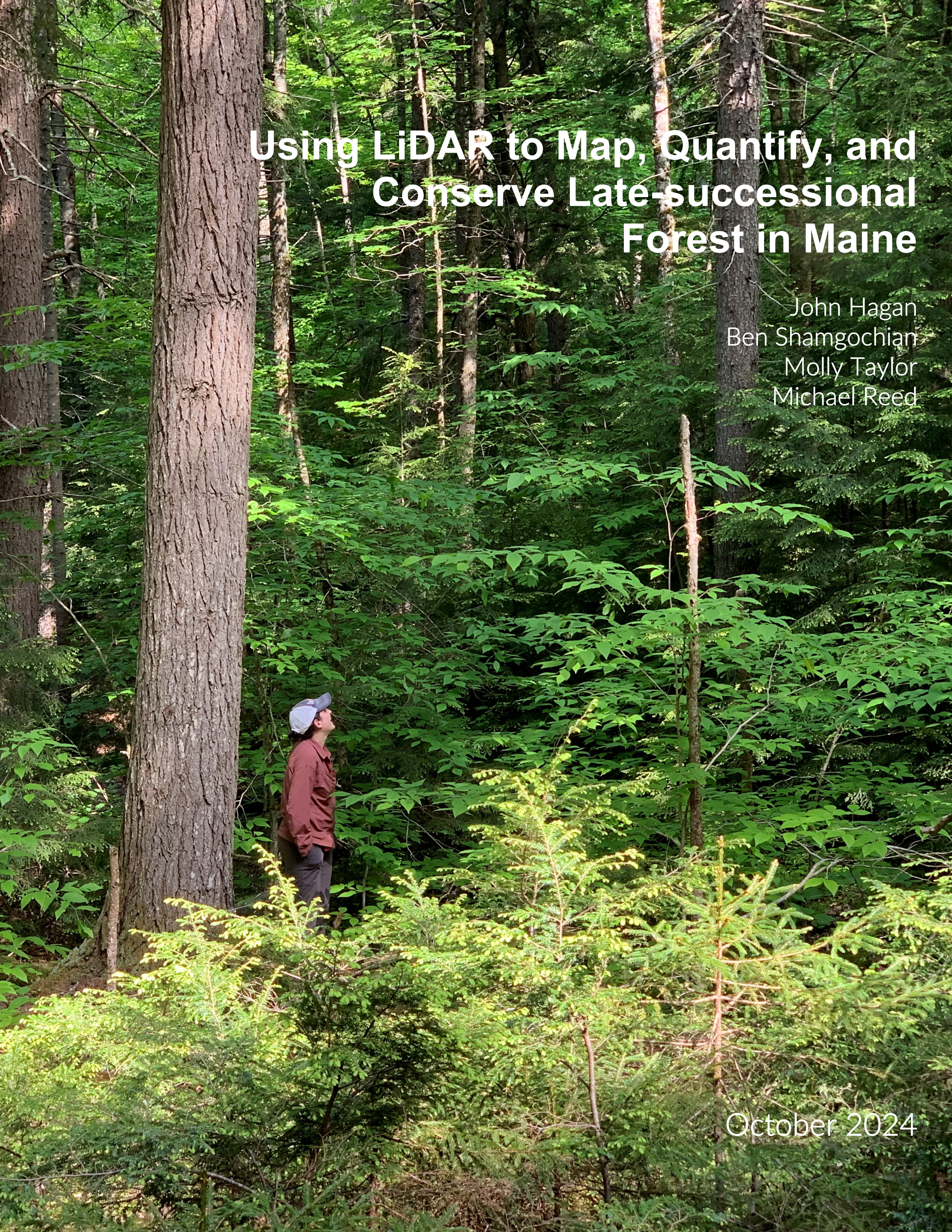

Using LiDAR to Map, Quantify, and Conserve Late-successional Forest in Maine

John Hagan
Ben Shamgochian
Molly Taylor
Michael Reed

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P.O. Box 228
Georgetown, Maine 04548
(207) 837-4868
jhagan@ourclimatecommon.org

Authors

John Hagan, Ph.D., President, Our Climate Common[1]

Benjamin Shamgochian, Research Associate, Our Climate Common

Molly Taylor, Ph.D. Student, Tufts University

Michael Reed, Ph.D., Professor, Tufts University

[1] Corresponding author: jhagan@ourclimatecommon.org

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Cover Photo

Molly Taylor in a late-successional stand near Greenville, Maine that we discovered using LiDAR (photo by J. Hagan)

OUR CLIMATE COMMON

Executive Summary

WHY THIS WORK MATTERS

Next to conversion of forest to other land uses, the loss of older forest age classes is a major threat to forest biodiversity worldwide. Late-successional and old-growth forests (LSOG) have a high density of large trees, large snags, and large downed logs, all of which are important to many species. The loss of these structural elements, as well as breaking the ecological continuity of LSOG stands over time, puts many forest species at risk. However, humans need wood for everything from paper and packaging to dimensional lumber for construction. Managing forests for such wood products results in a much younger forest across the landscape. Our challenge, then, is to manage for both wood production *and* LSOG forest. LSOG forest also has social value, irrespective of biodiversity benefits, and the Biden Administration made protection of mature and old-growth forest a national priority. To manage for LSOG forest, first we need a good sense of how much exists and where it exists. Then we can better manage the larger forest landscape for society's varied forest values. This study uses LiDAR (light detection and ranging) data to quantify and map LSOG forest in the 4.2-million hectares (10.3 million acres) of unorganized territory in Maine.

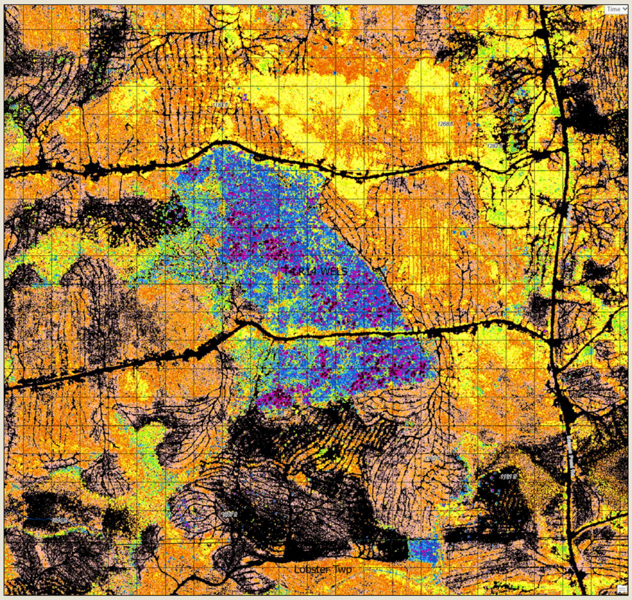

Figure A. The blue-magenta canopy height "signature" often indicates a late-successional stand in the unorganized townships of Maine. Grid=1 ha units.

METHODS

We used publicly available airborne LiDAR data, flown mostly between 2015 and 2018 in the unorganized townships of Maine ("study area"), to generate a canopy height model at 1m^2 resolution for the entire area. In a commercial forest, LSOG stands "light up" because they are significantly taller than the surrounding managed forest (see Fig. A). Using sites of known forest successional stage, including true old-growth, we built a computer model based on eight canopy metrics that classified all 4.2-million hectares of the study area into one of four categories:

(1) Not LSOG (not late-successional or old-growth),
(2) Transitioning Late-Successional
(3) Late-successional, and
(4) "Old-growth-like" (Fig. B).

Although our classification was primarily structural (sizes of trees, amount of downed wood) and compositional (shade tolerant species), Transitioning LS forest typically had dominant trees 100-150 years old and LS forest had dominant trees 150-200 years old. Old-growth reference sites had overstory trees 200-400 years old. Note that our method was not designed to find stunted, high-elevation forest or old wetland forest. It was designed to find LSOG forest in the 85% of the landscape that would be accessible to logging, and where LSOG forest is most at risk in the near term. We plan to build a new model that maps just old wetland forest using LiDAR.

VALIDATION

We used two methods to validate the accuracy of the classification. First, the computer model (called *random forest*) does an "internal" validation using a subset of the reference-site data *not* used to build the model. This validation method indicated that the model correctly classified a hectare as Not LSOG or one of the three LSOG classes 94% of the time. The second validation method involved field verification—visiting novel hectares in the field to determine whether the computer model correctly classified the hectare. This more rigorous and expensive approach to validation showed virtually the same result—94% accuracy. We also challenged the model to distinguish more finely among the three LSOG classes. It performed well here too but struggled to distinguish between LS and true old-growth. Still, it correctly classified the older age classes most of the time, and thus provides an excellent map for directing landowners and conservationists to potentially exceptional LSOG stands. Ground verification is always essential.

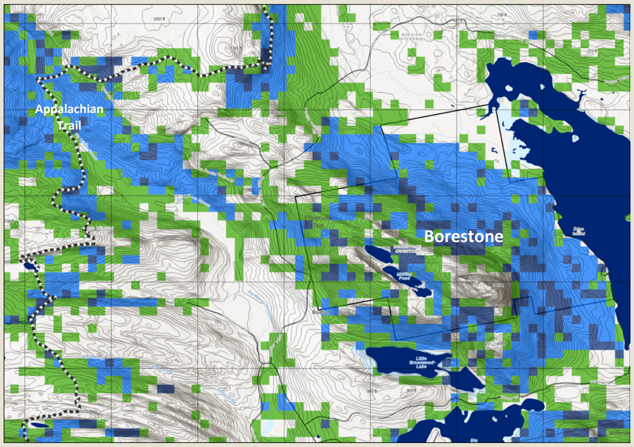

Figure B. An example of the computer model classification of each hectare in the landscape. Maine Audubon's Borestone Sanctuary southeast of Greenville is well-known to be late-successional forest. White=Not LSOG; Green=Transitioning LS; Blue=LS; Dark Blue="old-growth-like." Grid=1 km^2

HOW MUCH LSOG SUCCESSION FOREST REMAINS?

We estimate that about 16% of the unorganized territories of Maine was in Transitioning LS (green, Fig. B) and about 3% was in LS (blue, Fig. B). Only about 0.9% was classified as "old-growth-like." Fig. C summarizes percentages for different landscape units/ownerships. LSOG stands have a significantly higher density of late-successional forest characteristics than the average commercial forest stand. In our view, all LS stands should be conserved (or managed lightly) because of their increasing rarity. The model was not good at distinguishing between LS and true old-growth. We plan to build a more refined model to distinguish between just these two classes using a larger suite of canopy metrics.

HOW BIG (or SMALL) ARE LSOG STANDS?

Because the computer algorithm classified each hectare independently, we were able to examine the size class distribution of the three LSOG classes. For example, in the 4.2M hectare study area, there were 21,783 distinct parcels of LSOG forest in the 1-5 hectare area class, totaling some 58,621 hectares. At the other end of the area distribution, there were 386 stands ≥ 250 ha, totaling 432,000 hectares. While it is tempting to focus only on the larger stands for conservation prioritization, that would be a mistake. Some of the most vulnerable species to forest age (many mosses and lichens) can persist in small patches of forest for decades. If retained, these many small patches could function as source populations for the surrounding forest as it regrows. At the same time, larger stands allow for species and functions that require larger areas. The important point is that both large stands and the thousands of widely distributed small patches contribute to ensuring healthy populations of LSOG-related species in Maine's unorganized townships.

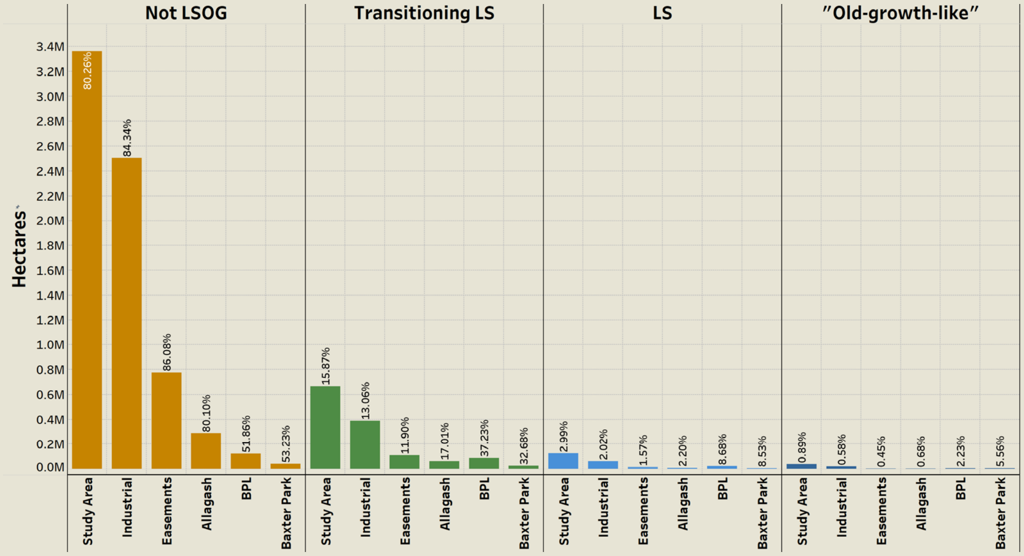

Figure C. Based on our computer classification model, the amounts (hectares) of Not LSOG, Transitioning LS, LS, and "old-growth-like" forest in different geographic units. The numbers above the bars indicate the percentage of the land unit in the indicated forest class. E.g. 8.68% of BPL ownership is in the LS class.

WHERE IS LATE-SUCCESSIONAL FOREST?

Maine Bureau of Parks and Lands (BPL) had the highest percentage of LS forest (8.7% of ownership), reflecting an ecological emphasis on publicly held forest. By contrast, only 2% of commercial timberland was classified as LS forest. Despite this small percentage, private commercial timberlands still contained most of the remaining LS forest (60,148 hectares) because private commercial timberlands made up 85% of the study area. Therefore, private commercial forest is an important place to focus LSOG conservation efforts. Baxter Park, BPL's Ecological Reserves, and some private conservation lands are the only places that are likely growing new LS forest.

HOW FAST ARE WE LOSING LSOG FOREST?

Because the LiDAR we used was flown 6-8 years ago, we were able to calculate rate of loss of LSOG forest using Global Forest Watch forest change data, updated through 2023 (Table A). We estimated that the LS forest class is being lost at a rate of 1.4%/year for the entire study area. Within the study area, BPL was losing LS forest at a relatively slow rate of 0.6%/year, but private commercial landowners were losing LS forest at 2.2%/year, or nearly 4 times as fast as public land. Expressed in terms of half-life, half of the remaining LS forest on private commercial forestland would be gone in 21 years, again arguing for a focus on private commercial timberlands for LSOG conservation.

Table A. Estimates of the rate of loss of LS stands from selected ownership types.

	LS Initial Hectares [1]	LS 2023 hectares	LS Annual Rate of Harvest	Half-life (years)[3]
Study Area	135,672	125,581	-1.40%	35.0
Maine BPL (Bureau of Parks and Lands)	21,135	20,523	-0.60%	96.1
Maine BPL (without Ecological Reserves)	17,381	16,388	-0.97%	48.2
Baxter State Park [2]	6,496	6,471	-0.02%	787.0
Large "industrial" forest owners	68,723	60,603	-2.16%	20.8

CONSERVATION STRATEGIES

In this report we outline six strategies for LSOG conservation. We can anticipate the need to pay commercial landowners for LSOG forest because it can be a financial cost to maintain stands in these older age classes. Some strategies include: using our new LSOG maps to target areas for public acquisition; the purchase of precision LSOG easements, paying landowners to forgo the timber revenue from LSOG stands; and engaging the forest carbon offset market to conserve LSOG stands because they have high volumes of carbon relative to younger forest. As the price of carbon goes up to $15-$25/tonne for CO_2 in the voluntary carbon market, LS stands are close to being worth more for their carbon than for their wood value. Fiduciary responsibility of commercial forest owners would argue for paying attention to this rapidly emerging opportunity. Simultaneously, some landowners are willing to manage LS stands in a lighter fashion. Forest certification systems (SFI and FSC) do not prevent LS stands from being harvested.

CONSERVATION IMPLICATIONS

In other parts of the world, we have seen the biodiversity implications of a long history of forest management. For example, Sweden, which has forest types similar to Maine's, has a long list of "red-listed species" (equivalent to our threatened and endangered species), most as a result of the loss of older forest age classes. Species conservation becomes expensive when species become endangered; it is more cost effective to conserve them before they become endangered. We need a social conversation about how much LSOG forest we want and how we want it distributed. Then we can take action to get there. We need commercial landowners and conservationists to bring their respective skills together to change the trajectory of LSOG loss. We believe this can be done, while maintaining or even growing a healthy forest products economy, if we all work together.