A publication of the Natural Capital Initiative of Manomet Center for Conservation Sciences FMSN-2009-1 July 2009

forest mosaic science notes

Abstract

Late-successional forest typically has grown beyond silvicultural or financial maturity, and yet forest in this age class appears to be important for maintaining biodiversity. Maintaining and managing for late-successional forest therefore is an important consideration for sustainable forestry. A key step in developing management and conservation strategies for late-successional forest is having the ability to recognize it. Here we present the LS Index, a simple, fast (<30 minutes), science-based tool that foresters can use to identify late-successional forest. Although built from a large number of variables, the LS Index relies only on the density of large-diameter trees (≥16", 40 cm, alive or dead). The LS Index was designed for foresters. With the LS Index, new opportunities for conservation, management, and quantification of LS forest are possible.

Lobaria quercizans
(A. Whitman photo)

A Revised Rapid-Assessment Late-Successional Index for common northeastern forest types

by Andrew A. Whitman and John M. Hagan

A late-successional (LS) forest is one that is approaching ecological maturity or old-growth condition. 'Late-successional' is not a precisely defined scientific term. In northern New England, LS forest might be described as a stand that contains a dominant canopy cohort of trees between about 120 and 200 years old. Typically, stands in a LS condition are well past their economic or silvicultural prime, which occurs at about 60 to 100 years of age, depending on the forest type. It is therefore problematic to maintain substantial amounts of LS forest in a landscape that is managed primarily for forest products. With increased efficiencies in forest harvesting and silviculture, increased accessibility, and intense global competition, remaining LS stands are rapidly being lost from commercial forest landscapes in northern New England.

There are hundreds, possibly thousands, of LS stands scattered throughout the commercial forests of New England as remnants of a different era. In Maine, an assessment by the ME Forest Service suggests than LS acreage has been declining 1.5% / year since 1982 (~50% decline between 1982 and 2003) and now constitutes <1.8% of Maine's forest . We need new management strategies and tools to prevent this forest age class, and species that might be associated with it, from being lost from extensive commercial forest landscapes (Hagan and Whitman 2004).

Our ecological knowledge of LS forest is poor, but growing. What species or ecosystem processes might be lost with LS forest? A modest but significant number of species (~100s) appear to be tightly linked to old trees, or big trees, or the structural attributes of LS forest. Maintaining these species, well-distributed across their original range in Maine, will require maintaining LS stands, also well-distributed throughout Maine.

It seems that economic and ecological realities are at odds with respect to conserving LS forest. However, these differences may not be irreconcilable. A forest stand does not instantly become LS, but rather slowly accumulates LS attributes and species over time (Hunter and White 1997). That is, being LS is not a black-and-white issue. LS is a matter of degree, and therefore it can be measured. If it can be measured, it can be managed. A corollary is that trees can be removed from a stand without removing all of the LS content. Our research indicates that timber harvesting can be compatible with managing and conserving LS attributes. To succeed, however, foresters and loggers must be keenly attuned to those attributes of a stand that represent the LS component of forested landscapes.

To help maintain and manage for LS (LS) forest, we have developed a simple, rapid-assessment procedure that foresters can use to quantify the degree to which a stand is in a LS condition. The procedure takes less than 30 minutes to apply and

Table 1. Examples of LS-related indices from northern temperate and boreal forests.

Author	Location	Forest Type	Variables	Ecosystem Components	Scoring System	Specialist Required?	Level of Effort	Reference Points	Complex?
Selva 1994	Maine	Northern hardwoods	# of LS lichen species	species	Index = (No. of LS lichen spp. / 20) x 100	Yes	High	Yes	Yes
Lähde et al. 1999	Finland	Boreal spruce	Diversity index for tree DBH, snags and log volume, charred wood, special trees	structure	Index = Σ diversity indices	No	High	No	No
Trass et al. 1999	Estonia	Boreal spruce	Tree age, log density, log decay, history, forest herbs, bryophytes, lichens, and fungi	species & structure	Index = Σ variable scores (1, 2, 3)	Yes	High	No	Yes
Van Den Meerss-chaut & Vande-kerkhove 2000	Belgium	Temperate deciduous forest	Canopy closure, stand age, vertical structure, horizontal structure, large tree density, forest herbs, bryophytes, snags, large log density, history	species & structure	Index = Σ variable scores (1, 2, 3)	Yes	High	No	Yes
Drakenberg & Lindhe 1999	Sweden	Temperate and boreal forest	Presence/Absence of 80 variables (Site, dynamics, habitats, tree, structure, and deadwood)	species & structure	Index = Σ variables/conditions present	No	High	Yes	Yes

yields a score between 1 and 10, with 10 being an old-growth condition. With this score a forester will be able to quantify LS condition, and, as much as possible, modify harvest prescriptions to retain LS attributes. Armed with the LS Index, the forester can make informed decisions about LS conservation and management. To date, no such tool has existed for foresters, and many LS stands have been lost, often unknowingly. The LS Index does not overcome the problem that individual LS trees are often past their financial and silvicultural maturity. It does provide a tool and a framework for addressing LS conservation in a concrete, quantifiable manner. And that opens the door to innovation in management to achieve conservation goals, with foresters taking the lead role on the ground.

Brief Review of LS Scoring Systems

Several researchers have developed methods for quantifying LS content in a stand (Table 1). Selva's (1994) Index of Ecological Continuity is derived from the presence of indicator lichens that prefer old forest and old trees. Lähde et al. (1999) developed an LS scoring system based solely on forest structure (e.g., tree size). Other systems combine species composition and structure into the scoring system to capture a greater array of LS attributes and to increase accuracy of the score (Table 1).

Most of these systems are data demanding; much time and effort is needed to collect the required data. Only Selva's system can work in northern Maine. Most systems also require considerable taxonomic skill with non-woody plants. Some systems are based only on expert opinion and have not been statistically validated. Selva's (1994) and Drakenberg and Lindhe's (1999) systems have benchmarks (or endpoints) to help users interpret the meaning of the system's score, but others do not.

Our Goal

Our goal was to develop an LS Index that had the following characteristics: (1) is simple for foresters to use, (2) does not require taxonomic specialists, (3) is comprised of variables that can be measured at any time of year, (4) has wide ecological breadth (captures many other unmeasured LS attributes), (5) is statistically validated, (6) has benchmark scores for reference, (7) includes variables that foresters can manipulate or manage for, and (8) takes less than 30 minutes to complete in a stand.

We have met all of these criteria with our LS Index. We designed the LS Index especially for foresters because they are the key decision makers in the woods. Foresters have many diverse responsibilities, so we were determined to produce a simple index that foresters could and would use routinely.

How We Developed the LS Index

Based on the scientific literature and our own research, we identified 13 categories of variables that could potentially function to distinguish between LS forest and younger forest classes (Table 2). Within these 13 categories, we identified 54 specific variables for study. We then sampled all variables in 160 stands of all age classes in 41 townships in Maine and New Hampshire. Northern hardwood, upland spruce fir stands, and northern pine stands were sampled. Because of inherent ecological differences among forest types, we created an LS Index for

Table 2. Candidate indicator variable categories

1. trees and snags
2. large trees &snags
3. selected epiphytic lichen & moss spp.
4. logs
5. large logs
6. selected epixylic[1] lichen & moss spp.
7. selected herbaceous plant spp.
8. soil organic layer depth
9. woodpecker use
10. selected bracket fungi spp.
11. shrub density
12. vertical structure
13. canopy closure

[1] living on dead wood substrate

each type. We sampled clearcuts and true old-growth forest to calculate end-points for the scoring system. Stand age classes were assigned based on stand history. Stands were classified as 'LS' if they met the following criteria: (1) no evidence of stand replacing events in the last century (based on historic records and/or the presence of tip-up mounds, and/or the lack of sawn stumps, skid roads, and charcoal in the soil 'A' horizon), and (2) less than 40% canopy removal in the last 30 years (based on harvest records).

Selecting the best variables for the LS Index

Using a statistical procedure called stepwise discriminant function analysis (DFA), we identified which of the 54 measured variables best distinguished among the forest age-classes. We especially focused on variables that were effective at distinguishing between silviculturally mature forest and LS forest.

In DFA, the more variables used by the model, the better the model is at distinguishing among groups (in this case, age classes). We wanted to select a model with the fewest possible variables to keep the LS Index simple. The best model for northern hardwood forest had only one variable: large-tree (≥16" [40 cm] DBH, alive or dead) density (Table 3) which we used to create the LS Index for northern hardwoods (see below). For upland spruce-fir forest, the two best variables were large-tree (≥ 16" [40 cm] DBH, alive or dead) density and density of large logs. Although statistically significant, the density of large logs was not a practically improvement compared to the effectiveness of large tree density alone. Therefore, the upland spruce LS index was developed using only the density of large trees. For northern pine, we found a similar result. Adding more variables did not significantly improve the power to distinguish among age classes. Therefore, each LS index was developed using large tree density.

Converting to the LS Index

We used the results of the analyses above to develop the LS Index for each forest type with LS Index scores ranging from 0 to 10. We used data from old growth (OG) stands to provide reference levels where scores of 7 to 10 indexed based indicator levels at the 5, 25, 50, and 75 percentile of large trees using data from OG stands. We used threshold analysis to determine the break point between economically mature stands and LS stands for large tree density for each forest type. An LS Index score of 5 indicates economically mature (EM) stands, an LS Index score of 6 indicates LS stands. The threshold levels between EM and LS stands for each of the three indices were >17 large trees / acre for northern hardwoods, >15 large trees / acre for upland spruce-fir forest, and >13 large trees / acre for northern pine.

Table 3. Statistically candidate indicators of LS forest, and their r^2 values three forest types in Maine. Large r^2 values (up to 1.0) signify that the variable is more tightly correlated with forest age. r^2 values indicate the results of single indicator assessment. DFA partial r^2 values indicate the results from multivariate discriminant function analysis.

Candidate Indicators	Northern hardwoods		Upland Spruce-fir		Northern Pine	
	r^2	DFA partial r^2	r^2	DFA partial r^2	r^2	DFA partial r^2
Tree Basal Area	-	-	0.129	-	-	-
Large tree density	0.513	0.513	0.514	0.514	0.341	0.341
Large tree basal area	0.520	-	0.500	-	0.271	-
Large log density	-	-	0.046	-	-	-
Sum of large log lengths	-	-	0.049	-	-	-
Total large log volume	-	-	-	-	-	-
Density of trees with *Collema* spp..	0.066	-	-	-	-	-
Density of trees with long *Usnea* spp.	-	-	0.086	-	-	-

We evaluated the effectiveness of LS Indices using an independent dataset. The LS Indices had modest error rates of when used to classify EM stands and LS stands from a new and independent dataset. These error rates were 17% for northern hardwood stands, 16% for upland spruce/fir stands, and 0% for northern pine stands. The LS Indices smoothly increased across a range of seral classes ranging from clearcuts to OG with the greatest jump in index score occurring between EM, LS, and OG classes. The LS Indices were moderately well correlated to other LS attributes. You can find out more about the index in Whitman and Hagan (2007).

Differences between the first and final version of the LS Index

The revised version of LS Index is different from the 2004 version. First, the revised index has only one indicator: large tree density. This is because the revised LS Index was developed with more plots than the 2004 LS Index, better representing the ecology of a broader area. As a result, the lichen indicators from the 2004 LS Index were found to be statistically redundant with large tree density. However, the lichen indicators from the 2004 version (*Collema* spp. and long *Usnea* spp.) can still be used as indicators of LS forest. Second, OG data were used as reference data for the LS index scoring system because OG conditions should be more immutable and ecologically unchanging than reference conditions from managed forests.

Discussion

We achieved our goal of developing a simple LS Index that met all our criteria. Both the hardwood and softwood LS Indices are derived from the density of large trees. It is not surprising that the density of large trees plays a major role in the index because tree size is closely related to stand age. Like all indicators, the LS Index has limitations: (1) the danger of oversimplifying one's understanding of forests (e.g., it takes more than large trees to make an LS stand), (2) no indicator can capture all of the biological complexity of old forests; and (3) indicators face trade-offs between simplicity and accuracy. However, what is new here is that this simple variable is derived from a large and complex data set. Statistically, we could have produced a more powerful LS Index. But the power gain would have undermined our goal of keeping the index simple. An index that is too complicated or too time consuming is of no use. Our simple, science-based index, fashioned especially for foresters, should contribute to new ideas in conservation and management for this disappearing age class.

Although our LS Indices were developed for forests in northern New England (Ecological Sections 212A-D and M212A), the same process could be applied to any region or forest type. Once the initial investment of building the reference data set is made, the simplicity, practicality, and effectiveness of the LS Index can pay off in terms of conservation gains for the long term. Our LS Index is not perfect, but nor does not have to be to yield significant gains in LS conservation.

Other forest types

Although the LS Indices were built for three major NE forest types, foresters can use these results to identify LS stands of other forest types in the NE. We recommend using the large tree indicator and an LS threshold of > 15 large tree / acre to identify LS stands in other forest types with the exception of small-tree forest types (e.g., bogs, lowland black spruce-fir forest, sub-alpine forest, etc.).

How could a forester use the LS Index?

Many LS stands are harvested every year in Maine. Restoring LS attributes, once lost, could take a century or more. Our goal is to help foresters "know LS forest when they see it." The LS Index can be used in the following ways:

(1) To screen stands prior to harvest. With the LS Index, foresters can quickly score a stand for LS content prior to writing a harvest prescription. In Maine, private and public land managers have adjusted harvest prescription when the score is high (≥ 8). When the score ≥ 8, we recommend that land managers retain high levels of LS attributes (big trees or trees with indicator lichens) for retention or not harvest the stand.

(2) To assess the effectiveness of a harvest prescription for LS content. If the stand was screened prior to harvest, the forester can re-run the LS Index after harvest and determine how much LS content was retained. With the LS Index, foresters might set specific goals (e.g. harvest 50% of the wood, but allow the LS Index to only drop from 8 to 7.).

(3) To build an inventory system for LS stands. Because stands can now be easily quantified for LS content, land managers have a way to inventory LS stands. A catalog of LS stands could be built over time by adding the LS score to polygons in a GIS timber stand database. One major land manager has taken this approach to conserve stands with an LS Index ≥ 9 to address objectives set out by sustainable forestry certification.

We hope that the LS Index will be used by foresters; we worked hard to develop the index with their needs in mind. Although the inherent conflict between growing large, old trees, and making a financial profit remains, we believe that this tool will help foresters find new ways to manage for LS attributes. This is one simple step that can be taken to stem the tide of LS forest loss. It could make the difference for many species in the northern Forest region.

Acknowledgements

Development of the LS Index was generously supported by the University of Maine Cooperative Forestry Research Unit, the Merck Family Fund, the Harold Whitworth Pierce Charitable Trust, the National Fish and Wildlife Foundation, the Laird Norton Endowment Fund, the Maine Outdoor Heritage Fund, and the Joan Benson Baker Fellowship to JMH. Field staff was ably lead by Chris Lavertu and Anne Chounard. We especially thank Si Balch, Amanda Farris, and Julie Beane for improving earlier drafts of this note. We thank the many land owners and managers who provided maps and sites for sampling: Baskahegan Co., Baxter State Park, International Paper Co., J.D. Irving, Ltd., ME Bureau of Parks and Lands, MeadWestvaco, the Penobscot Indian Nation, Plum Creek Timber Co., 7-Islands Land Co., ME TNC, the Town of Eustis, the White Mtns. NF, and US Forest Service. We also thank all the foresters who helped us understand the importance of keeping the LS Index simple.

References

Drakenberg, B. and A. Lindhe. 1999. Indirekt naturvärdesbedömning på beståndsnivå en praktiskt tillämpbar metod. Skog and Forskning 2(99):60-6.

Hagan, J.M. and A.A. Whitman. 2004. Late-successional forest: a disappearing age class and implications for biodiversity. Forest Mosaic Science Notes 2004-2, 4 pp. Manomet Center for Conservation Sciences, Brunswick, Maine.

Hunter, M.L., Jr. and A.S. White. 1997. Ecological thresholds and the definition of old-growth forest stands. Natural Areas Journal 17: 292-296.

Lähde, E., O. Laiho, Y. Norokorpi, and T. Saksa. 1999. Stand structure as the basis of a diversity index. Forest Ecology and Management 115:213-220.

Selva, S.B. 1994. Lichen diversity and stand continuity in the northern hardwoods and spruce-fir forests of northern New England and western New Brunswick. Bryologist 97:424-9.

Trass, H., K. Vellak, and N. Ingerpuu. 1999. Floristical and ecological properties for identifying primeval forests in Estonia. Ann. Bot. Fennici 36:67-80.

Van Den Meersschaut, D., and K. Vandekerkhove. 2000. Development of a stand-scale forest biodiversity index based on the state forest inventory. Pp. 340-350 in: Hansen, M. and Burk, T. (eds.) Integrated tools for natural resources inventories in the 21st century, proceedings of the IUFRO conference; 1998 August 16-20; Boise, ID. GTR-NC-212. St. Paul, MN: USDA, Forest Service, North Central Forest Experiment Station.

Whitman, A.A. and J.M. Hagan. 2007. A late-successional index for temperate and boreal forest. Forest ecology and Management 246:144-154.

Published by:
Manomet Center for Conservation Sciences
Natural Capital Initiative
14 Maine St., Suite 305
Brunswick, ME 04011
(207)721-9040
www.manometmaine.org

Manomet's mission is to conserve natural resources for the benefit of wildlife and human populations.