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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) and the density of three easily-identified lichen species. The LS Index was designed for foresters. With the LS Index, new opportunities for conservation, management, and quantification of LS forest are possible.

Usnea spp.

A Rapid-Assessment Late-Successional Index for Northern Hardwoods and Spruce-Fir Forest

by Andrew A. Whitman and John M. Hagan

A late-successional 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, late-successional 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 late-successional 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 late-successional 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 late-successional stands are rapidly being lost from commercial forest landscapes in northern New England. There are hundreds, possibly thousands, of late-successional stands scattered throughout the commercial forests of New England as remnants of a different era. Most will be gone in a matter of a few years. We need new management strategies and tools now 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 late-successional forest is poor, but growing. What species or ecosystem processes might be lost with LS forest? We do not yet know for sure, but an increasing number of species appear to be tightly linked to old trees, or big trees, or the structural attributes of late-successional forest. Maintaining these species, well-distributed across their original range in Maine, will almost certainly require maintaining late-successional stands, also well-distributed throughout Maine.

It seems that economic and ecological realities are at odds with respect to conserving late-successional forest. However, these differences may not be irreconcilable. A forest stand does not instantly become late-successional, but rather slowly accumulates late-successional attributes and species over time (Hunter and White 1997). That is, being late-successional is not a black-and-white issue. Late-successional 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 late-successional content. Our research indicates that timber harvesting can be compatible with managing and conserving late-successional attributes. To succeed, however, foresters and loggers must be keenly attuned to those attributes of a stand that represent the late-successional component.

To help maintain and manage for late-successional (LS) forest, we have developed a simple, rapid-assessment procedure that foresters can use to quantify the

Table 1. Examples of LS-related indices from north 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	80 variables P/A (Site, dynamics, habitats, tree, structure, and deadwood)	species & structure	Index = Σ variables/conditions present	No	High	Yes	Yes

degree to which a stand is in a late-successional condition. The procedure takes less than 30 minutes to apply and 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. Heretofore, 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 late-successional 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 late-successional 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 to use by foresters, (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 late-successional 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 throughout western, eastern, and northern Maine. Both northern hardwood and upland spruce fir stands were sam-

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

pled. Because of inherent ecological differences in these two forest types, we created an LS Index for each type. We sampled clearcuts and true old-growth forest to calculate endpoints for the scoring system. Stand age classes were assigned based on stand height and stand history. Stands were classified as 'late-successional' 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 late-successional forest.

In DFA, the more variables used by the model, the better the model is at distinguishing among groups (in this case, age classes). However, there is a diminishing value in adding more variables. We wanted to select a model with the fewest possible variables to keep the LS Index simple. The best '2-variable' model for northern hardwood forest contained the variables large-tree (≥16" [40 cm] dbh, alive or dead) basal area and density of trees (alive or dead) with lichens in the genera *Collema* or *Leptogium* (Table 3). *Collema/ Leptogium* spp. occur most commonly on large maples, ash, and basswood. To simplify field application of the LS Index, we replaced large-tree basal area with large-tree (alive or dead) density, and found a trivial reduction in the model's ability to distinguish among age classes. Large-tree density and lichen tree density were used to create the LS Index for 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 trees (alive or dead) with long-stranded lichen *Usnea* spp. (or 'beard' lichen) longer than 15 cm, or 6"). Adding more variables did not significantly improve the power to distinguish among age classes.

Converting to the LS Index

We used the results of the analyses above to develop the LS Index for northern hardwoods and for spruce-fir forest. Large-tree density had much greater explanatory power than the density of trees with *Collema/ Leptogium* species. Therefore, we created a scoring system that reflected this weighting, in which large-tree density accounts for 8 of the possible 10 points, and density of trees with *Collema/Leptogium* accounts for up to 2 of the 10 total points (see Insert: LS Index: Northern Hardwoods). Using this scoring system, 90% of LS and older stands were correctly identified as being LS stands or old-growth. Ten percent of all stands were assigned to the wrong age class (categorized as LS when they were not, or categorized as not LS when they were).

For upland spruce-fir, we followed the same procedure to create the LS Index. Again, large-tree density contained most of the explanatory power, so large tree-density was weighted more heavily than density of trees with long *Usnea* spp. We weighted the spruce-fir variables in the Index in the following way: large-tree density accounts for 9 of the possible 10 points, and density of trees with long *Usnea* spp. accounts for 1 point (see Insert: LS Index: Upland Spruce-fir). Based on this scoring system, 85% of LS and older stands were correctly identified as being LS stands and 15% of stands were assigned to the wrong age class.

Table 3. Statistically significant candidate indicators of LS forest, and their r^2 values for northern hardwoods and upland spruce-fir forest 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. Although the lichen indicators, Collema/Leptogium *spp. and long* Usnea *spp., perform poorly by themselves, they explain significant additional variation when added to large-tree density.*

	Northern hardwoods		**Upland Spruce-fir**	
Candidate Indicators	**r^2**	**DFA partial r^2**	**r^2**	**DFA partial r^2**
Tree Basal Area	0.204	-	-	-
Large tree density	0.497	0.497	0.657	0.657
Large tree basal area	0.507	-	0.611	-
Large log density	0.222	-	0.186	-
Sum of large log lengths	0.282	-	0.211	-
Total large log volume	0.257	-	0.177	-
Density of trees with *Collema/Leptogium*.	0.001	0.071	-	-
Density of trees with long *Usnea* spp.	-	-	0.013	0.14

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 and density of trees with one or two lichen species. 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. What is new here is that this simple variable is derived from a large and complex data set. Conveniently, this variable is also very powerful at identifying late-successional forest. Additional discriminatory power comes by adding the density of trees with *Collema/ Leptogium* spp. or *Usnea* spp. These lichens may add power to the model because they are indicators of ecological continuity. Continuity refers to the persistence of big trees and big logs in a forest stand over a very long period of time (centuries), even though the stand might be subjected to many different disturbances, such as fire, wind, disease, or even selection logging. The lichens thus contribute to assessing the ecological history/age of the stand. Together, large-tree density and these three lichens do a remarkable job of identifying LS forest.

Lichens may seem to be an obscure, "unfriendly" taxonomic group upon which to base a field tool designed for foresters. However, foresters only need to know these three easily-identified genera (*Collema/Leptogium* and *Usnea*). Moreover, lichens can be identified year-round (unlike herbaceous plants), and they "stay put," unlike vertebrates. 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 built for northern hardwood and spruce-fir forest in Maine, the same process we used to build our indices could be used in 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 it does not have to be in order to yield significant conservation gains in LS conservation and management.

How would a forester put the LS Index to use?

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. If the score is high (≥ 8), we recommend that the harvest prescription be adjusted to target LS attributes (big trees or trees with the indicator lichens) for retention or not harvesting 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 harvesting 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. This would allow land managers to begin to quantify this particular component of biodiversity for sustainable forestry certification. We are in the process of converting the stand-level LS Index to a landscape level index.

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 late-successional 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 Maine.

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