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Development of stand structural stage indices to characterize forest condition in Upstate New York

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Abstract

Stand development stages are often used to describe temperate forest dynamics, but defining them using stand history or age can be difficult, especially for extensive surveys. The purpose of this study was to define stand development stage indices for forest stands on state forest land in Upstate New York using stand structure alone. A total of 508 stands were sampled, including 442 in Upstate New York. Two structural stage indices were defined for each of the 442 stands. The first index, based on SILVAH, was calculated using weighted mean diameter of trees in different size classes. The second index, based on work from Frelich and Lorimer, was calculated using the ratio of basal area of large trees to mature trees and either (1) exposed crown area (ECA) of trees in different size classes, or (2) basal area of trees in different size classes. Both indices were tested on stands with known stand histories. The second index was preferred for its superior ability to distinguish old-growth stands and was used to characterize structural stages of major forest types in Upstate New York: hemlock–hardwood (9% of state forest land), red spruce-fir (16%), and northern hardwood (51%). Results showed that the vast majority of stands in Upstate New York are in the mid-developmental stages. Structural characteristics of old-growth stands from this study were found to be in agreement with other old-growth stands in the northeastern United States.

Keywords: Forest stands; Forest dynamics; Stand development stage index; Structural characteristics; New York; Northern hardwood; Hemlock–hardwood; Red spruce-fir; Old-growth

1. Introduction

Developmental stages are a response to natural and anthropogenic disturbances, and are shaped by various rates of regeneration, growth, and mortality (Rubin et al., 2006). Each stand development stage has a host of associated processes and characteristics that create a distinct environment to which species respond. For example, the high nutrient and light availability that occurs after a stand has been clear-cut promotes rapid growth and establishment of ruderal herbs and early successional tree and shrub species (e.g., *Rubus* spp. and *Prunus pensylvanica*) (Mark, 1974). Stand structural characteristics may influence the animal, lichen, or the microbial community within a stand (Hansen et al., 1991; Halpern and Spies, 1995). Forest development stages have been used to represent unique levels of structural complexity for studying animal or plant communities (Carey and Johnson, 1995; North et al., 1999). At the landscape level, assessing stand development stages could be important for maintaining biological diversity. Different species may depend upon one or more stand development or structural stages; thus, preserving a mosaic of stands in each stand development stage may be necessary to protect biodiversity (Lorimer and White, 2003; Spies and Turner, 1999).

Two of the best known stand development models, that of Oliver and Larson (1996) and Bormann and Likens (1979), identify unique structural and functional characteristics of each developmental stage. Both models are similar in that the initial stage is structurally simple, with new trees establishing after a major disturbance, and progress to become more structurally complex with time. Several recent studies have shown that structural characteristics are unique among developmental stages (Tyrrell and Crow, 1994; McGee et al., 1999).

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Forest stands are often placed into development stages based on age, structural, or functional characteristics. Although stand age is an accurate way of establishing developmental sequences, its use for general surveys can be limited by time constraints and the difficulty of counting rings from trees with hollow cores, a problem often encountered in stands of advanced ages. For this reason, developmental stages based on stand structure are also used. However, validation of the link between structural features and developmental stages is critical.

We assessed two indices for defining stand development based on stand structure characteristics. The first index, referred to as SILVAH, was developed by the U.S. Forest Service to help prescribe silvicultural treatments for stands in the Allegheny region. SILVAH uses commonly measured parameters, i.e., diameter at breast height (dbh) and basal area, to calculate the mean diameter of the stand weighted by basal area (Marquis et al., 1984). The advantage to the SILVAH index is its simplicity and that it weights tree size class by basal area to account for the large trees within a stand. However, defining a stand stage using only average diameter works best for even-aged stands, which typically fall into the early to mid-development stages of Oliver and Larson (1996). Therefore, SILVAH appears to be applicable for stands immediately after a major disturbance or under even-aged management practices.

The second index we assessed to define stand stage using structure was developed by Frelich and Lorimer (1991) to help study natural disturbance regimes of hemlock–hardwood forests in three wilderness areas of Upper Michigan. They defined stand development stages using exposed crown area (ECA). The advantage to Frelich and Lorimer's index is its applicability to stands under a range of natural disturbance regimes. Unlike the SILVAH index, Frelich and Lorimer base their stage not on the tree size class with the average ECA, but on the percent of the total stand ECA in four tree size classes. Frelich and Lorimer's approach allows interpretation of the dominant tree size in multi-aged stands and allows classification into all of Oliver and Larson's (1996) stages. A disadvantage to this approach is that ECA is not commonly measured in the field.

While the ECA and SILVAH stand stage indices have disadvantages, modification of both methods could create a relatively simple, ecological index for defining stand development stages based on stand structural attributes. The objectives of this study were to (1) compare and test these two approaches of defining stand development stages on Upstate New York state forest lands, (2) use this information to find the percent of these forest lands in each structural stage, and (3) characterize the features of each structural stage of major forest types. This study provides a basis to which future forest assessments of the proportion of land in each stand structural stage can be compared.

2. Study area

The study area chosen was the public state forest lands of New York. This large area spans many physiographic provinces that differ in geology and geologic history, including bedrock formation, plate tectonics, and glacier coverage (Van Diver, 1985). Sandstone, silt, and granite are the predominant rock types in upstate New York (Cline and Marshall, 1992). The Wisconsin glaciation extended throughout the state, except for part of Allegany State Park in the southwest, leaving behind many typical features of glaciation on soil and landscape properties.

The elevation in New York ranges from sea level to the highest peak in the Adirondacks, Mt. Marcy, at 1628 m (5340 ft), with 60% of the State at an elevation of less than 305 m (1000 ft) (Pack, 1978). For most of New York, summer temperatures generally do not exceed 30 °C (86 °F), with the coolest temperatures in the mountainous Adirondacks region (Garoogian, 2000). Number of growing days in New York varies from 103 to 203 days (Daly and Taylor, 2000). Areas in upstate New York with the most growing degree days are in the western and northern parts of the Erie-Ontario Plain and southernmost part of the Hudson Valley.

Average annual precipitation ranges from more than 127 cm (50 in.) in the Tug Hill and Catskills to less than 89 cm (35 in.) near Lake Ontario in western NY and near Lake Champlain (Garoogian, 2000). About 60% of the state receives at least 177 cm (70 in.) of snowfall annually with the most in the Tug Hill and in the western section of the Allegheny Plateau region and the least in the Long Island Coastal Plain (Garoogian, 2000).

New York lies in several forest regions defined for eastern North America by Braun (1950). The Allegheny Plateau and the Adirondacks are a division of the hemlock–white pine–northern hardwood region. The Erie-Ontario Plain is in the beech–maple region. Finally, southeastern New York is the glaciated section of the oak–chestnut forest region. The forest type that predominates throughout upstate New York is the maple–beech–birch forest type (northern hardwoods), although hemlock–hardwoods, spruce-fir forests, and oak forests are also common (Armstrong and Bjorkbom, 1956).

3. Methods

3.1. Field procedures

Field site locations for 508 stands were randomly selected and distributed throughout public state forest lands under the jurisdiction of the New York State Department of Environmental Conservation (DEC), as part of a comprehensive forest health survey (Fig. 1) (Manion et al., 2001, 2002, 2003). The total area included in the survey was 16,627 km^2 (4,106,869 acres). Stands were sampled between May and August of 2000–2002. Selected (primary) points were assigned a set of geo-coordinates (latitude, longitude). Additional (secondary) points were also selected, so that if the primary set of coordinates could not be reached (i.e. the coordinates were found in a private forest or in a body of water) or did not have at least two trees greater than 8.9 cm dbh, the secondary set of coordinates was used instead. In the field, a DeLorme Street Atlas computer program (DeLorme, 1997) on a laptop