Long-term Monitoring of Stand Development after Selection System Silviculture in Uneven-aged Northern Hardwoods of New York State

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Background

Selection system silviculture in uneven-aged stands can meet a variety of objectives from timber production to maintenance of non-commodity values, including wildlife habitat and a continuous cover of large trees. Cutting cycles occur at regular intervals, generally between 10 and 25 years, in order to sustain consistent structural conditions and improve tree growth and stand quality. At each cutting cycle, removal of large trees creates space for regeneration, and tending within the younger age classes equalizes competition. The residual stand is structured so that each age class occupies an equal area of growing space and trees of all ages are uniformly interspersed throughout the stand. Since tree age and size are correlated in uneven-aged northern hardwoods, a target diameter distribution is used to structure the stand (Nyland 1998). A suitable target diameter distribution for northern hardwoods was first identified in the upper Lake States by Eyre and Zillgitt (1953) and later described by Arbogast (1957). This provides a means for consistent production when the cutting intensity is matched to an appropriate cutting cycle length (Hansen and Nyland 1987).

Although uneven-aged silviculture traditionally has received less attention than even-aged silviculture, there has been a growing interest in this type of management with shifts to a more ecosystem-based approach to practicing forestry. Important information about the outcome in northern hardwoods has come from continuing US Forest Service research in the upper Lake States and studies in New England. In addition, long-term monitoring began during the early 1970's at SUNY-ESF in nine uneven-aged stands in New York State. Changes in stand structure and species composition have been monitored over two cutting cycles.

The Sites

One set of study sites is located on State Forest lands in Cortland County, NY, and another at the Huntington Wildlife Forest in Essex and Hamilton Counties, NY (Figure 1). The Southern Tier sites are located along the upper edge of the Allegheny Plateau in central NY, on lands managed by the New York State Department of Environmental Conservation (DEC). Huntington Wildlife Forest is located within the Adirondack Mountains and is managed by SUNY College of Environmental Science and Forestry.

The central NY sites had originally been farm woodlots that received an unspecified number of undocumented partial cuts prior to ownership by the NYS DEC. Then their foresters did light improvement cutting (1950's) prior to the formal selection system treatments that we implemented beginning in the early 1970's. The stands had trees as old as 150 years of age at the time of the first research cutting, and contained multiple age classes.

Adirondack sites had originally been uneven-aged old-growth stands with a component of trees that dated to the late 1700's. Each received some kind of partial cutting (late 40's, mid-50's, or late 60's) prior to the selection system trials. Two of the sites also were used for experiments with site preparation to reduce understory beech that interferes with regeneration of more desirable species. Adding that treatment made the stands unique among experiments with uneven-aged silviculture, in that ingrowth of new trees must restock the younger age classes (e.g., trees <4 in. dbh), and each cutting must also manage the older ones in accord with selection system principles.

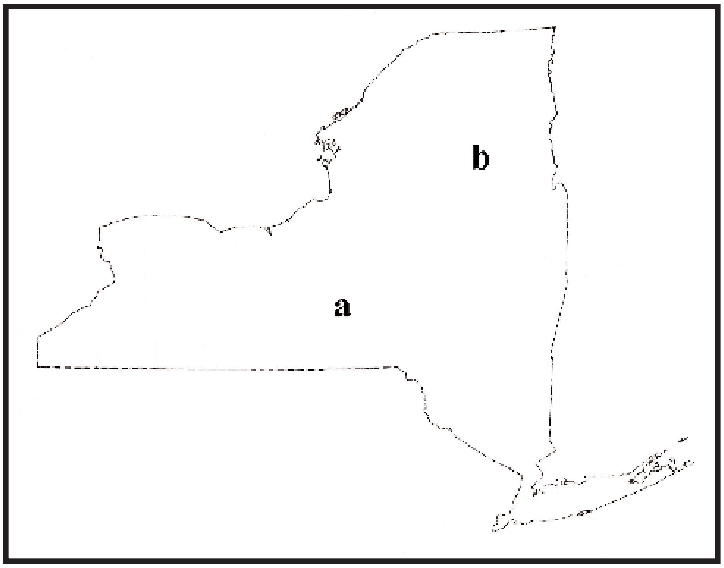


Figure 1. Study sites were located at: a) Cuyler Hill State Forest in Cortland County and b) Huntington Wildlife Forest in Essex and Hamilton Counties, NY.

Forest types at both locations are classified as northern hardwoods. The species composition of all the age classes consists of primarily sugar maple (*Acer saccharum* Marsh.) and American beech (*Fagus grandifolia* Ehrh.). Both locations experienced heavy mortality of pole- and sawtimber-sized American beech as the killing front of beech bark disease moved through the region (mid-60's in the Adirondacks, and late 70's in central NY). At the central NY sites white ash (*Fraxinus americana* L.) and black cherry (*Prunus serotina* Ehrh.) comprise a minor component of the large and mid-sized trees, while in the Adirondacks yellow birch (*Betula alleghaniensis* Britton) is present in the overstory. Eastern hemlock (*Tsuga canadensis* (L.) Carr), red maple (*Acer rubrum* L.), striped maple (*Acer pennsylvanicum* L.) and eastern hophornbeam (*Ostrya virginiana* (Mill.) K. Koch) are also present at both sets of sites.

When long-term studies were begun in the early 1970's in Cortland County, and in the 1980's at Huntington Wildlife Forest, permanent plots were established along a grid system in each stand. These plots have been periodically remeasured to monitor regeneration and growth responses (Table 1). Data had been collected prior to the cutting treatments and at regular intervals between cutting cycles. Each of the stands under investigation either had one or two selection system treatments to date, though of varying intensity.

Within the stands we maintain a combination of permanently located point samples (BAF-10 prism) and fixed-radius plots. This framework provides a temporal continuity in the monitoring. For a subset of the former and in all the fixed area plots we number the trees by hanging a tag from an aluminum nail set in the tree at 1 ft above the ground. This provides a permanent reference point for dbh without damaging the cambium and inducing callus formation at the measurement point. We have periodically recorded the condition of each tree, as well as its species and diameter. By standardizing the remeasurement work by starting at

Site	Year Plots Established	Data Collected	Re-measurement Intervals (yrs)
Cuyler Hill	1973	Basal area- variable radius plots	3 –5
		Regeneration tallies- milacre plots	5
		Diameters of tagged trees	5
Cuyler Hill	1980	Density- nested, fixed area plots	5
Huntington	1986	Basal area – variable radius plots	10
		Regeneration tallies- milacre plots	10

Table 1. Remeasurement information and frequency of data collection.

north and moving clockwise around the point or plot we can keep track of unnumbered trees in most cases. That provides a consistency in the organization of our electronic data base, and allows us to track changes in the size and condition of each sample tree.

Stands also have permanent milacre regeneration plots centered at the point and plot centers. On these we track the numbers of trees by height class and species up to 1.0 in. diameter, and take the dbh and species of larger trees. Historic records indicate the surface condition and surface objects at each of these milacres following the first entry to the stands. In some stands we have also used the plot locations as a framework for inventorying the abundance of coarse woody debris, cavities and snags, and the composition and abundance of herbs. Current research is also documenting the abundance and species of lichens on the tree trunks and in the crowns of the larger trees.

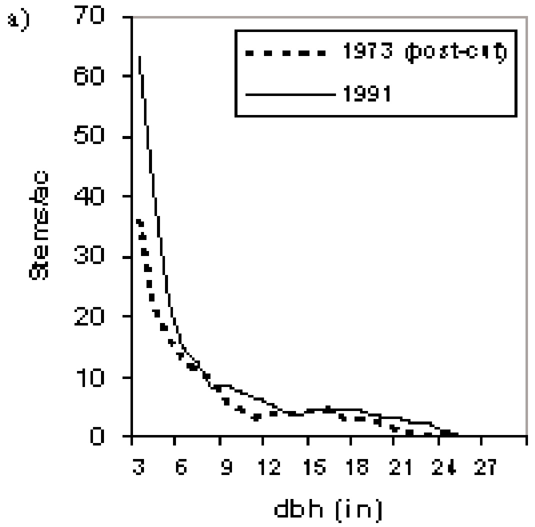
Major Findings

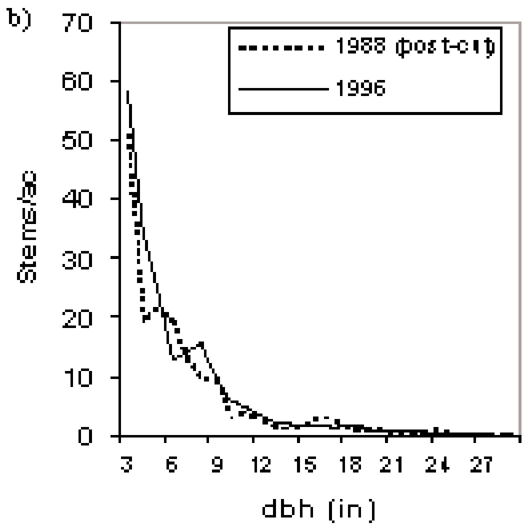
Some Past Findings and Uses

Early studies associated with plot establishment evaluated effects of timber harvesting on soil and residual tree conditions, the composition and abundance of songbird communities using the stands, and directional felling and pre-cutting skid trail layout on logging efficiency (Nyland et al. 1976). Sites at both locations have provided opportunities for field trips for classes from SUNY-ESF and other forestry programs, and for continuing education workshops dealing with silviculture and wildlife habitat management. They also have served as sites for several graduate student thesis research projects that evaluated regeneration responses and stand structure dynamics (Mader 1981, Savage 1990), wildlife habitat structure (Kenefic 1995, Quinlan 1996), stand visual qualities (Hoffman 1997a), sapling growth and ingrowth (Donoso 1998), and understory beech responses (Bohn 2001, Mallett 2002). Findings from those studies were integrated with later research to provide a broad and continuing picture of the outcomes from selection system cutting in uneven-aged northern hardwoods.

Diameter Distributions

One of the original intents of establishing permanent plots was to identify whether selection system silviculture would lead to a stable diameter distribution and consistent levels of production in the stands. Conceptually, the residual diameter distribution after cutting should optimize the ratio between trees of different sizes so that accelerated growth occurs on trees of all ages. Over time the diameter distribution should essentially shift to the right without becoming distorted as all trees increase in size.





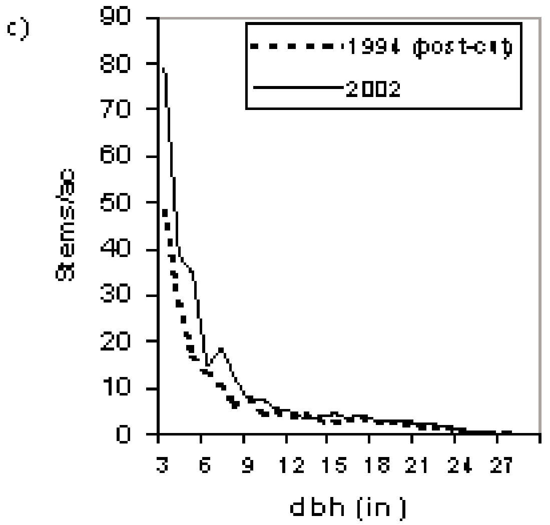


Figure 2. Development of the diameter distribution after an initial selection system treatment at a stand in: a) Cuyler Hill State Forest and b) Huntington Wildlife Forest; and c) after a second selection system treatment at Cuyler Hill.

This shift in the diameter distribution has been observed after the initial selection system treatments at both the central NY and the Adirondack sites (Figures 2a and 2b). In addition, cutting stimulated the ingrowth of trees to the sapling class (Donoso et al. 2000) and the growth to larger sizes among the bigger saplings and poles. This helped to even out some previous deficiencies in the sapling and pole classes. Development of the desired diameter distribution continued in a predictable fashion after the second selection system cut (Figure 2c). Production rates averaged 2.5 ft^2 basal area/ac/yr at the sites cut to a residual basal area of 70-80 ft^2/ac associated with a 15-yr cutting cycle. Board-foot production reached around 300 bd ft/ac/yr during the first cutting cycle (maximum merchantable height of 2.5 usable sawlogs in the larger sawtimber trees).

Stand development at these sites indicates that at each cutting cycle an equivalent amount of board-foot volume can be removed, and from trees having the same range of diameters. The stand can also be restructured back to the target residual diameter distribution (they remained stable), and the yield should be equal to the amount produced during the growth interval. As long as regeneration and ingrowth are maintained, the diameter distribution will remain stable and predictable, with selection system silviculture providing consistent yields and consistent ecological conditions through multiple entries.

Species Composition

Uneven-aged stands tend to promote shade-tolerant species such as sugar maple and American beech. Over the last decades, American beech lost much of its commercial value after becoming infected with beech bark disease. Also, the large pole and sawtimber trees died. However, evidence from a broad geographic region suggests that it is becoming a more dominant component of the understory in many stands (Twery and Patterson 1984, Ostrofsky and McCormick 1986), interfering with the regeneration of commercially valuable species like sugar maple (Nyland et al. 2006). Where that has occurred at our sites, we see the same result. However, when we controlled the understory beech, and also had low deer density, desirable species regenerated after the selection system cuttings.

Regeneration data from selection system stands in Cortland County and the Huntington Wildlife Forest were used to evaluate the development of understory beech and other species 10 years after the cutting treatments. Changes in the importance of a species in the understory were estimated using an index value based on the relative abundance and heights of stems less than 5 in. dbh (Bohn and Nyland 2003). Beech was more likely to increase in dominance after cutting when already present in the understory at moderate to high levels (an importance value of 40% and greater). Changes in importance values tended to occur because of better height growth among the well-established beech compared to other species, and due to shading by its dense foliage. Beech importance did not change when saplings of the species were not present in the understory, or where they already were the dominant understory species. This is likely due to the fact that most understory beech had a sprout or sucker origin, and the lateral spread of beech by this regeneration mechanism is slower than the 10-yr time period used to evaluate changes in species composition.

Findings indicate that site preparation should be considered for stands having advance regeneration of beech at moderate to very high levels. Treatments can range from broadcast application of glyphosate, to individual-stem herbicide injection (also glyphosate), or manual cutting (Nyland et al. 2006). The most appropriate treatment depends on the density of stems, size of treatment area, and the patchiness of a beech understory across the stand. Site preparation treatments to remove understory beech at our sites must be further monitored to confirm the long-term outcome with respect to the species composition of new age classes. However, short-term observations indicate that removing the understory beech dramatically improved species diversity within the most recent cohort.

Current Studies

Although the effects of silvicultural treatments may take decades to truly play out, advances in technology and our understanding of forest dynamics are rapidly developing. Interest in the effect on ecological and social values after silvicultural treatments has increased as well. The availability of long-term data documenting silvicultural treatments allows us to investigate these evolving interests without having to wait long periods for post-cutting vegetation responses to show the effects. Our ever-expanding data base also provides an historic record of previous stand conditions so we can reconstruct the actions and factors that triggered favorable responses. In addition, we can use the data with emerging kinds of analytic techniques, both to explore the benefits of those methodologies and to take advantages of the new kinds of information that they provide. To that end, several new studies have begun to use these modern analytical tools to assess effects of selection system on stand dynamics and an array of non-commodity values, and to evaluate the continuity of structural characteristics developed through selection system silviculture.

Visual Qualities

Increased public concern about forestry practices has led to a greater awareness of the effects of silviculture on the visual qualities of a stand after logging. Availability of the well-documented selection system stands, and nearby plots under other management strategies, provided opportunities for such investigations. To illustrate, Hoffman (1997b) and Hoffman and Palmer (1996) used on-site interviews and assessment of photographic images from the stands to measure reactions of observers to the post-logging appearances, and through time afterward. They found that viewers reacted most negatively to stumps, logging slash, and exposed mineral soil. Yet perceptions changed appreciably with time as understory development, newly fallen leaf litter, and decay of unused tree tops mitigated the obviousness of those elements. The high degree of vertical structural diversity that develops after selection system cutting also reduces visibility through an uneven-aged stand. Further, the interspersion of large and small trees in a managed uneven-aged stand, and the sense of orderliness created by the uniform spacing between and within the different age classes, enhance the reaction of viewers to the selection system stands.

Spatial Pattern

In addition to structuring the diameter distribution, another aim of single-tree selection system is to maintain uniform spatial distribution of all sizes of trees across a stand. In recent decades, improved methods of quantitative spatial analysis have become more prevalent for assessing spatial distributions of plants. We initiated a study at the central New York sites to evaluate the degree that selection system has enhanced the spatial distribution of residual trees.

Trees were mapped on several 2-ac plots, and point pattern analysis was used to assess whether the residual trees were clumped, random, or uniform in spacing. Spacing of sawtimber (trees >/= 12 in) in treated stands was uniform (Figure 3), though more so for the stand that had received two cuts than those with only one cutting treatment. Among poles (trees 6 – 11 in) tree spacing was random, and saplings tended to be clumped (Figure 3). The patterns observed to date do not differ from those among equivalent size classes in unmanaged, uneven-aged stands (Mouer 1993, Chokkalingam and White 2001).

Selection cutting maintained or slightly enhanced the uniformity of spacing among the larger trees. But tending within the pole classes has been limited to date, primarily due to initial stocking deficiencies in those size classes. These shortages among poles allowed only some cutting to reduce localized crowding, which had little stand-level impact on spacing of trees less than sawtimber size. Future monitoring will indicate if this changes as ingrowth to poles increases the stocking of trees between 6 and 11 in. dbh, and as future selection cutting includes new opportunities to tend the pole classes.

Stem maps from these stands are being used in a simulation experiment to see if pole stocking does increase and if eventual tending of those trees changes in spatial structure over multiple cutting cycles. In addition, research is comparing the changes in spatial conditions after a series of diameter-limit cuttings in stands having a comparable initial diameter distribution and level of stocking. This will provide a helpful comparison of that cutting strategy to selection system silviculture.

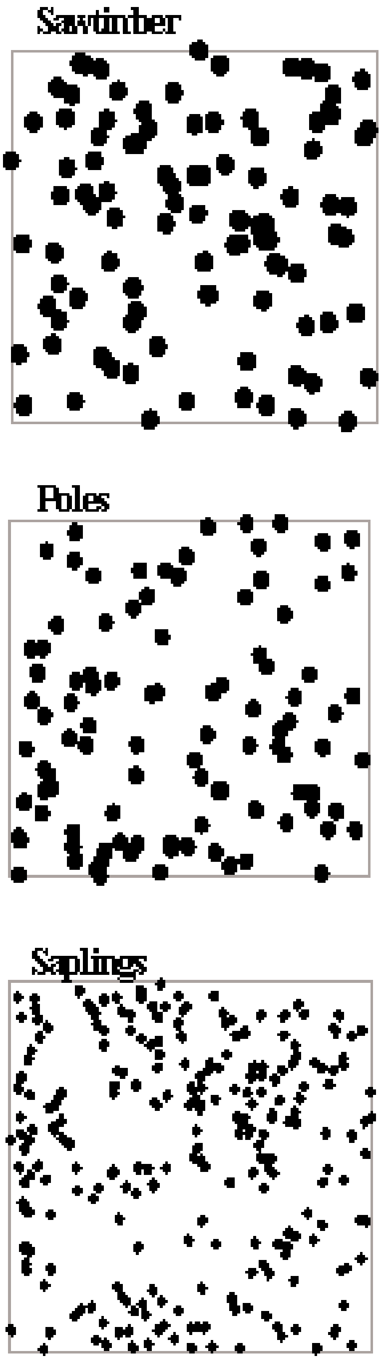


Figure 3. Spatial pattern of residual trees after of selection system silviculture.

Growth modeling

Other past work with selection system at SUNY-ESF led to development of a simulator to predict changes in tree diameters and abundance following cutting to a range of residual stand densities associated with cutting cycles that range from 10 through 25 years (Hansen and Nyland 1987). Findings showed the effect of matching the level of residual stocking with the cutting interval to optimize volume production, and reinforced the importance of regulating the diameter distribution in order to maintain structural stability within a stand.

Current research has begun to update the original selection system stand simulator by using remeasurement data from long-term monitoring of the permanently documented stands in central New York and the Adirondacks. This research will incorporate recent advancements in using competition indices as a growth modifier, and it will also update the ingrowth and mortality functions based on long-term sample tree and regeneration tallies. Growth modeling in uneven-aged northern hardwoods has been limited to date, so the simulator will provide a unique opportunity to explore the potential effects of uneven-aged silvicultural practices. The enhanced simulator will then provide opportunities for additional studies of the production potential of uneven-aged silviculture, and of financial analyses targeting long-term volume production from stands under selection system.

Completion of the simulator will also allow other kinds of research. This will include using information about changes in tree sizes and abundance, along with other attributes of the tree and herbaceous plant community, to explore effects of different selection system alternatives on the habitat for selected groups of wild animals. The work will also integrate findings from other studies that are currently evaluating uneven-aged stand structural features like herb community abundance and diversity, abundance and distribution of coarse woody debris, presence and development of snags and cavity trees, and other features important to wildlife. Assessment of understory responses (tree regeneration) will update findings reported earlier by Mader and Nyland (1984), and allow us to determine how the development of new trees alters conditions for animal species that depend on low vegetation for satisfying some of their life requirements.

Future Plans

Selection system silviculture places much emphasis on the residual structure of stands in order to ensure consistent production and stable ecological conditions between cutting cycles. Findings from stand monitoring during one to two cutting cycles over the last 30 years indicate that the diameter structure can be controlled. These stands are due for a second or third cutting treatment within the next few years, and monitoring will continue to follow impacts on structure, composition, and the effects on wildlife habitat and other non-commodity values. As additional data become available from continued monitoring of the plots, research can begin to explore additional effects of selection system cutting. These might include an assessment of ecologic consequences of several kinds, of carbon sequestration, of effects on hydrologic conditions, and additional evaluations of visual qualities and other non-market values attributed to uneven-aged northern hardwood stands.

The long-term value of permanent research sites like these, and the research we can link to them, depends on continuity of purpose, approach, and funding. Limiting plot installation to lands under the jurisdiction of a university or public entity minimizes chances that a change of landowner objectives might result in a loss of the plots. Also, having a well-defined set of objectives helps to guide decisions about plot maintenance and moving ahead with any new or supplemental treatments. Yet the program must often flex with time to accommodate new questions for research and new approaches to data gathering, even while preserving a continuity of conditions essential to the long-term purposes for the monitoring.

In all cases, permanency also depends on continuity of leadership. Organizations dedicated to silvicultural research may provide continuity by their organizational structure and long-term program plans, and by their policies for assigning work responsibilities to new personnel after others retire or move. In most cases, leadership by committed individuals also seems critical to ensuring timely remeasurement and maintenance of the research areas and the data derived from them. That has been at the center of the legacy silvicultural plots developed at SUNY-ESF, where any research program depends upon interests of individual faculty members and whether they have a commitment to a long-term monitoring program like the one dealing with uneven-aged silvicutlure. In our case, the future of the legacy silviculture plots depends on eventually having a new faculty member take an interest in the program and assume responsibility for it. It will also depend on an administrative commitment to dedicate at least part of a permanent technical staff member to work with the program and help oversee the field work and data base management.

In many cases, a university can provide no assurance of recurring internal funding to maintain permanently-documented plots or implement regular monitoring of silvicultural responses on them. That has been true at SUNY-ESF. Rather, we depended on grants from outside sources to support a line of research that drew on the permanent plots, and integrated plot maintenance with data gathering for work to satisfy the objectives for each separate research project. This introduced some variation in the frequency of remeasurement work at specific sites, but has still allowed us to maintain a basic set of data that documents long-term changes in stand conditions in response to the treatments.

As funding sources continue to redirect important amounts of their support to more politically popular projects and those offering a short-term payback, funding for long-term monitoring programs like ours will become more difficult to obtain. We've seen that trend in recent years, and expect it to continue in the years ahead. So even given a commitment by the College to pay salaries of a faculty member and a technical assistant who will work with the legacy silvicultural plots, the future of our long-term monitoring program depends on developing creative approaches to ensure regular funding as needed for fieldwork costs.

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