Dynamics of Connecticut Hemlock Stands

Jeffrey S. Ward [1] *and David M. Smith* [2]

Abstract

The stand dynamics and production of two one-acre plots of eastern hemlock (*Tsuga canadensis* L) in Connecticut have been followed for more than six decades. Data were recorded for all individual trees. One plot (Saltonstall) was established in 1924 after the removal of a hardwood overstory. This stand had a nearly pure, almost fully closed understory of hemlock that was subjected to partial cuttings in 1936, 1954, and 1956. The stand was lost to the hemlock woolly adelgid (*Adelges tsugae*) in 1993. The other plot (Perry) was established in 1931 in a nearly pure hemlock stand that had arisen on an abandoned pasture around 1850. This plot had a crop-tree release cutting in 1931 and has not been infested with hemlock woolly adelgid.

Both plots developed a rotated sigmoid diameter distribution, characteristic of uneven-aged forests, after sixty years of management. The 1936 attempt at group-selection cutting in the Saltonstall plot did not maintain the reverse J-shaped diameter distribution that had initially existed. The stand was essentially even-aged and the diameter distribution shifted to a broad bell-shaped form and then to a rotated sigmoid curve when a new age class grew large enough to be included in the tally. The thinning of the Perry plot also turned the initial bell-shaped diameter-distribution curve to the rotated sigmoid form for the same reason. Annual periodic increment (including harvested volumes) was 52 and 50 cubic feet/acre for the Saltonstall and Perry plot, respectively. Annual basal area growth decreased from over 3 ft^2/acre to approximately 2 ft^2/acre on both plots over sixty years. These findings indicate that hemlock is capable of rapid growth with stand management. Implications for managing hemlock forests are discussed.

Introduction

Eastern hemlock is an important component of northeastern and Appalachian forests, often forming nearly pure stands. Although hemlock can be found from ridgetops to swamps, best development in southern New England is on moist, fertile soils with a northern aspect. The dense evergreen cover provided by hemlock is a critical habitat for many species, and is fully as important as wood production.

Hemlock woolly adelgid was first reported in Virginia in 1951, in Connecticut in 1985 and has since spread to at least eleven states (McClure[3], pers. comm.). The unique ecological and esthetic values provided by hemlock stands are lost when these stands are replaced by hardwoods such as red maple and yellow birch. Once an effective biological control for hemlock woolly adelgid is realized, it will be feasible to reestablish hemlock in critical habitats. Thinning stands to accelerate growth should decrease the time required to achieve stand characteristics (biomass, coarse woody debris, canopy cover, etc.) typical of mature stands. This paper will summarize the effects of two long-term thinning studies in nearly pure hemlock stands on biological (diameter and species distribution, basal area) and economic (commercial volumes) attributes.

Study Plots

Detailed records of more than sixty years of development and production by nearly pure stands of eastern hemlock are available from two rather different plots in Connecticut. Stand ages were determined from increment cores. Cubic-foot volumes (Scott 1981) were determined using minimum top diameters (outside bark) of 4 inches. Board-foot volumes (Scott 1981) were determined using minimum top diameters (outside bark) of 7 and 9 inches for conifers and hardwoods, respectively.

Perry

The older of the two stands was the Perry plot (one acre) established in Tunxis State Forest in East Hartland, Connecticut in 1931. The stand appears to have arisen on a pasture during the 1850s and browsing by sheep or cattle had greatly reduced the hardwood species. In 1931 the stand was predominantly hemlock (74% of basal area) with minor components of maple (15%), birch (9%), and northern red oak (1%). The site is located on a very rocky loam soil, a Lithic Dystrochrepts of the Holyoke series on a gentle to moderate slope.

In 1931, at an estimated age of 81 years, a crop-tree release thinning was done to enhance the growth of residual hemlocks. Selection criteria for crop-trees were not stringent, "the best trees, which promised to make the final crop." Crop-trees trees were banded with blue paint at dbh (4.5 ft). Diameters at were recorded to the nearest 0.1 in and heights were recorded to the nearest 1 ft for all crop-trees. All other trees > 0.5 in dbh were tallied by species in 1 inch classes. Trees that were cut to release crop-trees were also tallied by species and 1 inch classes. The thinning removed 40 ft^2/ac and left a residual stand with 143 ft^2/ac. Measurements were repeated in 1935.

The plot was reestablished in 1994. Original plot corners (iron pipes) were relocated and crop trees were identified by faint paint bands. All trees (> 4 inch dbh) were numbered, mapped. Diameters were measured in 1994 and 1998. Tree heights were measured in 1996 along with sawlog and pulpwood heights. Although the plot was

[1]The Connecticut Agricultural Experiment Station, Department of Forestry and Horticulture, P. O. Box 1106, New Haven, CT 06504

[2]Yale University, School of Forestry and Environmental Studies 360 Prospect Street, New Haven, CT 06511

[3]McClure, M.S., Valley Laboratory, The Connecticut Agricultural Experiment Station, Windsor, CT 06095

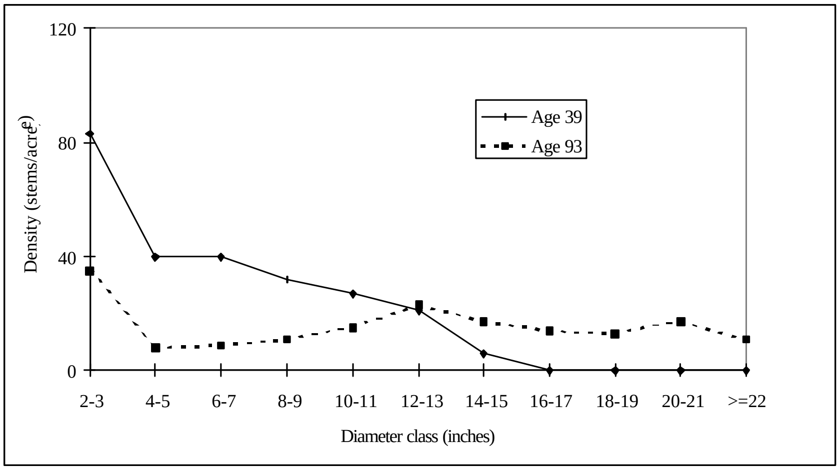

Figure 1.—Diameter distribution of trees Saltonstall hemlock plot in East Haven, Connecticut in 1939 (stand age 59) and 1993 (stand age 113).

thinned for fuelwood between 1975-1990 by removing some poles and culls, exact tallies have been lost. Therefore, estimates of volume removed during this period was accomplished by measuring stumps.

Saltonstall

The second plot, Saltonstall, was established in 1924 on an acre of hemlock forest in East Haven, CT. Every tree was numbered and measurements of total height and diameter were recorded. Subsequent measurements were made at intervals of 2-13 years. Hardwoods were not tallied until 1939. The hemlock had been the understory of a stratified mixture that had started from advanced regeneration left by a complete cutting about 1880. Chestnut was killed by the blight in 1913 and virtually all the oak and other hardwoods were harvested in 1923. The stand was on a steep slope below a basalt ridge on a mesic sandy loam soil, a Lithic Dystrochrept of the Holyoke series. During the post-World War I housing boom the prices of hemlock construction lumber had become high. That, and the good volume growth of hemlock, made the conversion to a hemlock monoculture seem desirable. There was also the purpose of testing the view that the previously suppressed hemlock would not die of exposure, but respond vigorously and promptly.

Results and Discussion

Diameter distribution

During the 1930s the concept of the all-aged selection forest was fashionable. Many of its advocates claimed that tree diameter was an effective operational surrogate for age (Meyer 1952). This theory stated that reverse J-shaped distribution curves defined the stand dynamics of a functionally all-aged condition and could be used to guide the management of such stands. Therefore, if one periodically removed trees above some guiding diameter limit and thinned the smaller ones in patterns that preserved the reverse J-shaped curve, subsequent diameter growth would maintain this diameter distribution permanently. It was assumed that large numbers of new seedlings would automatically start after each cutting, grow up to breast height and continually provide the large numbers of saplings needed in smallest DBH classes.

In 1936, the late R.C. Hawley instituted a test of the idea of treating the Saltonstall stand as if it were all-aged because it had a reverse J-shaped curve (Fig. 1). To this end, a group-selection cutting was made in 1936. In this case, none of the postulated developments took place. The small trees, which were supposed to grow fast, died of suppression in large numbers and the larger trees grew rapidly. Enough new hardwoods had developed by the time of the final 1993 measurement that the diameter distribution curve began to shift to the form of the rotated sigmoid curve (Fig. 1).

The Perry plot was initially managed under an even-aged system. Crop-trees were selected in 1931 with a view to maximize growth of existing trees with no provision for regeneration. Perry had a normal diameter distribution typical of even-aged stands in 1931 (Fig. 2). Although unintended, regeneration quickly established in the openings created by thinning, and grew into the smaller diameter classes. The influx of trees in the smaller diameter classes and growth of trees into the largest diameter classes shifted the diameter distribution of the Perry plot towards a rotated sigmoid curve by 1995 (Fig. 2).

Results of this study suggest that a rotated sigmoid curve will develop in partially cut hemlock stands regardless of the initial diameter distribution. Thinning encouraged the development of a rotated sigmoid through two mechanisms. First, thinning created openings where regeneration established and developed. This increased the density of small diameter trees. Second, released hemlocks grew faster in diameter in response to thinning and suppressed growth of other trees. This increased the density of larger diameter, and depressed the density of mid-diameter trees.

Species composition

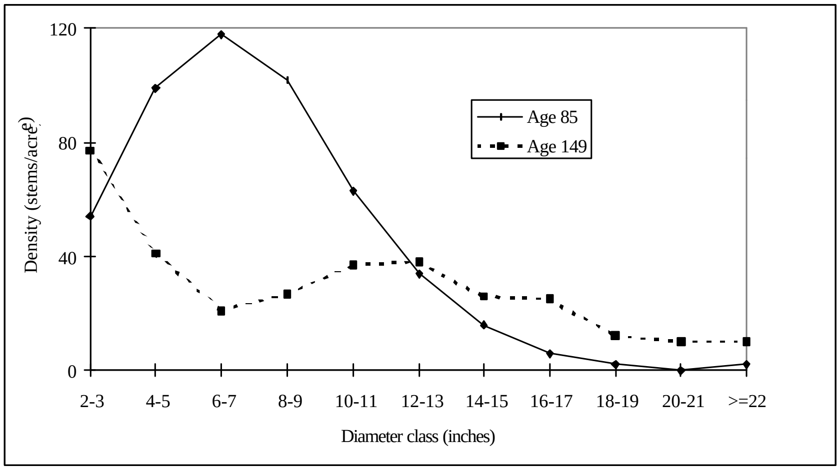

Figure 2.—Diameter distribution of trees in Perry hemlock plot in East Hartland, Connecticut in 1931 (stand age 85) and 1995 (stand age 149).

Table 1.—Species distribution on Saltonstall plot in 1939 (stand age 59) and 1993 (stand age 113) by diameter class (inches). HEM-eastern hemlock, BIR-birch, MAP-maple, OTH-other species.

1939 density (stems/acre)						1993 density (stems/acre)					
Dbh	HEM	BIR	MAP	OTH	Tot	Dbh	HEM	BIR	MAP	OTH	Tot
2-3	29	25	11	18	83	2-3	3	9	3	20	35
4-5	31	3	4	2	40	4-5	1	2	2	3	8
6-7	40	0	0	0	40	6-7	4	3	0	2	9
8-9	32	0	0	0	32	8-9	4	7	0	0	11
10-11	27	0	0	0	27	10-11	5	8	2	0	15
12-13	21	0	0	0	21	12-13	9	10	0	4	23
14-15	6	0	0	0	6	14-15	12	2	1	2	17
16-18	0	0	0	0	0	16-18	11	2	0	1	14
18-19	0	0	0	0	0	18-19	11	0	0	2	13
20-21	0	0	0	0	0	20-21	17	0	0	0	17
>=22	0	0	0	0	0	>=22	11	0	0	0	11
Total	186	28	15	20	249	Total	88	43	8	34	173

Some regeneration, mostly of black birch (*Betula lenta*) and red maple (*Acer rubrum*), appeared in the group openings on the Saltonstall plot, but only in rather small numbers (Table 1). Those few that began to grow well in height were often bent over and permanently deformed by wet snow sliding off the crowns of the surrounding evergreen hemlocks. There was a small amount of damage to the stand by the 1938 hurricane. The low density of hemlock regeneration prior to the arrival of adelgid is probably due to a very high deer population (~120 deer/mile^2) around Lake Saltonstall. Beech (*Fagus americana*) was the most numerous species in the 2-3 inch diameter class in 1993 and should form part of the future upper canopy.

Unlike the Saltonstall plot, hemlock was the major component of the smaller diameter classes on the Perry plot (Table 2). Density of hemlocks in the 2-3 inch diameter class nearly doubled between 1931 through 1995. The higher hemlock regeneration density relative to Saltonstall is likely due to deer hunting on state forests. As at Saltonstall, black birch, red maple, and beech also colonized the openings created by thinning.

Curiously, several of the hemlocks originally in the smaller diameter classes at Saltonstall survived even until 1993 when adelgid attack caused the stand to be salvaged. These few, standing beneath much larger ones, escaped logging damage and survived with minuscule cambial growth. Root excavations confirmed that these saplings had survived by parasitizing their much larger companions through root-grafts. We also observed hemlock stumps that have callused over on the Perry plot and speculate that they are also surviving by parasitizing neighboring trees.

Basal area

Both stands exhibited rapid basal area growth (Fig. 3). After age 50, annual basal area increments commonly ranged from 2 upwards to 5 ft^2/acre. Basal area growth on both plots increased several years after thinning before begining to

Table 2.—Species distribution on Perry hemlock plot in 1931 (stand age 85) and 1995 (stand age 149) by diameter class (inches). HEM-eastern hemlock, BIR-birch, MAP-maple, OTH-other species.

1939 density (stems/acre)						1993 density (stems/acre)					
Dbh	HEM	BIR	MAP	OTH	Tot	Dbh	HEM	BIR	MAP	OTH	Tot
2-3	28	7	13	6	54	2-3	49	14	9	5	77
4-5	40	20	36	3	99	4-5	23	9	5	4	41
6-7	75	27	14	2	118	6-7	16	3	0	2	21
8-9	80	13	9	0	102	8-9	11	7	9	0	27
10-11	49	3	8	3	63	10-11	16	11	9	1	37
12-13	29	0	5	0	34	12-13	30	4	4	0	38
14-15	13	1	2	0	16	14-15	23	1	2	0	26
16-18	4	0	1	1	6	16-18	24	1	0	0	25
18-19	0	0	2	0	2	18-19	11	0	0	1	12
20-21	0	0	0	0	0	20-21	9	0	0	1	10
>=22	2	0	0	0	2	>=22	8	0	0	2	10
Total	320	71	90	15	496	Total	220	50	38	16	324

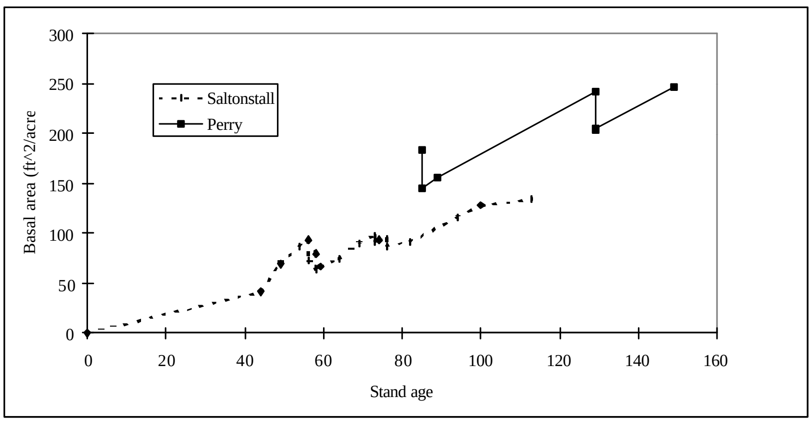

Figure 3.—Basal area (ft^2/acre) by stand age on Saltonstall and Perry hemlock plots in Connecticut.

decline as stand stocking increased. The trees of the younger Saltonstall plot started rapid diameter growth immediately after the release. This is always the case with released hemlocks in this part of their range. Although basal area growth gradually declined with age; it is quite remarkable that basal area growth on the Perry plot at 149-years-old was still over 2 ft^2/acre/year.

Growth and yield

Wood production per acre of both stands, exclusive of mortality, was determined on the basis of volume tables of Scott (1979, 1981) and the data are shown in Figs. 4 and 5. Wood production on both of these plots is higher than is typical for pure hemlock stands (Godman and Lancaster 1990). The annual production rates of both plots were very similar. Production rates sagged temporarily after each partial cutting, including those that removed some of the larger trees, but recovered and remained stable over remarkably long periods of time. The periodic annual increment (including harvested trees) of the Perry plot was 50 ft^3/acre at age 149, and the periodic annual increment of the Saltonstall plot was 52 ft^3/acre at age 113. Mean annual growth averaged approximately 80 ft^3/acre between ages 60 to 110 for both plots and fell to 60 ft^3/acre through age 149 on the Perry plot. The rapid growth decrease on the Saltonstall plot for the final 13 years was probably caused by the adelgid infestation.

In contrast to basal area and cubic-foot growth, board-foot volumes increased faster on the Saltonstall plot after age 40 (~400 b.f./acre/year) than on the Perry plot (300 b.f./acre/year, Fig. 5). The continued relatively high growth rate on the Perry plot through age 149 suggests hemlock can continue acceptable volume increases through at least age 200. Much of this increase is probably due to maintaining a high live crown ratio on residual trees.

Application

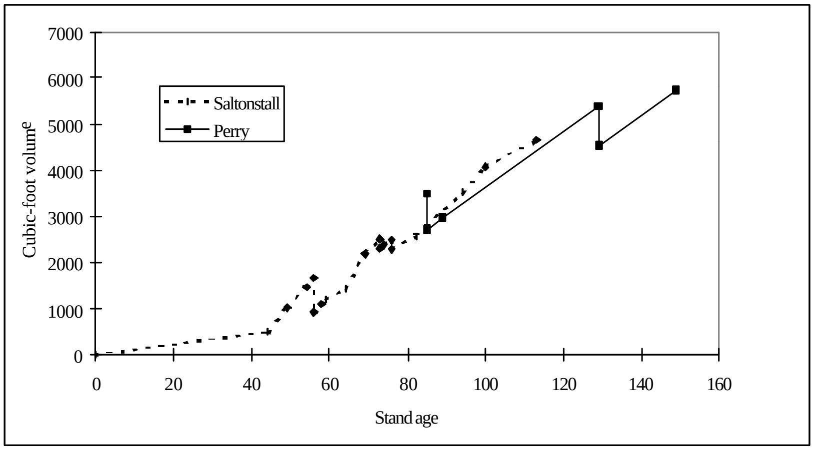

Figure 4.—Cubic-foot volume (ft^3/acre) by stand age on Saltonstall and Perry hemlock plots in Connecticut.

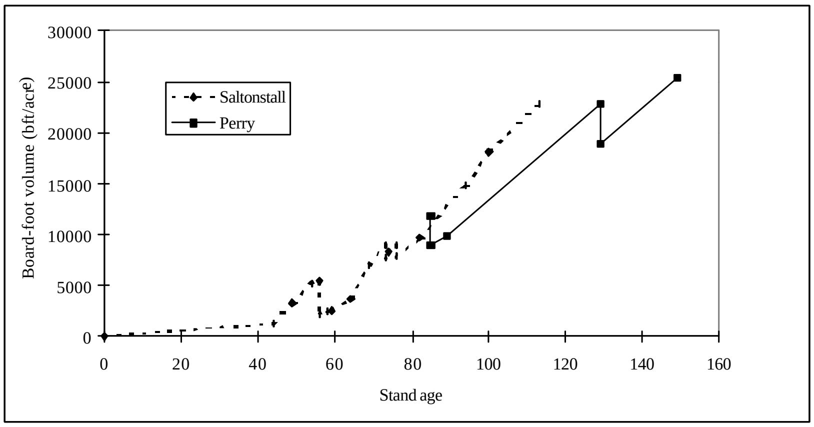

Figure 5.—Board-foot volume (Int. ¼ b.f./acre) by stand age on Saltonstall and Perry hemlock plots in Connecticut.

Forest managers will want to reestablish hemlock forests as soon as there is an effective biological control for hemlock woolly adelgid. These two cases studies show that eastern hemlock can respond vigorously to release even if they were previously oppressed by larger hemlocks. This means that it is possible to prolong the lives of vigorous stands with broad ranges of size classes over long periods of time for multiple purposes of timber, aesthetics, and biological diversity. This does not necessarily mean that old, large hemlocks will not suffer rots and ring-shake, or that single stands can be made into perfect sustained -yield units.

Acknowledgments

We would like to thank the late R.C. Hawley and A.F. Hawes for the foresight in establishing the Saltonstall and Perry plots. Additionally, we would like to thank J.P. Barsky and R. Hart for assisting in the latest field measurements; the Connecticut Department of Environmental Protection-Division of Forestry and South Central Regional Water Authority for protecting these sites; and the students of Yale University and foresters who assisted in earlier inventories.

This research was funded in part by McIntire-Stennis CONH-550.

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