THIRTY-THREE YEAR CHANGES IN ABOVE- AND BELOW-GROUND BIOMASS IN NORTHERN HARDWOOD STANDS IN VERMONT

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SUMMARY

In 1957-1960, R. O. Curtis and B. W. Post surveyed 81 even aged (45-90 y old) northern hardwood stands on acid till soils over the length of Vermont's Green Mountains. The purpose of the original study was to determine predictive relationships between site index and site characteristics, including latitude, elevation, soil drainage class, soil organic matter content and soil nutrients. The sites were not randomly selected in the 1950s. Rather, they were chosen to represent a range of stand ages and the range of environmental conditions associated with northern hardwood forests growing on acid till. In 1990-92 we were able to reliably relocate 40 of the original plots using sketch maps and witness trees. In 1990-91 we sampled 23 of the plots which were relocated exactly by blazed witness trees. These plots showed no signs of human disturbance other than possible minor removal of red maple for stand improvement. In 1992, we relocated 17 sites that had been selectively logged. The original witness trees had been removed in most cases, and these plots were located from roadside monuments, measured distances and compass bearings. Remeasurements of tree and soil characteristics allowed comparison of tree heights, basal areas, volumes, above-ground biomass, and soil organic matter pools.

These comparisons allowed us to explore some issues of environmental quality that surfaced in the 1980s. Areas of sugar maple decline were identified in Vermont and neighboring Canada, and several studies were conducted to determine what factors were related to maple decline, and if there was evidence of air pollution involvement. We reasoned that if there were adverse environmental changes in air or soil quality that had chronic effects on maple growth, patterns of individual and stand growth, and/or statistical relationships between growth and site characteristics established in the early part of this century might have been different in the latter half of the century.

In addition to the maple decline issue, long-term trends in soil organic matter are of interest in refining carbon budgets on local, regional and global scales. Careful determination of bulk density and soil organic matter in the Post and Curtis project has allowed a comparison of soil organic matter content. As we sampled both disturbed and undisturbed stands, the effect of forest harvesting on soil organic matter pools could be evaluated.

We have been able to test four hypotheses as outlined below.

Hypothesis 1

In undisturbed plots, changes in DBH, volume and biomass show that shade tolerant species, especially sugar maple, increased to a greater degree than less tolerant species as predicted by normal trends in aggrading northern hardwood stands.

Basal area increased in 19 of the 23 undisturbed plots, and volume decreased in only 1 plot, apparently due to the removal of large red maples for stand improvement. Red maple showed large decreases in basal area and volume in two other plots, and we suspect that this too is related to stand improvement. White and yellow birch decreased in several other plots as might be expected on the basis of shade tolerance of these species and competition in

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aggrading northern hardwood stands. Of the six species for which changes were determined, sugar maple showed the most consistent increases and the greatest relative and absolute increases. Figure 1 and table 1 show the results for biomass change. Changes in basal area and volume are, of course, similar to the biomass trends.

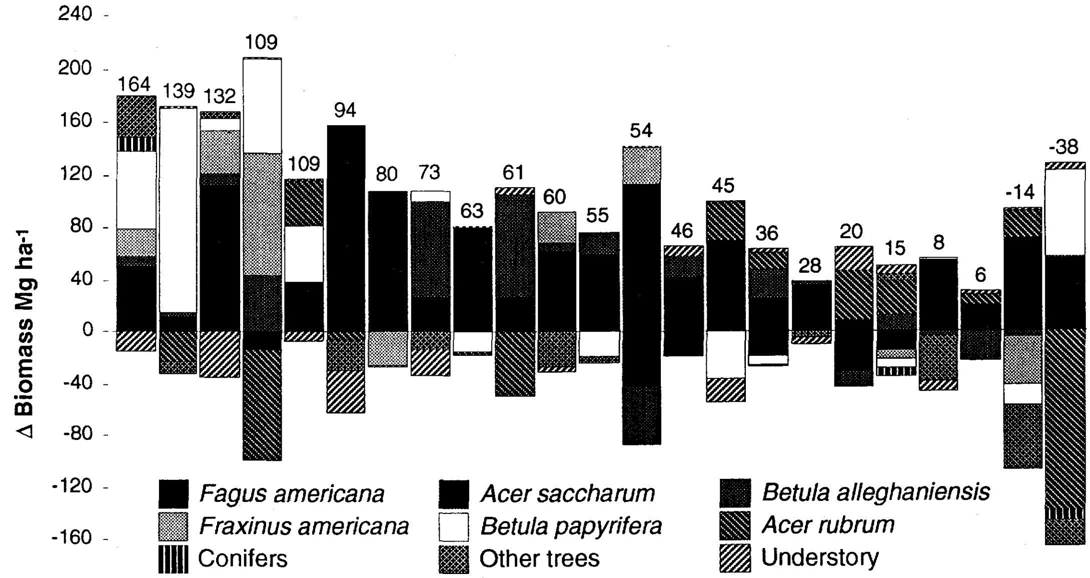


Figure 1. Change in biomass by species for the 23 remeasured plots. Numbers are net change in biomass.

Table 1. Biomass Summary.

Plot	Acer rubrum	Acer saccharum	Betula alleghaniensis	Betula papyrifera	Fagus americana	Fraxinus americana	Conifers	Other trees	Understory	Total biomass Mg ha-1	Stand Age	CSI
Δ Biomass												
5703	0.000	107.987	0.000	0.000	0.000	-26.775	0.000	0.000	-1.107	80.105	73	73.6
5704	30.526	36.482	-0.048	-36.238	32.557	0.000	0.000	0.000	-18.466	44.815	63	59.9
5706	0.000	61.742	6.100	0.000	0.000	23.813	0.000	-27.226	-4.612	59.817	69	75.7
5708	21.344	70.894	-5.512	-15.941	0.000	-36.621	0.000	-49.277	1.055	-14.058	63	78.0
5802	0.000	49.564	-3.468	2.189	3.581	0.000	0.000	-35.471	-8.018	8.377	47	59.5
5803	0.000	30.605	2.971	0.000	4.649	0.000	0.000	-5.340	-4.880	28.005	N.D.	N.D.
5804	0.000	21.074	73.261	7.766	5.166	0.000	0.000	-14.649	-20.028	72.590	50	65.8
5806	-24.199	11.084	3.655	155.486	0.000	0.000	0.000	-8.851	1.521	138.695	48	55.2
5807	0.000	23.431	6.846	59.297	26.865	21.746	9.913	31.817	-16.008	163.907	53	74.6
5819	0.000	112.748	-46.484	0.000	-41.821	27.616	0.000	0.000	1.583	53.643	95	75.9
5820	8.395	19.433	-23.779	0.000	0.000	0.000	0.000	0.000	2.116	6.165	50	91.2
5821	-85.437	-14.241	43.039	70.578	0.000	93.238	0.000	0.000	2.277	109.453	67	78.9
5826	0.000	39.311	17.207	-19.614	19.173	0.000	0.000	-5.901	4.573	54.749	56	50.7
5836	33.877	34.669	-0.032	43.139	3.398	0.000	2.115	0.000	-8.431	108.735	60	73.6
5901	-49.400	7.832	78.967	0.000	17.816	0.000	0.000	0.000	5.748	60.964	85	67.7
5902	38.344	-30.981	-12.667	0.000	7.724	0.000	0.000	0.000	17.846	20.266	82	66.4
5903	26.174	-8.609	11.941	-6.023	-6.898	-7.064	-6.277	5.402	6.803	15.449	69	67.2
5909	-7.092	157.133	0.000	0.000	0.000	0.000	0.000	-23.136	-32.627	94.279	64	72.7
5911	0.000	83.632	9.272	9.223	28.088	31.801	0.000	5.734	-35.333	132.416	54	85.4
5913	13.292	-19.926	23.116	-6.028	24.355	0.000	0.000	-1.052	2.011	35.768	74	63.1
5914	-2.398	64.447	0.000	-15.486	14.944	0.000	0.000	0.000	1.824	63.330	60	72.0
5915	-139.380	55.576	1.352	65.642	0.000	0.000	-7.488	-19.042	4.890	-38.450	75	75.3
5917	0.000	41.219	15.887	0.000	-19.956	0.000	0.000	0.000	8.634	45.785	97	56.0
Mean	-5.911	41.526	8.766	13.652	5.202	5.554	-0.076	-6.391	-3.853	58.5	66.1	69.9

Hypothesis 1 is supported by the comparisons, suggesting that normal stand dynamics have prevailed in the development of these stands.

Hypothesis 2

In undisturbed plots, the relationships between height (or BA/volume/biomass) and candidate predictors (site index, stand age and dbh) was unchanged between 1957-59 and 1990-91.

To test this hypothesis, we determined how height and biomass in the undisturbed plots were related to log dbh, stand age and site index. In both the 1957-59 and 1990-92 data sets, these variables explained ca. 70 percent of the variation in height. Figure 2 shows that the coefficients for these variables were not significantly different in the two studies. Both site index and stand age are significantly correlated with stand biomass as shown in figure 3 (shown for pooled data). The equations for the individual data sets are not different, with $R^2 = .65$ for the 1990-92 data set, and $R^2 = .59$ for the 1957-59 data set. We interpret these results to mean that stand growth from the late 1950s through the early 1990s has proceeded as expected based on the 1957-59 data, which integrates growth during the first half of the 20th century.

With respect to sugar maple, figure 4 shows that for a given DBH, sugar maple in 1990-92 were slightly (though not significantly) taller than in 1957-59. This is an expected result for aging stands, and adds more weight of evidence to the contention that sugar maple growth has not been adversely affected by changed growing conditions.

Hypothesis 3

In undisturbed stands, growing vegetation is an important sink for carbon, whereas there would be either a small change or no change in soil organic matter/soil carbon.

While there exists much uncertainty in the role of forest soils in global carbon budgets, hypothesis 4 follows conventional thinking with respect to accumulation of carbon in most forested ecosystems. Careful consideration of problems in delineating horizon boundaries, and of bulk density/depth/organic matter content relationships suggests some problems in comparing the organic matter content of soils sampled decades apart by different investigators. We have computed organic matter content on the basis of a fixed weight of soil mineral particles as being the least biased way of making the comparisons. Figure 5 shows that there was no change in soil organic matter in the profile (Oa through Bw horizons) at the undisturbed sites.

Hypothesis 4

In logged stands disturbed only by commercial harvesting operations, soil organic matter would be unchanged.

In accordance with recent reviews of the effect of forest harvesting on soil organic matter, figure 5 shows that there was no significant change in the soil organic matter content between 1958 and 1992 at the 17 logged sites.

CONCLUSION

With respect to questions about recent trends in forest productivity, we found no evidence from these stands that the growth of sugar maple (or other northern hardwoods) was adversely affected by changes in growing conditions. Height and biomass of stands in the early 1990s can be predicted within reasonable error, from relationships derived from measurements of 45-90 y old stands done in the 1950s. With respect to the accumulation of carbon in these northern hardwood stands, the growing live biomass is a significant sink for atmospheric carbon, where as the soil appears to neither gain nor lose appreciable carbon regardless of whether the stands were logged or not.

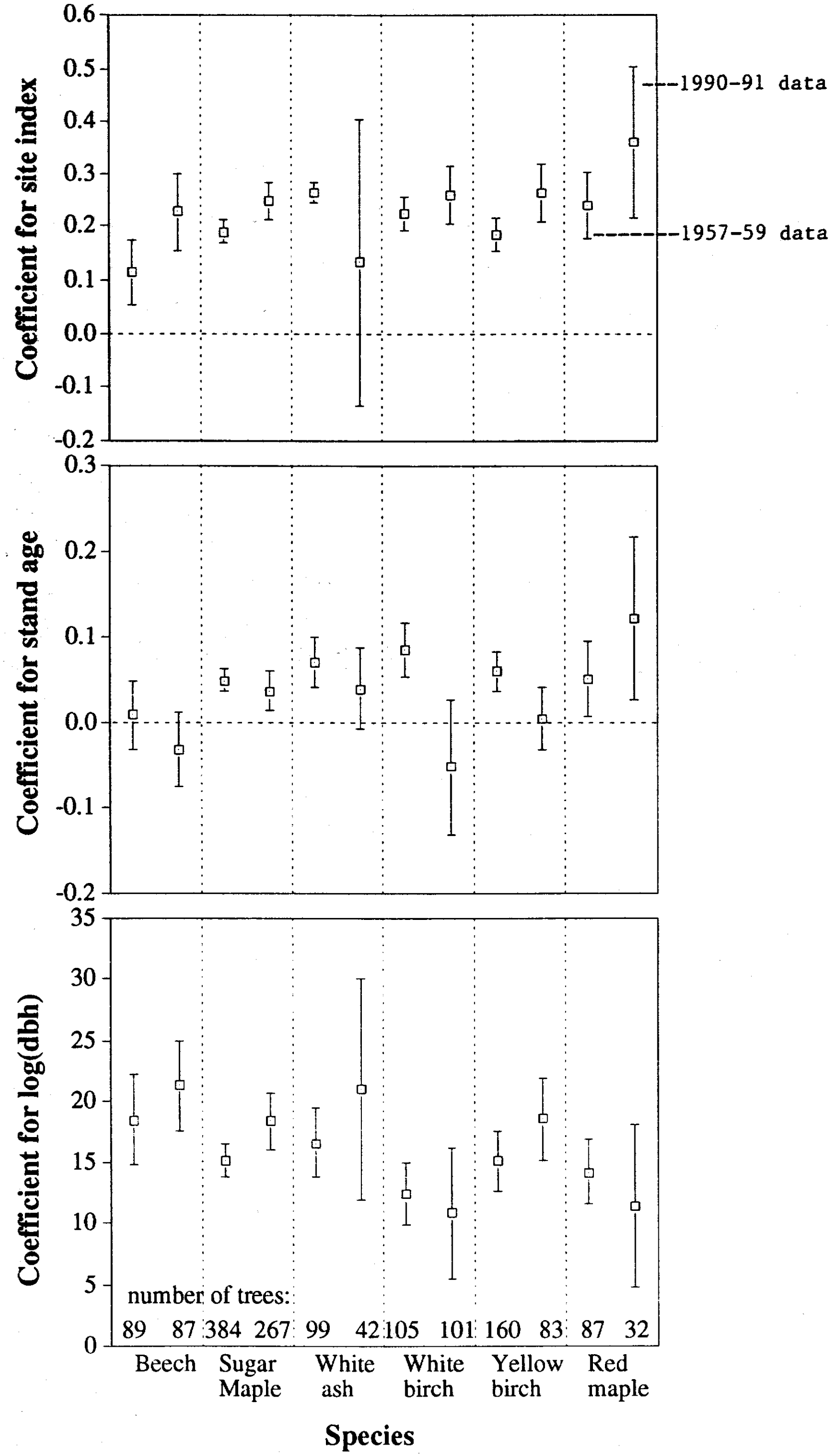


Figure 2. Coefficients for the equation Tree Ht = a + b(log dbh) + c(stand age) + d(site index).

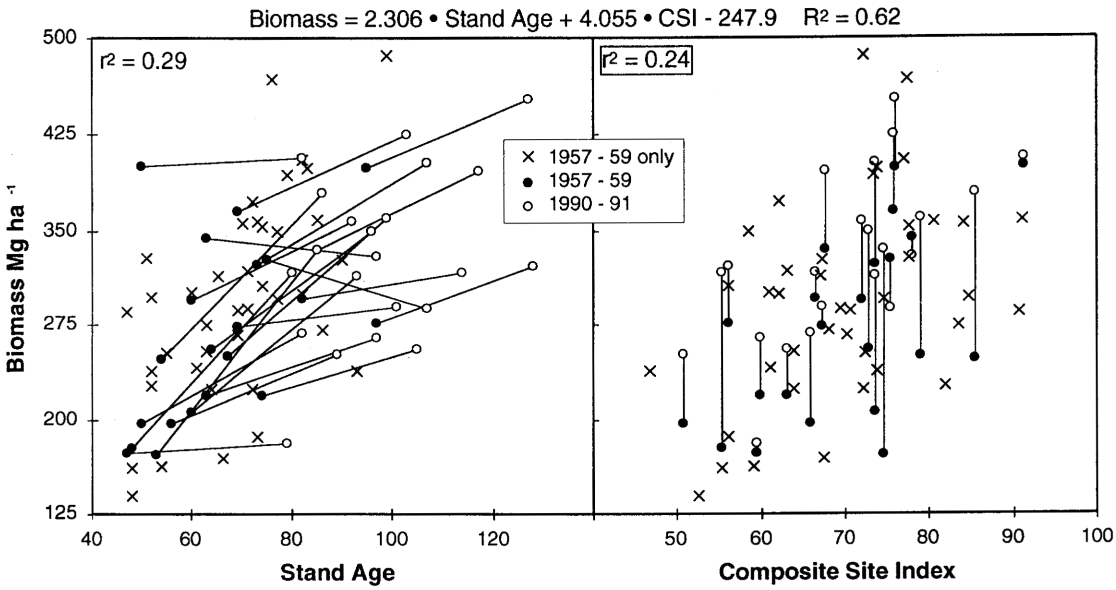


Figure 3. Biomass as a function of stand age and composite site index (height in ft at age 75).

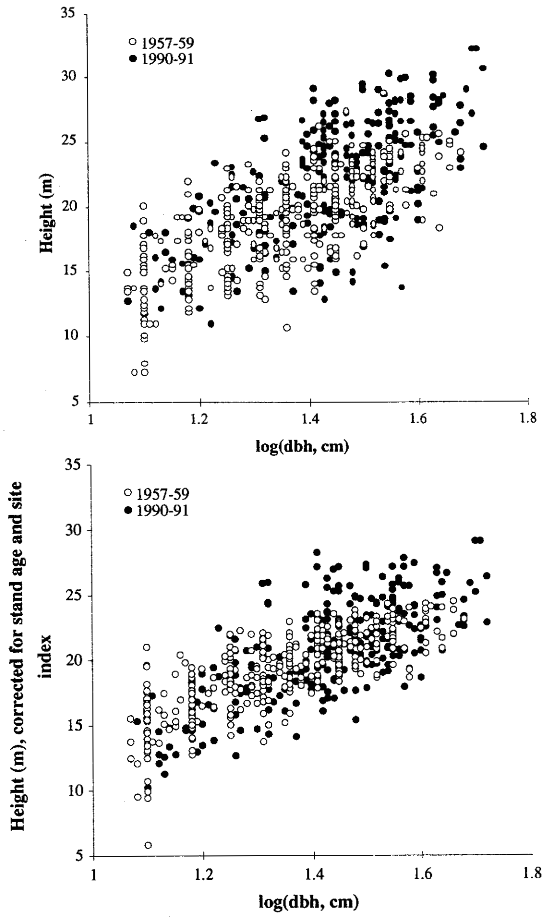
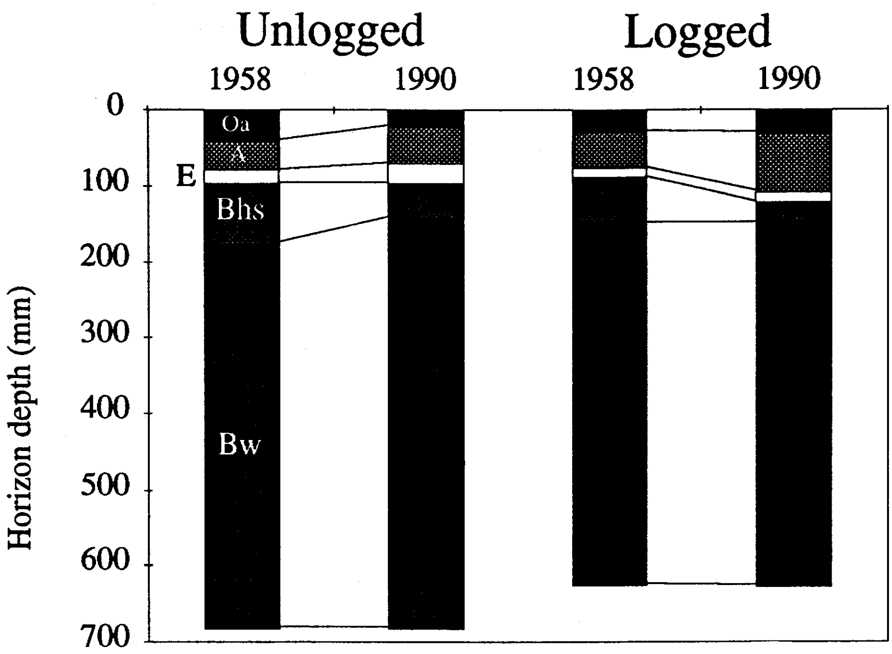


Figure 4. Height-diameter relationship for sugar maple.



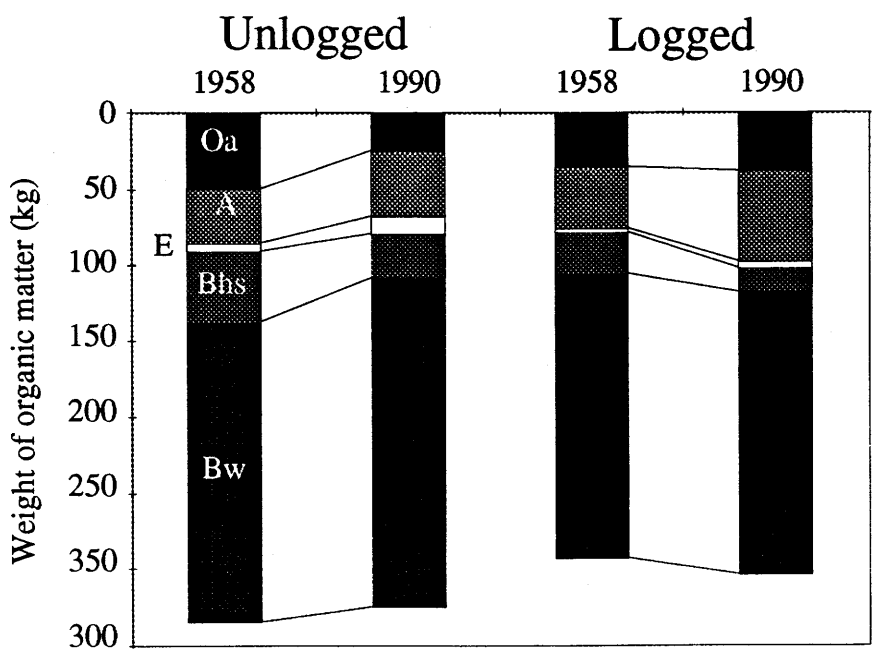


Figure 5. Changes in average horizon depth (top) and SOM mass (bottom) across all plots.