Predicting Effects of Even-aged Silviculture on Commodity Production and Carbon Sequestration in Northern Hardwood Stands

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The research modified an existing northern hardwood stand simulator to accommodate the characteristics and dynamics of even-aged communities. It substituted growth and mortality functions based on stand relative density, using measured responses from managed even-aged northern hardwood stands.

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http://www.nsrcforest.org

Project Summary

The research modified an uneven-aged northern hardwood stand simulator to accommodate characteristics and dynamics of even-aged communities. It has growth and mortality functions based on measured responses in even-aged stands. Further, it uses measures of relative density rather than stand basal area to alter growth rates and survival of trees at different levels of stand stocking. The new simulator has localized equations for converting tree volumes to estimates of sequestered carbon. It allows users to compare outcomes from different intermediate treatments. Findings can inform decisions about managing even-aged northern hardwood stands with respect to sustainable production, yields of wood, and sequestration of carbon.

Background and Justifications

The need …

… understanding and predicting forest stand development has proven central to sustainable forest management

… by forecasting the outcomes, managers can make better choices from among alternate strategies that might satisfy a landowner's objectives

… the even-aged stand simulator will give landowners and managers that option

We sought to …

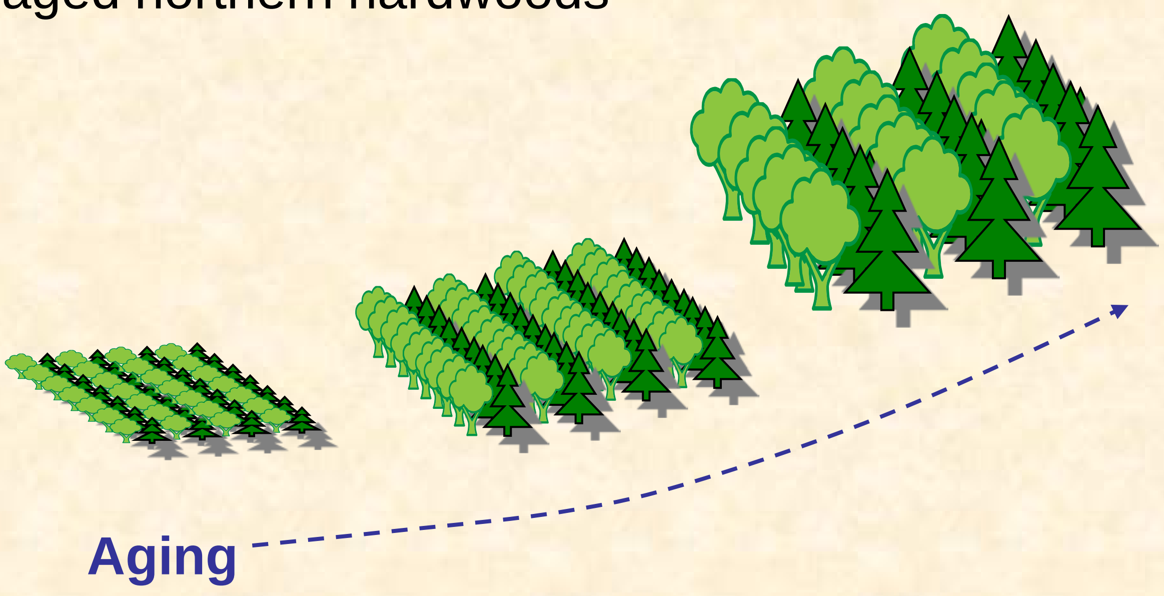
… forecast future stocks and flows

… estimate yields of traditional products

… determine the quantities of carbon sequestered in managed and otherwise manipulated even-aged stands

… predict the effects of those different intermediate treatments

... for even-aged northern hardwoods



Methods

The work --

- Remeasured experimental stands to document change in tree sizes and abundance
- Devised a process for converting basal area to relative density for modifying change functions for even-aged stands
- Developed growth and mortality functions using the remeasurement data from even-aged stands
- Modified the ESF uneven-aged stand simulator to portray even-aged stands and how they develop
- Integrated the new change functions and other information about even-aged stand attributes into a functioning simulator
- Accumulated and compiled stand characteristics data from multiple even-aged northern hardwoods to use for future simulations
- Shared these findings through workshops, conferences, and publications

Data gathered from fully documented even-aged northern hardwood stands given crown thinning to different levels of relative density (after Stout 1990)[1]…

… documented and remeasured plots in the Adirondacks at Wanakena and Newcomb

Data for developing growth and mortality functions included:

- sugar maple (n = 372)
- red maple (n = 212)
- American beech (n = 729)
- black cherry (n = 44)
- white ash (n = 34)
- yellow birch (n = 194)


Unthinned


45% Plot

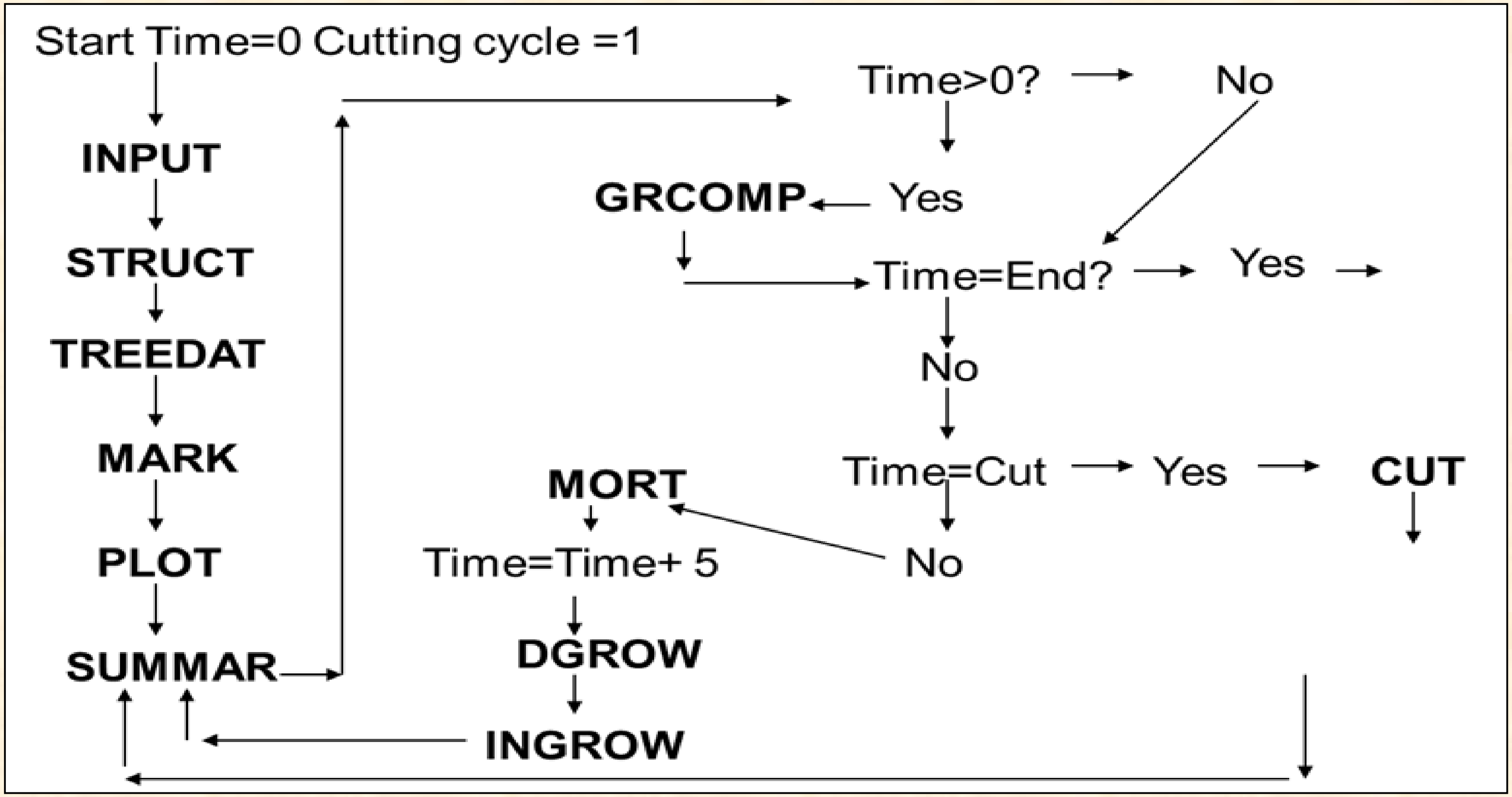

60% Plot


75% Plot

[1]Stout, S.L. 1990. Progress report for relative stand density in northern hardwoods throughout the Northeast. US For. Serv. Northeast. For. Expt. Stn. 4110-FS-NE-1152-119.

Results and Project Outcomes

Structure of the simulator –



… coded in FORTRAN

Data for growth functions included sugar maple, red maple, American beech, black cherry, white ash, and yellow birch

New growth functions use stand relative density, time since treatment, and initial tree diameter to predict change in tree size …

Growth Model --

- Dependent variable:
  - Future diameter (DBHa)
- Predictor Variables:
  - Initial diameter (DBHo)
  - Time (Years)
  - Relative density (PLTRD)
  - Site (as classification variable)

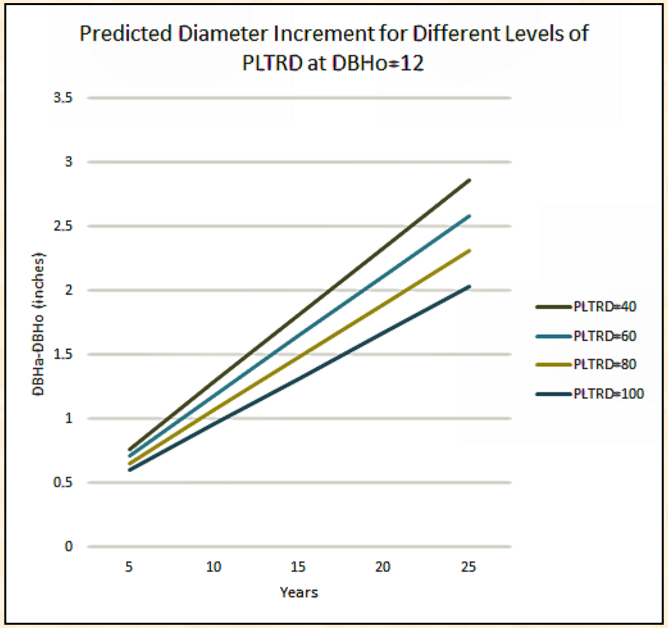
$$\boldsymbol{DBH_a = \beta_o DBH_o + \beta_1 Years + \beta_2 Years \cdot DBH_o + \beta_3 Years \cdot PLTRD + \beta_4 Site + \varepsilon}$$

- No-intercept model
  - Initial diameter term functions like an intercept
- Best model selected by AICc values (lower = better)

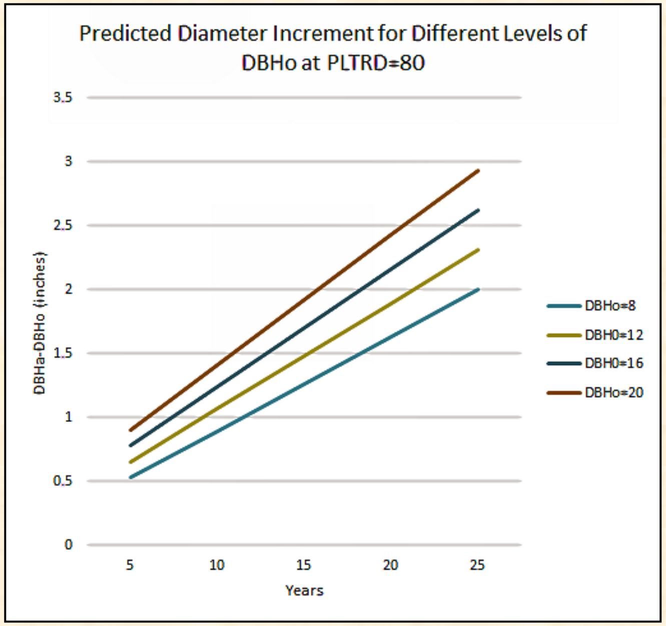
Findings show that …

… the larger trees of upper canopy positions grow the most rapidly
… even small trees grow better after release by thinning, but not nearly as well as ones in upper canopy positions
… all trees grow more rapidly at lower stand relative density

As an example, sugar maple trees will grow like this …



12-inch tree
at different relative densities



Trees of different diameters
at 80% relative density

Data for mortality functions included sugar maple, red maple, American beech, black cherry, white ash, and yellow birch

Mortality Model --

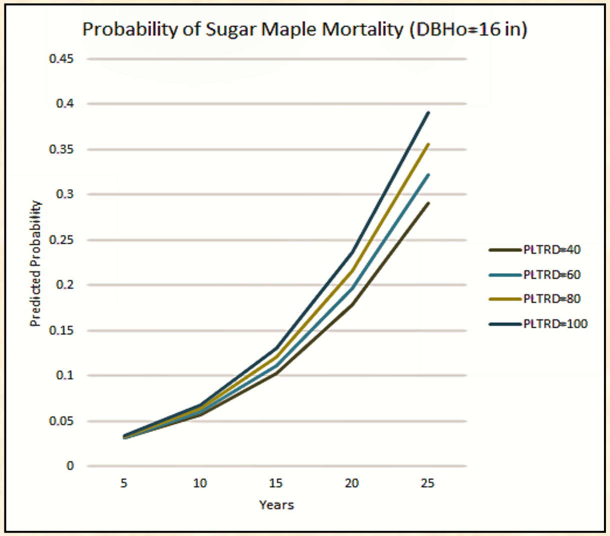
- Logistic function used to estimate probability of mortality
- Dependent variable:
    - Probability of mortality
- Predictor variables:
    - DBHo, Years, PLTRD, Site (location)
    - Interactions

$$\boldsymbol{P(Y) = \frac{1}{1 + e^{-X\beta}}}$$

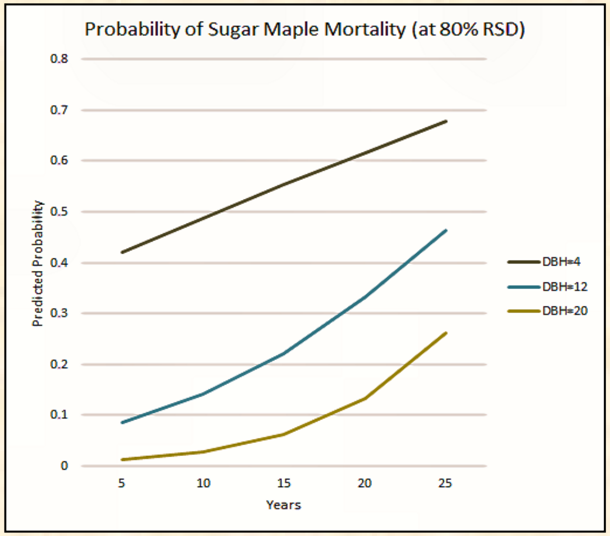
Estimates of mortality show …

… greater losses among small than larger trees
… rate of mortality related to stand relative density
… potential for mortality increases with time

As an example, sugar maple mortality curves look like this



16-inch tree
at different relative densities



Trees of different diameters
at 80% relative density

The simulator projects growth and development by 5-year intervals ...

Showing change by diameter class for …

- number of trees
- basal area
- total merchantable volume
- sawtimber volume
- sequestered carbon

Simulations can project multiples of 5-year periods for cycles of up to 30 years …

Sample of Simulation Output

Time: 0

Dbh Class (cm)	Number per hectare	Basal Area (M^2/ha)	Total Merchantable Volume (M^3/ha)	Sawtimber Volume (M^3/ha)
20.00-24.99	65.0	2.38	16.32	0.00
25.00-29.99	43.0	2.33	18.45	0.00
30.00-34.99	88.0	6.78	59.58	38.22
35.00-39.99	22.0	2.32	21.99	17.31
ALL			116.34	55.53

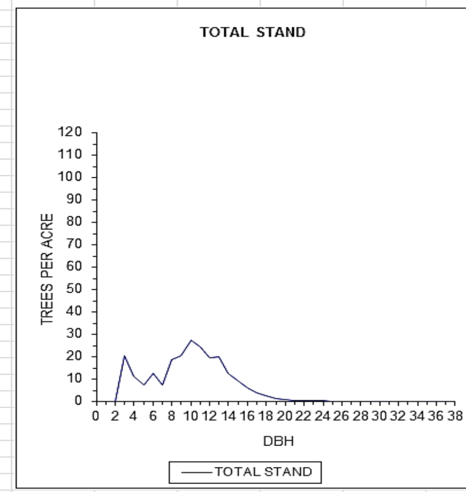
Time: 5 years

Dbh Class (cm)	Number per hectare	Basal Area (M^2/ha)	Total Merchantable Volume (M^3/ha)	Sawtimber Volume (M^3/ha)
20.00-24.99	59.0	2.39	17.08	0.00
25.00-29.99	43.0	2.48	20.00	0.00
30.00-34.99	84.0	6.98	62.50	43.20
35.00-39.99	29.0	3.18	30.36	24.15
40.00-44.99	3.0	0.40	3.91	3.21
ALL			133.85	70.56
		Change	+ 17.51	+ 15.03

Stochastic characteristics of the change functions results in variation of outcomes across multiple runs …

Data from an additional 65 even-aged northern hardwood stands in New York's Adirondacks and Southern Tier also compiled and converted to stand tables for use in later experiments to test effects of alternate intermediate treatments in a variety of previously unmanaged stands ...

DIA CLASS	# OF TREES	TREES PER ACRE	SQ FT PER ACRE
1	0	0	0.0
2	0	0	0.0
3	2	20.4	1.0
4	2	11.5	1.0
5	2	7.3	1.0
6	5	12.7	2.5
7	4	7.5	2.0
8	13	18.6	6.5
9	18	20.4	9.0
10	30	27.5	15.0
11	32	24.2	16.0
12	31	19.7	15.5
13	37	20.1	18.5
14	27	12.6	13.5
15	22	9	11.0
16	17	6.1	8.5
17	12	3.8	6.0
18	10	2.8	4.9
19	6	1.5	3.0
20	5	1.1	2.4
21	2	0.4	1.0
22	2	0.4	1.1
23	2	0.3	0.9
24	2	0.3	0.9
25	0	0	0.0
26	0	0	0.0
27	0	0	0.0
28	1	0.1	0.4
29	0	0	0.0
30	0	0	0.0
31	0	0	0.0
32	0	0	0.0
33	0	0	0.0
34	0	0	0.0
35	0	0	0.0
36	0	0	0.0
37	0	0	0.0
38	0	0	0.0
39	0	0	0.0
40	0	0	0.0
41	0	0	0.0
42	0	0	0.0
43	0	0	0.0
44	0	0	0.0
45	0	0	0.0
TOTAL	284	228.3	141.6
	AVG	5.1	3.15
	STDS	8.063	5.241



The outreach and products include …

A thesis …

- M.Sc. Thesis by David A. Schmidt from SUNY-ESF, 2014.

Coming manuscripts for research journals …

- findings from growth and mortality functions
- outcomes from coming simulation runs
- comparison of growth for trees in even- and uneven-aged stands

Future conference proceedings as invited …

The outreach and products also include …

Presentations that incorporated information related to the project, particularly about tree growth and general patterns of stand development …

- Workshops for forest managers and other natural resources professionals – 5
- Workshops for forest landowners - 2
- Conferences for forest managers and wood products industry personnel - 2

(See pages 19-20 for details)

Implications and applications in the Northern Forest region

Appropriate management of Northeastern forests has both ecologic and economic importance to people …

… to maintain biologically diverse and economically viable forests into the future

… to insure a rich array of values that sustain people's lives and enhance their quality of living

Access to information about the structure, character, and development of even-aged northern hardwood stands will inform management decisions about …

… alternative outcomes from different management strategies, including effects on stand structure and rates of change

… ways to balance sawtimber volume production and carbon sequestration

Future directions

Experiments with the newly developed even-aged stand simulator will allow comparisons of outcomes from …

… different methods of thinning on stand structure and production

… different residual relative densities on tree and stand development

… thinning versus exploitive harvesting (diameter-limit cutting)

Assessment of data from 65 sampled stands will reveal …

… overall variation in structural characteristics of different even-aged northern hardwood stands from several localities and at a range of degrees in initial stand development

… how initial stand structure and density may effect the outcomes

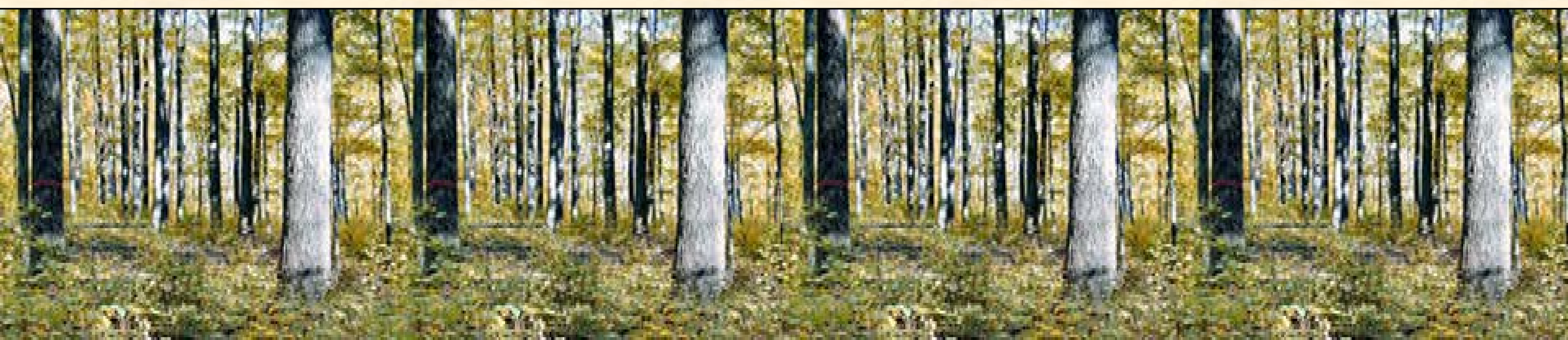
… the degree that differences in stand age (degree of development) temper the outcomes from alternate intermediate treatments

Matching simulation outcomes from the previous uneven-aged stand simulator with experiments by the new one for even-aged stands will inform discussion about …

… similarities and differences in long-term production potentials for silviculture with the two age arrangements

… potentials to sustain volume production and carbon sequestration through appropriate management of even- and uneven-aged stands

… long-term changes in structural attributes of even- and uneven-aged northern hardwood communities



List of products

These projects were supported by the Northeastern States Research Cooperative through funding made available by the USDA Forest Service. The conclusions and opinions in this paper are those of the authors and not the NSRC, the Forest Service, or the USDA.

Thesis:

Schmidt, D.A. 2014. *Modeling Growth and Mortality of Northern hardwoods in Even-aged Stands in the Adirondacks*. M.Sc. thesis. SUNY Coll. Environ. Sci. and For., Syracuse, NY.

Workshop and conference presentations that included materials associated with the project:

Nyland, R. D. 2013. *Rehabilitating Disturbed Forests: Where We Stand And What We Need*. http://www.conservationwebinars.net/webinars/rehabilitating-disturbed-forests.

Schmidt, D.A., R.D. Nyland, E. Bevilacqua, and D.H. Kiernan. 2013. Modeling Growth of Even-aged Northern Hardwood Stands in the Adirondack Region of New York. A presentation to NY Soc. Am. For. Annual Meeting, January 2013, Syracuse, NY. (~45 attending).

Nyland, R.D. *Rehabilitating Disturbed Forests – Where We Stand And Want We need*, 17 September 2013, an online webinar sponsored East National Technical Support Center, Natural Resources Conservation Service, 243 participants from 43 states/territories.

Nyland, R.D. *Rehabilitating Disturbed Forests*, two workshops for Central NY Chapter, Society of American Foresters, Tully, NY, 4 presentations each occasion, plus one-half day field trip, 15 and 29 June 2012. (65 participants).

Nyland, R.D. *Rehabilitating Disturbed Forests*, an invited presentation at a workshop organized by Ministère des Ressources naturelles et de la Faune, Direction de la recherche forestière. Québec City, Québec. 20-21 June 2012. (~ 60-65 participants)

Nyland, R.D. *Rehabilitating Disturbed Forests*, two workshops for Adirondack Chapter, Society of American Foresters, Newcomb, NY, 4 presentations each occasion, plus one-half day field trip, 21 and 22 June 2012. (56 participants).

Nyland, R.D. *Rehabilitating Disturbed Forests: Where We Stand and What We Need,* an invited presentation at the 51st Annual Spring Program, NY Forest Landowners Association, Syracuse, NY, 23 March 2013. (~ 65-70 participants)

Nyland, R.D. *Is Forestry Dead … Or Where Has It Gone,* an invited presentation at the 1st Annual Meeting of the Massachusetts Forest Alliance, Marlborough, MA, 20 March 2013. (~ 100 participants)

Nyland, R.D. *Rehabilitating Disturbed Forests: Where We Stand and What We Need,* an invited webinar presentation through *ForestConnect* for Cornell Cooperative Extension Service, 20 May 2013. (105 participants from Illinois and the Upper Lake states through Ontario and Maine, and southward to Pennsylvania, Maryland, Georgia, and Arkansas).