Role of silvicultural intensity and species composition objectives on the growth and dynamics of Northeastern forest stands

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- A new set of additive aboveground component biomass models were developed for naturally regenerated and planted small trees in the region
- Early successional Acadian stands can be shifted in distint long-term trajectories depending on the intensity of silvicultural treatment applied

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http://www.nsrcforest.org

Project Summary

Early successional stands in Maine are often composed of a mixture of desirable and undesirable conifer and hardwood species. Stands are rarely managed, resulting in forest productivity declines. The goal of this project was to examine the effects of factorial combinations of silvicultural intensity (thinning, thinning + enrichment planting, plantations) and species compositional objectives (conifer, mixedwood, and hardwood) on the growth and dynamics of early successional Acadian stands. First, aboveground component biomass were developed for juvenile trees in Maine and compared to existing models. The new models were then used to predict biomass across the treatment array to examine temporal trends in biomass. In the high intensity hybrid poplar plantations, four clones were planted. Three years following planting, hybrid poplar height and ground line diameter growth rates began to diverge among clones, and by six years, the *P. nigra* x *P. maximowiczii* (NM6) clone clearly outperformed three *P. deltoides* x *P. nigra* clones (D51, DN10 and DN70) both in pure stands and in mixtures with white spruce. In mixture, we found the yield of white spruce to decline as the yield of hybrid poplar increased. Overall, yields of the white spruce monocultures were comparable to those reported in eastern Canada, while the hybrid poplar biomass yields were substantially lower than those reported from studies on abandoned agricultural lands, likely due to the harsher soil conditions at our site. Seven years after treatment, yields of the two hardwood thinning and thinning+enrichment ranged from 43.4 to 56.6 Mg ha^{-1}, which were similar to the 52.9 Mg ha^{-1} yield of the untreated control but with 17 and 46% lower densities, respectively. In the conifer release treatments, removal of hardwoods promoted conifer dominance and resulted in yields between 19.9 and 30.4 Mg ha^{-1} seven years after treatment. After seven years, yields of the mixedwood treatments were between 19% and 47% greater than the conifer release treatments due to the retention of thinned hardwood stems and represent stands that dominate much of the forestland in the region. Results from the experiment show that early successional Acadian stands can be shifted in different long-term developmental trajectories to meet a variety of landowner objectives with different intensities of silvicultural intensity.

Background and Justification

- The lack of consensus on whether to use extensive or intensive silvicultural practices to enhance forest growth in the Northern forest region reflects the need to better understand the role of silvicultural intensity and species compositional objectives on the long-term growth and yield of forest stands
- The aspen/birch forest type in Maine comprises 12.9% of all forestlands, third behind maple/beech/birch (40.7%) and spruce/fir (33.1%), yet information on silvicultural options for early successional stands is limited (McCaskill et al. 2011).

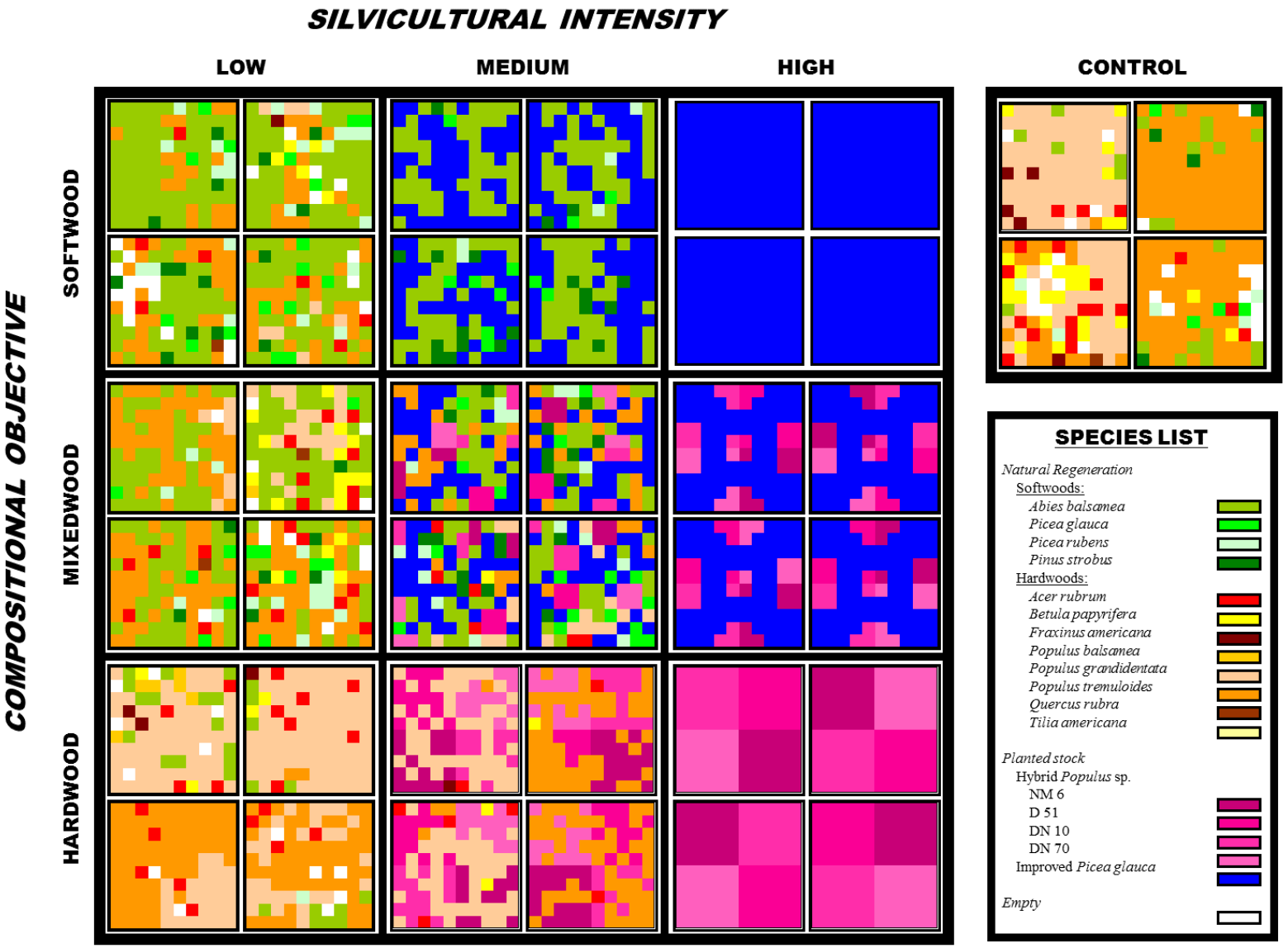
Methods: Biomass Models

Descriptive statistics of destructively sampled trees used to fit the additive aboveground biomass equations and evaluate published equations. The number of individuals per species (n), median values and ranges of DBH (cm), foliage biomass (kg), branch biomass (kg) and bole biomass (kg) are shown.

Species	n	DBH median (cm)	DBH range (cm)	Foliage median (kg)	Foliage range (kg)	Branch median (kg)	Branch range (kg)	Bole median (kg)	Bole range (kg)
Red maple	12	2.4	0.3-6.0	0.12	0.01-0.92	0.27	0.01-0.99	0.73	0.01-7.11
Paper birch	13	1.2	0.5-3.9	0.05	0.01-0.32	0.04	0.01-0.42	0.17	0.02-2.38
Gray birch	15	1.2	0.5-6.9	0.04	0.01-0.54	0.05	0.01-1.50	0.14	0.04-10.02
Bigtooth aspen	17	5.6	1.1-13.1	0.41	0.01-4.08	1.06	0.02-9.46	5.77	0.13-32.33
Trembling aspen	15	5.2	2.6-12	0.38	0.04-7.39	0.76	0.07-18.62	4.03	0.78-29.63
Hybrid poplar (D51)	5	4.3	1.4-7.5	0.56	0.06-1.46	0.72	0.11-2.39	2.52	0.33-7.98
Hybrid poplar (DN10)	5	4.6	2.3-10.9	0.45	0.11-2.67	0.77	0.16-4.70	3.08	0.70-14.94
Hybrid poplar (DN70)	5	4.1	0.7-8.7	0.66	0.02-1.53	1.45	0.04-2.67	2.51	0.10-9.69
Hybrid poplar (NM6)	5	6.8	3-13.7	1.32	0.30-4.12	2.48	0.52-14.99	7.06	1.01-27.89
White spruce	10	1.6	0.3-5.1	0.78	0.20-2.74	0.44	0.12-1.70	0.43	0.13-2.22

- Trees were destructively sampled, dried, and weighed by aboveground component (foliage, branch, and bole) for 102 trees encompassing the most prevalent species at the site
- Nonlinear seemingly unrelated regression (NSUR) was used to fit component biomass models. NSUR ensures that biomass predicted with component equations equal predictions from the total aboveground biomass equation
- Data were used to evaluate the performance of published biomass models for species in the Northern Forest region

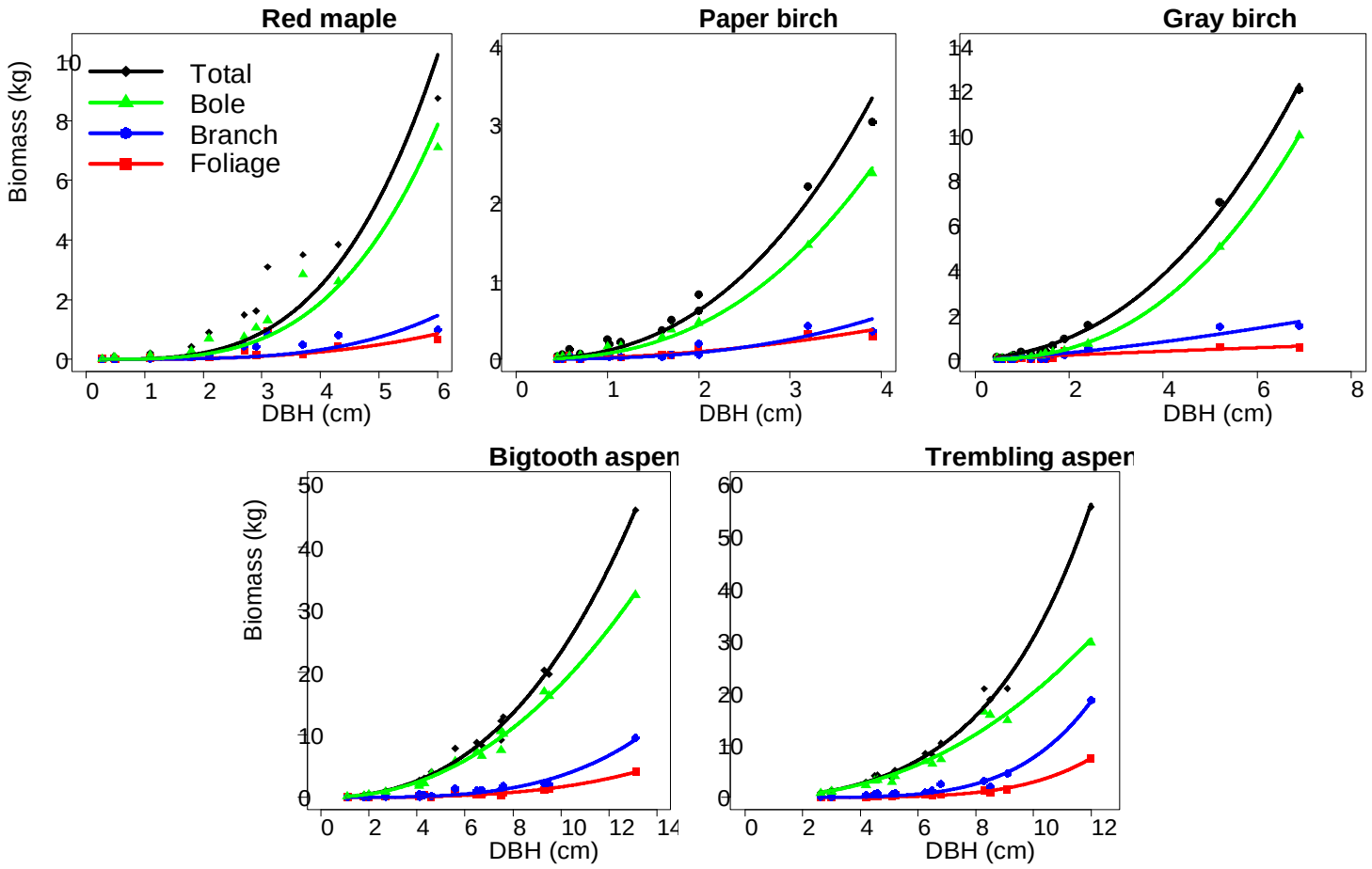
Methods: SIComp Experimental Design



Methods: SIComp Measurements

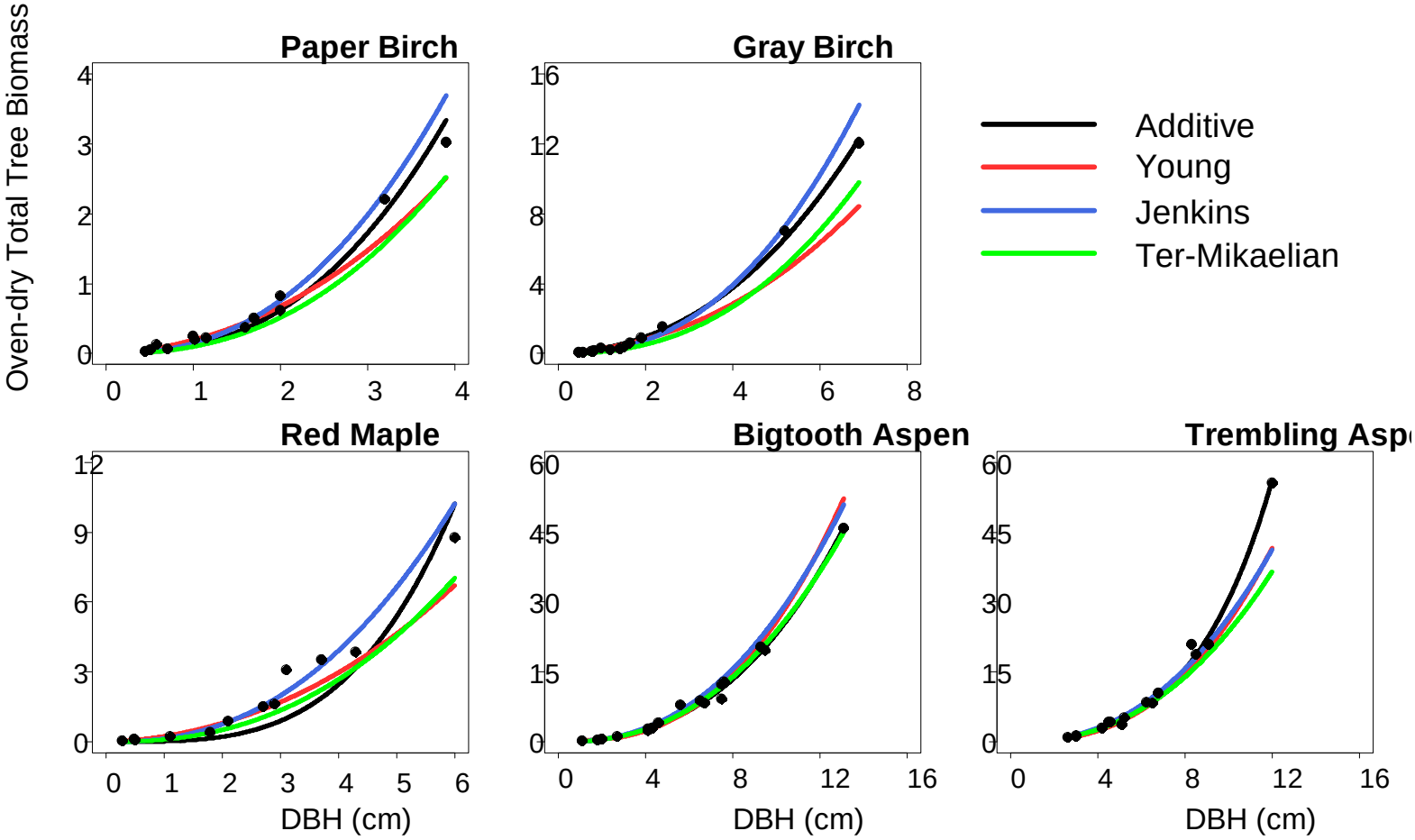
- Hybrid poplar-white spruce plantations
  - Measurements of stem diameter and height of the 100 crop-trees in each measurement plot
  - Only analyzed data from hybrid poplar plantations, white spruce plantations, and mixture plantation of the two
- Naturally regenerated treatments
  - Used data from 16 m^2 fixed area subplots where DBH was measured for all trees by species over the course of the experiment

Results: Biomass Models



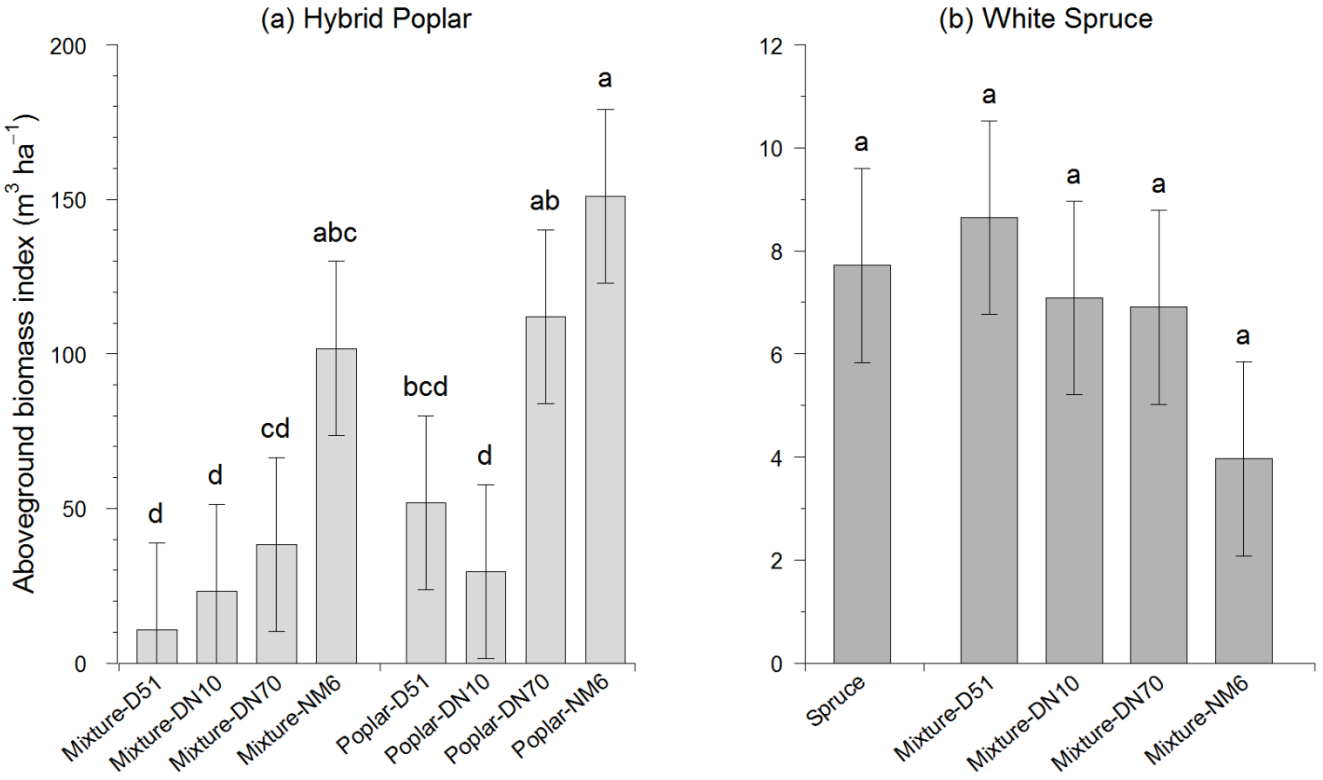
A nonlinear power function (Biomass = $\beta_0 DBH^{\beta 1}$) was found to best fit the observed data for all species with R^2 ranging from 0.47 for red maple foliage to 0.99 for paper birch and gray birch bole biomass

Results: Biomass Models



The national Jenkins et al. (2003) and regional Young et al. (1980) total aboveground biomass models produced estimates similar to the observed data for the aspen species. The fit of the Young et al. (1980) and Ter-Mikaelian and Korzukhin (1997) models had a poor fit to the red maple, paper birch, and gray birch data

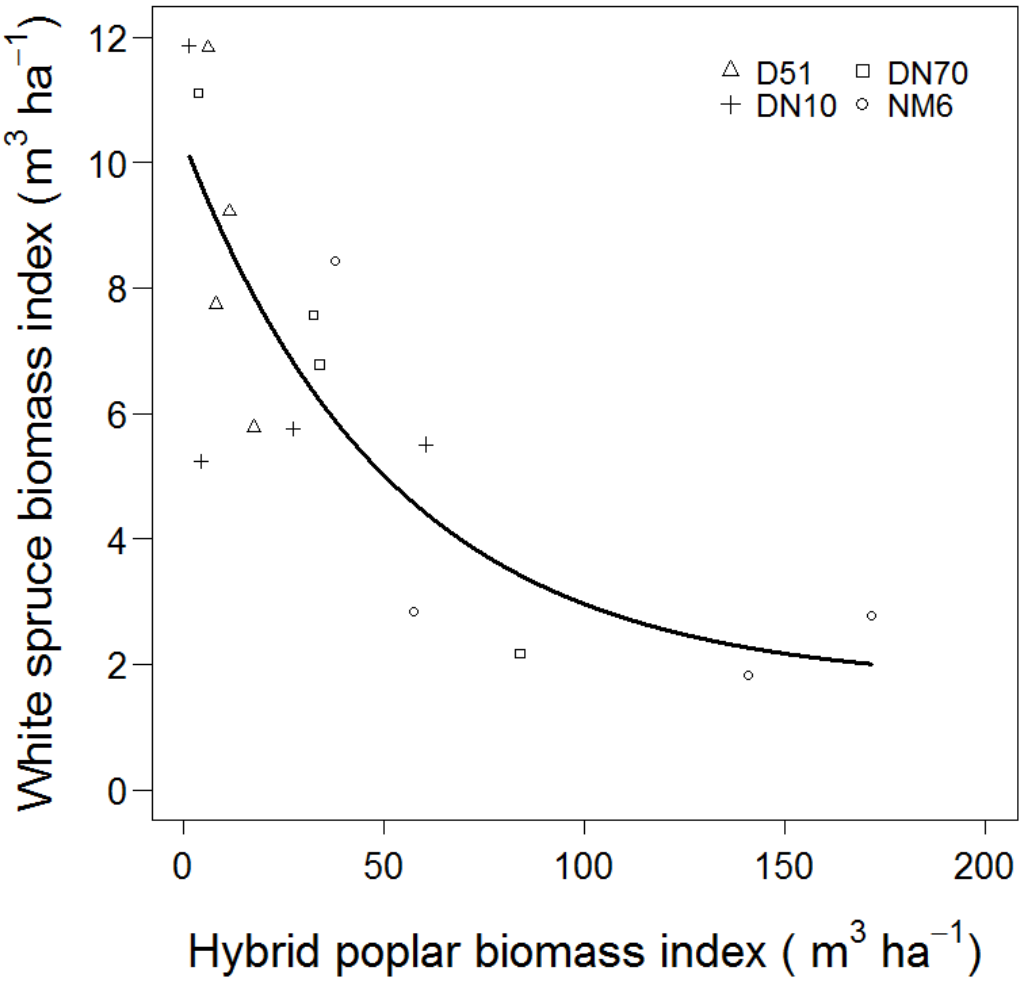
Results: Hybrid poplar-white spruce plantations



Six years after planting, the NM6 clone produced the most biomass both in pure plantations and in mixture with white spruce, followed by the DN70, and the D51 and DN10 clones. White spruce biomass yield did not differ in pure plantations when growing with either of the four hybrid poplar clones in mixture

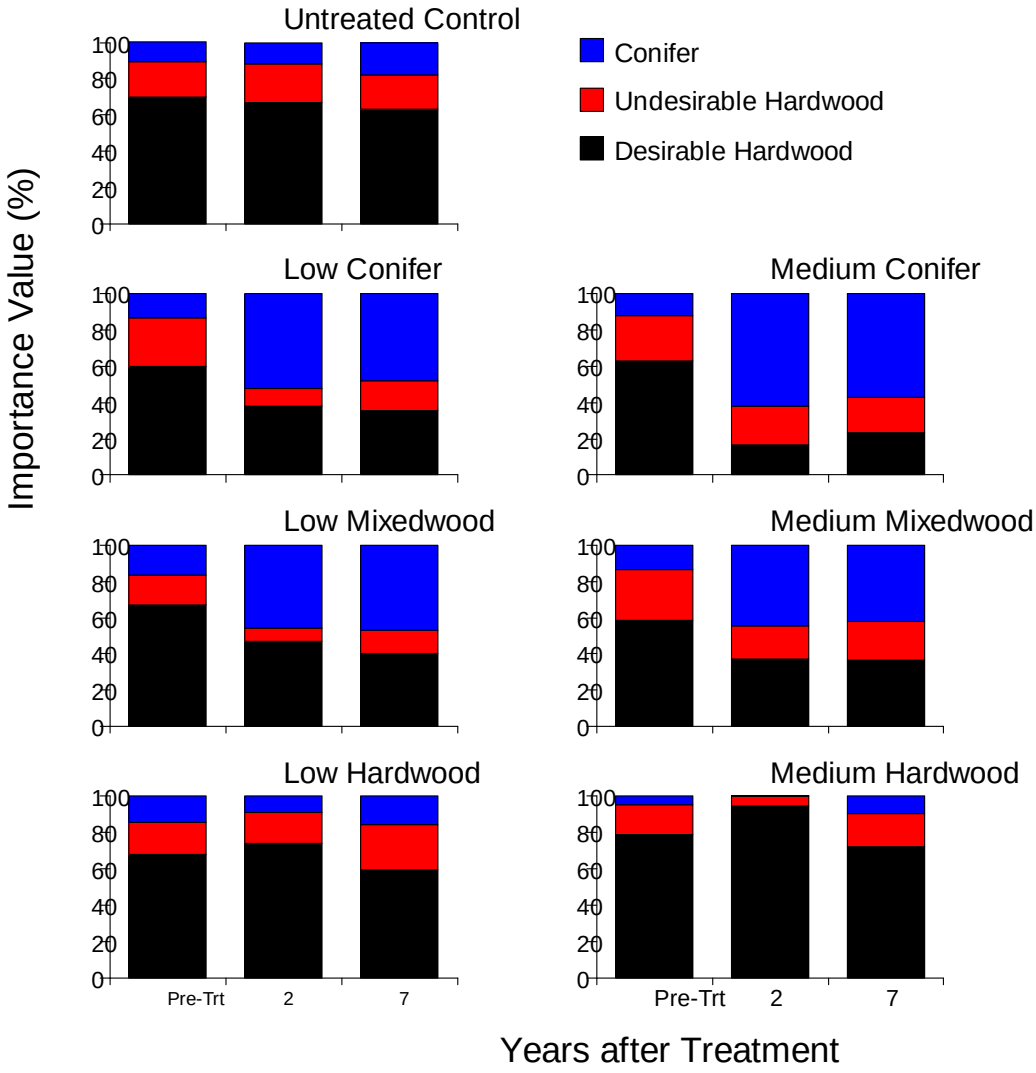
Results: Hybrid poplar–white spruce plantations

White spruce biomass yield was negatively related to hybrid poplar yield in mixture, where the lowest white spruce yields were found when growing near NM6, the clone with the greatest biomass production

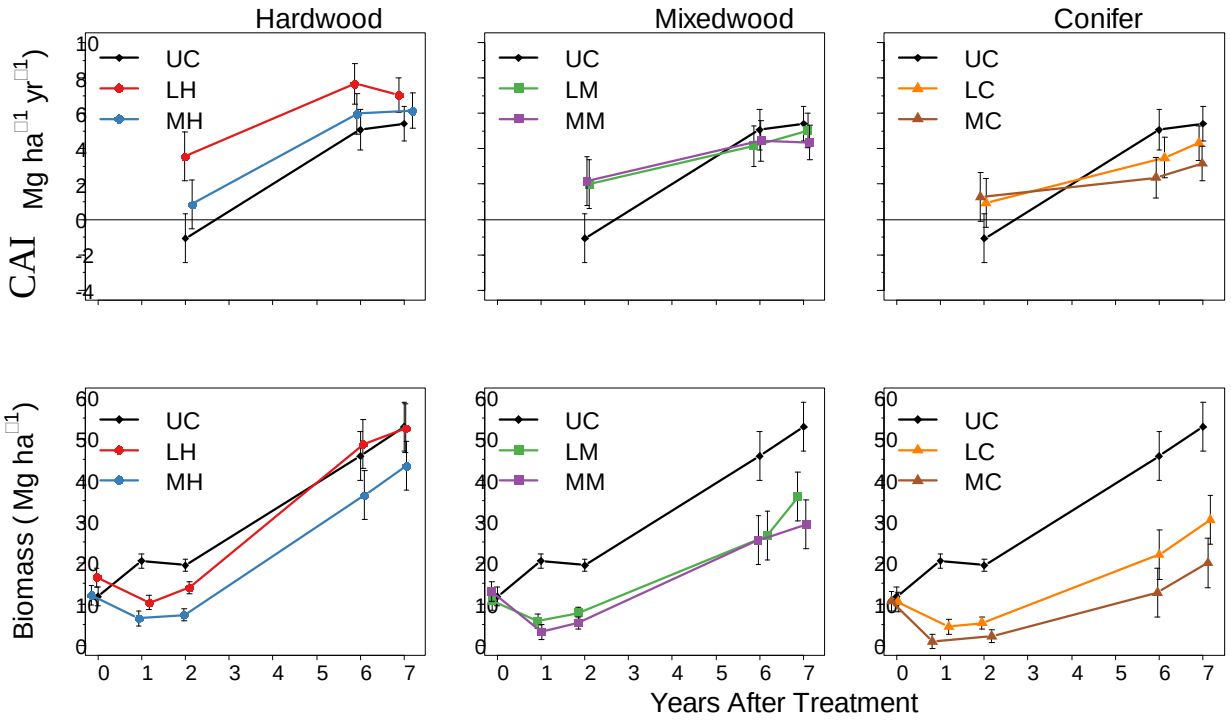


Results: Natural Stand Response to Silvicultural Intensity and Compositional Objectives

- Species composition calculated as the importance value (a function of relative frequency relative density, and relative dominance) of conifer species was increased in the conifer treatments due to the removal of overtopping hardwood species.
- Importance value (IV) of conifer species was also increased in the mixedwood treatments through a combination of conifer release and overstory hardwood thinning
- Hardwood IV was easily maintained in the hardwood treatments where the overstory hardwood component was thinned



Results: Natural Stand Response to Silvicultural Intensity and Compositional Objectives



- Growth, calculated as current annual increment (CAI) of aboveground biomass was greatest in the hardwood treatments, followed by the mixedwood treatments, and lowest in the conifer treatments.
- CAI of the hardwood treatments were greater than the untreated control, CAI of the mixedwood treatments were similar to the untreated control, and CAI of the conifer treatments were lower than the untreated control
- Even though hardwood stands were thinned, biomass yield seven years after treatment were not different than the untreated control. The biomass yield of the mixedwood and confer treatments were substantially lower than the hardwood treatments and untreated control

Implications and applications in the Northern Forest region

- Our results demonstrate:
  - The need for additional model evaluation of biomass models available in the region for accurate accounting of the forest resource and carbon storage,
  - The potential yield of juvenile white spruce and hybrid poplar plantations in the region, showing that the *Populus nigra* x *P. maximowiczii* clone clearly outperformed the three *P. deltoides* x *P. nigra* clones
  - Early successional Acadian stands that develop following complete overstory disturbance can be shifted early in stand development to achieve a variety of objectives, including hardwood stand for high yield biomass production, accelerated conifer growth following release from hardwood cover, and a combination of the two in mixedwood stands

Implications and applications in the Northern Forest Region

Array of silvicultural treatment plots seven years after treatment application. Images show the distinct trajectories of each treatment

Future directions

- Additional tree biomass data is necessary for the development of new regional biomass models and evaluation of existing models. Trees should be sampled from multiple sites to capture site variability across the region.

- Investigators should implement operational scale treatments similar to those examined in this investigation to encourage wide-spread adoption

List of products

Peer-reviewed publications

- Nelson, A.S., Weiskittel, A.R., Wagner, R.G., and Saunders, M.R. *In press*. Development and verification of aboveground small tree biomass models for naturally regenerated and planted tree species in eastern Maine, U.S.A. Biomass and Bioenergy.
- Nelson, A.S., Wagner, R.G., Saunders, M.R., and Weiskittel, A.R. 2013. Influence of management intensity on the productivity of early successional Acadian stands in eastern Maine Forestry 86(1): 79-89.
- Nelson, A.S., Saunders, M.R., Wagner, R.G., and Weiskittel, A.R. 2012. Early stand production of hybrid poplar and white spruce in mixed and monospecific plantations in eastern Maine. New Forests 43: 519-534.

Other publications

- Nelson, A.S., Wagner, R.G., and Saunders, M.R. 2014. Silvicultural options for early-successional stands in Maine: Six-year results of the silvicultural intensity and species composition experiment. *In:* Penobscot Experimental Forest:60 Years of Research and Demontsration in Maine, 1950-2010. U.S. Department of Agriculture, Forest Service, Northern Research Station. Gen. Tech. Rep. NRS-P-123. Pp. 91-102.
- Nelson, A.S., Weiskittel, A.R., Wagner, R.G., and Saunders, M.R. 2012. Verification of the Jenkins and FIA Sapling biomass equations for hardwood species in Maine. *In* Moving from Status to Trends: Forest Inventory and Analysis (FIA) Symposium 2012. *Edited by* R.S. Morin, and G.C. Liknes. USDA Northern Research Station Gen. Tech. Rep. NRS-P-105, Baltimore, MD. pp. 373-377.
- Nelson, A.S., Wagner, R.G., Weiskittel, A.R. 2012. Verification of regional and national aboveground sapling biomass equations in Maine. *In* Cooperative Forestry Research Unit 2012 Annual Report. *Edited by* B. Roth, Orono, ME.
- Nelson, A.S., Wagner, R.G., Saunders, M.R., and Weiskittel, A.R. 2011. Influence of silvicultural intensity and compositional objectives on the productivity of regenerating Acadian mixedwood stands in Maine, USA. *In* 7th International Vegetation Management Conference. IUFRO Unit 1.01.01 Forest Vegetation Management, Valdivia, Chile. pp. 90-92.
- Nelson, A.S., and Wagner, R.G. 2010. Productivity of hybrid poplar on forested sites in Maine. *In* Cooperative Forestry Research Unit 2010 Annual Report. *Edited by* W.J. Mercier, and A.S. Nelson, Orono, ME. pp. 16-22.

List of products

Leveraged grants

- Wagner, R.G., Weiskittel, A.R., and Nelson, A.S. 2012-2014. Incorporating young hardwood stand responses to various levels of silviculture and stand composition into new CFRU growth & yield models. Cooperative Forestry Research Unit. $67,871.

Conference presentations

- Wagner, R.G., Bataineh, M., Olson, M.G., Nelson, A.S., Rice, B. 2013. Infleunce of partial harvesting on hardwood regeneration. *Presented at*: Northern Hardwood Research Institute Fall Meeting. Edmundston, New Brunswick, Canada.
- Nelson, A.S., Wagner, R.G., Saunders, M.R., and Weiskittel, A.R. 2012. Influence of silvicultural intensity and species composition on the productivity of young Acadian stands in eastern Maine. *Presented at:* 2012 Eastern Canada-USA Forest Science Conference. Durham, NH.
- Nelson, A.S., Weiskittel, A.R., Wagner, R.G., and Saunders, M.R. 2012. Development and validation of aboveground sapling biomass equations in Maine. *Presented at:* 16th Annual Northeastern Mensurationists Organization Meeting. State College, PA.
- Nelson, A.S., Weiskittel, A.R., and Wagner, R.G. 2011. Crown and total biomass equations of young, naturally regenerated hardwood species in central Maine. *Presented at:* 15th Annual Northeastern Mensurationists Organization Meeting. Quebec City, Quebec, Canada.
- Nelson, A.S., Saunders, M.R., Wagner, R.G., and Weiskittel 2011. Hybrid poplar and white spruce stand production in mixed and monospecific plantations on the Penobscot Experimental Forest. *Presented at:* School of Forest Resources Noontime Seminar Series. University of Maine, Orono, ME.
- Nelson, A.S., Wagner, R.G., and Saunders, M.R. 2010. Influence of silvicultural intensity and compositional objectives on the productivity of regenerating Acadian forest stands. *In* Eastern Canada-USA Forest Science Conference, Université de Moncton, Edmundston, NB, Canada. p. 45.