Effects of Climate Change on Growth, Productivity, and Wood Properties of White Pine in Northern Forest Ecosystems

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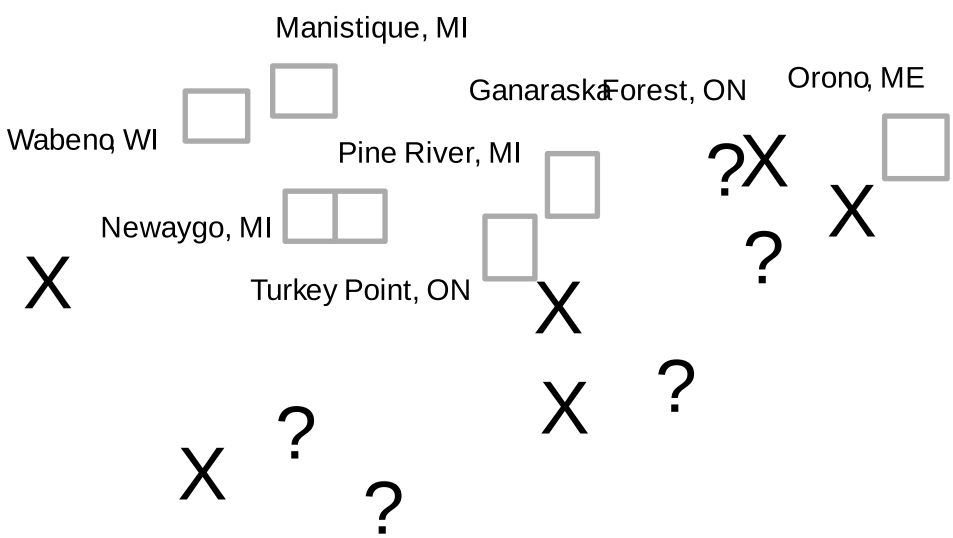
Using climate models and data collected from provenances grown in long-term trials established in the 1960s, our objectives were to:

1. Predict the effects of climate change on growth, productivity, and wood properties of existing white pine forests;
2. Estimate C sequestration potential of white pine under new climate regimes;
3. Quantify range of genetic variation in climatic response and adaptive traits of white pine;
4. Develop seed transfer models from historic climate data and provenance trial data from a subset of test locations;
5. Use validated models from (4) and future climate projections to: a) predict radial and stem growth response of white pine in the northeastern U.S., and b) contribute to provisional seed transfer recommendations for assisted migration of white pine seed sources to help adapt northern forests to future climate.

Figure 1. Seven proposed provenance trials for the current study. All sites with green tre were part of an original range-wide IUFRO white pine study established in the early 1960's the eastern United States and Canada. Trees with an "X" indicate trials that no longer exist, while the status of those marked "?" is uncertain.



Background and Justification

There is a need for long

Methods

The proposed project was conducted at seven sites belonging to a range-wide International Union of Forestry Research Organizations (IUFRO) white pine study established in the early 1960s in the eastern United States and Canada (Figure 1). In total, 13 white pine provenances were evaluated at each site, with the exception of the Orono trial that has 12 of the 13 (Table 1). Field protocols for tree measurement and sample collection were developed at the Ganaraska Forest, Ontario, Canada during October 2009. In addition, historic data from sites such as the Orono trial and those in Wisconsin and Michigan were assembled and used.

Table 1. Seed sources (provenances) to be used in the proposed study that belong a range-wide IUFRO white pine study established in the early 1960's in the eastern United States and Canada.

Seed Source Number				
Canada	United States	Location of Origin	Latitude	Longitude
1	1633	Union County, Georgia	34°5´	84°0´
2	1634	Greene County, Tennessee	36°0´	82°5´
3	1640	Monroe County, Pennsylvania	41°1´	75°3´
4	1639	Franklin County, New York	44°3´	74°2´
5	1638	Penobscot County, Maine	44°5´	68°4´
6	1632	Ashland County, Ohio	40°5´	82°2´
7	1624	Allamakee County, Iowa	43°2´	91°2´
8	1622	Cass County, Minnesota	47°2´	94°3´
9	1623	Forest County, Wisconsin	45°5´	88°5´
10	1637	Luneborg County, Nova Scotia	44°3´	64°4´
11	1635	Pontiac District, Quebec	47°3´	77°0´
12	1636	Algoma District, Ontario	46°1´	82°4´
13[a]	1670	Newaygo County, Michigan	43°3´	85°4´

[a] Seed source was not established at Orono, Maine.

- Height, diameter at breast height (dbh), and survival were recorded for each experimental tree located at each of seven sites (Wabeno, WI; Manistique, MI; Pine River, MI; Newaygo, MI; Turkey Point, ON; Ganaraska Forest, ON; Orono, ME)
- Two wood cores were collected from each tree, permanently mounted and sanded to prepare them for radial growth trend analysis using standard dendrochronology procedures and x-ray densitometry (see below)
- Scanned images of individual cores were processed with cross-dating (COFECHA) and tree ring analysis (WinDENDRO, Regent Instruments, Quebec) software.
- Mean tree ring width, mean annual basal area increment, and total tree ring basal area increment over the period 1980 to 2004 were estimated for each provenance.
- Quantitative genetic and dendrochronological analyses were used to develop the universal response functions
- X-ray densitometry was used to measure intra and inter-ring tree density

Key Findings and Accomplishments

- The universal response function for white pine height growth performed very well and indicated that it was sensitive to trial site and seed source temperature and precipitation and (Table 2).
- The universal response function for white pine diameter growth indicated that it was affected both by trial site and seed source temperature and precipitation (Table 3).
- Dendroclimatic analysis indicated that natural populations of white pine in Michigan were more responsive to the Climate Moisture Index (CMI) than temperature. In Wisconsin and in Canada (Turkey Point), white pine radial growth was more responsive to temperature than to CMI.
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Table 3. Multiple regression analysis predicting mean DBH growth of white pine from site and provenance climate in the form of a universal response function.

Independent Variable	Parameter Estimate	Partial R^2	Model R^2	F	P
Intercept	-22.024				
T_B11_TCOL_2	-0.0022	0.320	0.320	13.1948	0.0005
T_B05_MTWP_2	0.0095	0.147	0.467	17.3814	0.0001
T_B14_PDP_2	0.0006	0.049			

Implications and Applications in the Northern Forest Region

- For the dendroclimatic analysis of seed sources at each trial site location, the first principal component explained the most significant variation in growth which indicates that the regional climatic conditions exerts a generally uniform response in the seed sources at each trial site (Table 4). While the amount of variation in PC2 was not statistically significant, the explained variance is geographically and biologically meaningful (Table 4, Figure 2).
- In the Wabeno (WI) trial site location, PC1 was significantly associated with seed source elevation and PC2 was related to seed source longitude. For both Turkey Point (ON) and Orono (ME) assoc(s)-1(s)-1(oc)4(i)-2(a)4(t)-2(e)4()6(o)-2(a)4(l)d to seed sourcelev-10(g)10(43(O)2

Figure 2. Relationships between the first (PC1) and second (PC2) principal component axis of white pine radial growth of seed sources at each trial site location and monthly and seasonal a) mean temperature and b) Climate Moisture Index examined via multiple regression analysis. For

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Products

Papers in Progress

Growth response functions of provenance trials under past and future climate.

Dendroclimatic analysis of white pine natural forests under past and future climate.

Dendroclimatic analysis of white pine provenance trials under past and future climate.

Refereed Journal Publications

Zalesny, R.S. Jr., and Headlee, W.L. 2015. Developing woody crops for the enhancement of ecosystem services under changing climates in the North Central United States. Journal of Forest and Experimental Science 31:78-90.

Invited Papers and Presentations

Zalesny, R.S. Jr., and Headlee, W.L. 2014. Developing woody crops for the enhancement of ecosystem services under changing climates in the North Central United States. In: International Symposium on Tree Breeding Strategies to Cope with Climate Change; September 15-19, 2014; Suwon, Republic of Korea. (Invited Oral Presentation with Refereed Proceedings)

Offered Papers and Presentations

Parker, W.C. 2014. Forest ecosystem vulnerability in the Great Lakes basin of Ontario. Ontario Ministry of Natural Resources and Forestry Climate Change Symposium, November 24, 2014, Peterborough, Ontario. (Oral Presentation)

Parker, W.C. 2014. Pre-symposium field tour of the Ganaraska, ON white pine provenance trial site, November 23, 2014. Ontario Ministry of Natural Resources and Forestry Climate Change Symposium, November 24, 2014, Peterborough, Ontario. (Oral Presentation)

Zalesny, R.S. Jr., and Headlee, W.L. 2014. Comparing aboveground stand-level carbon storage potential of intensively-managed poplar with plantation-grown eastern white pine in the North Central United States. In: International Poplar Symposium VI; July 20-23, 2014; Vancouver, British Columbia, Canada. (Poster Presentation and Published Abstract). Also presented as: Zalesny, R.S. Jr., Headlee, W.L., Bauer, E.O., Birr, B.A., Hall, R.B., Parker, B., and Wiese, A.H. 2014. Contrasting ecosystem services of hybrid poplar and white pine in the Upper Midwest, USA. In: 10th Biennial Conference of the Short Rotation Woody Crops Operations Working Group; July 17-19, 2014; Seattle, WA, USA. (Poster Presentation and Published Abstract)

Zalesny, R.S. Jr., Bauer, E.O., Birr, B.A., Brissette, J., Colombo, S., Froese,, R.E., Groom, L.,

Populus and *Pinus* in North America. In: 9th Biennial Conference of the Short Rotation Woody