Assisted Migration and Forestry in Canada under a changing climate

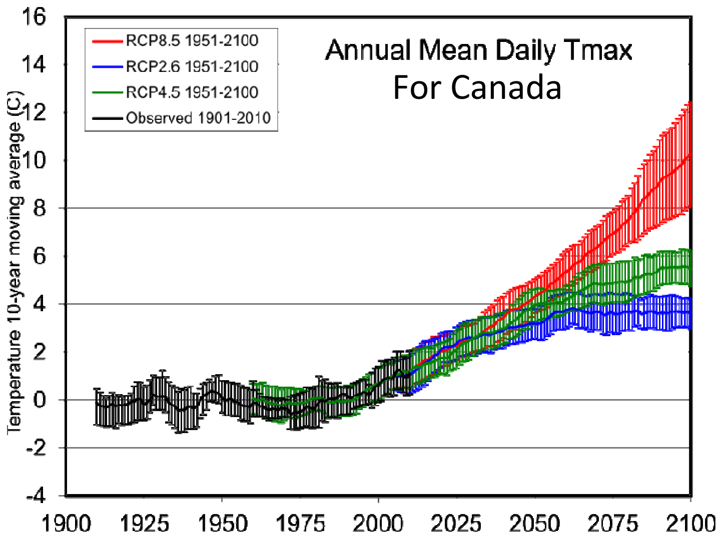
Dan McKenney, John Pedlar
Canadian Forest Service, Natural Resources Canada
dan.mckenney@canada.ca

- Some context
- AM in Canada
- Seedwhere

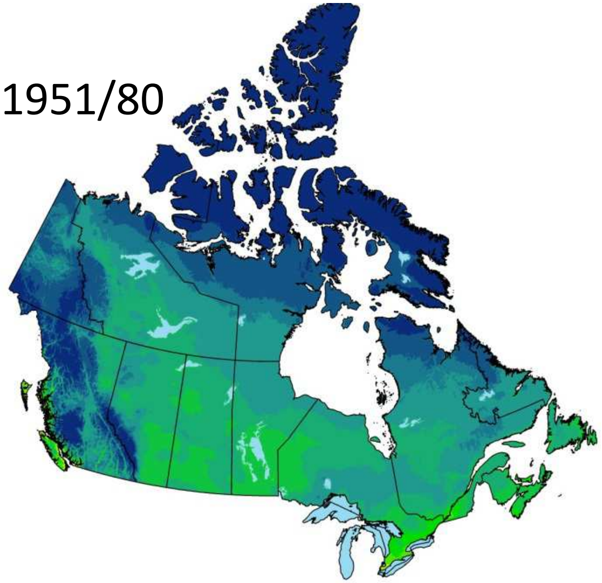
“The future ain’t what it used to be”

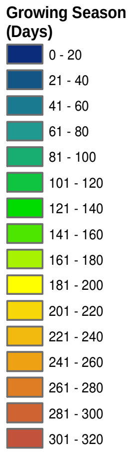
- Yogi Berra -

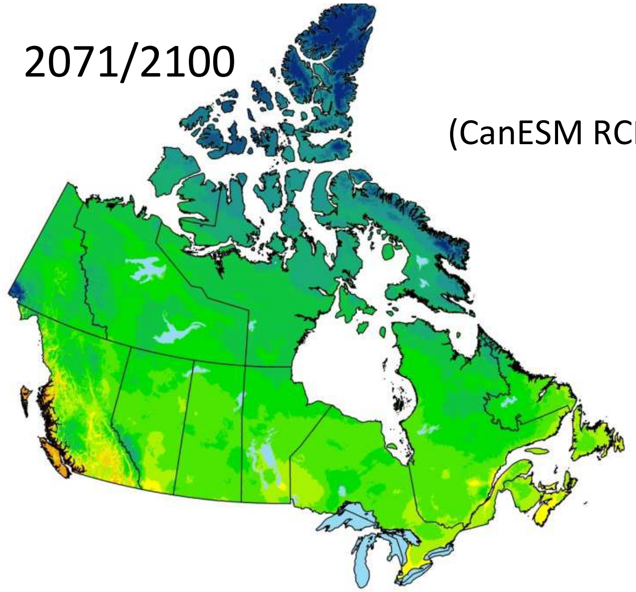
- Climate change has forced a rethink of many forest management paradigms
- Climate has already changed and we are locked into more change
- Do we continue with local seed sources the best option for forest regeneration? ….Or do we do some form of Assisted Migration?

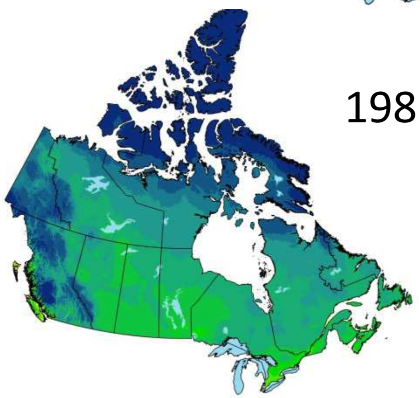


This shows a map of France overlapped onto Canada









Growing seasons have changed and are projected to change significantly more during the course of the coming century

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A Comparison of Two Approaches for Generating Spatial Models of Growing-Season Variables for Canada

JOHN H. PEDLAR, DANIEL W. MCKENNEY, KEVIN LAWRENCE, AND PIA PAPADOPOL

Great Lakes Forestry Centre, Canadian Forest Service, Natural Resources Canada, Sault Ste. Marie, Ontario, Canada

MICHAEL F. HUTCHINSON

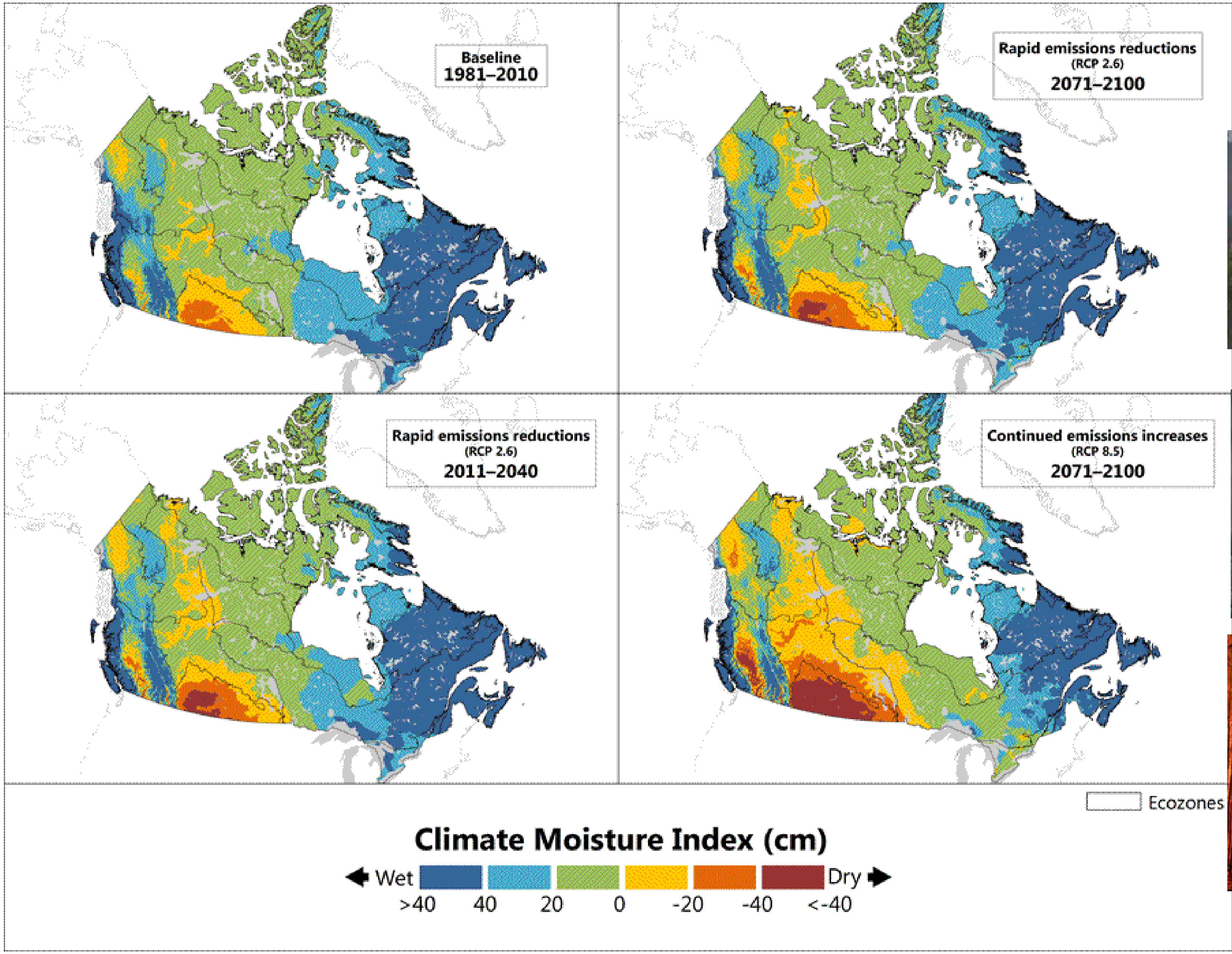
Fenner School of Environment and Society, Australian National University, Canberra, Australian Capital Territory, Australia

DAVID PRICE

Northern Forestry Centre, Canadian Forest Service, Natural Resources Canada, Edmonton, Alberta, Canada

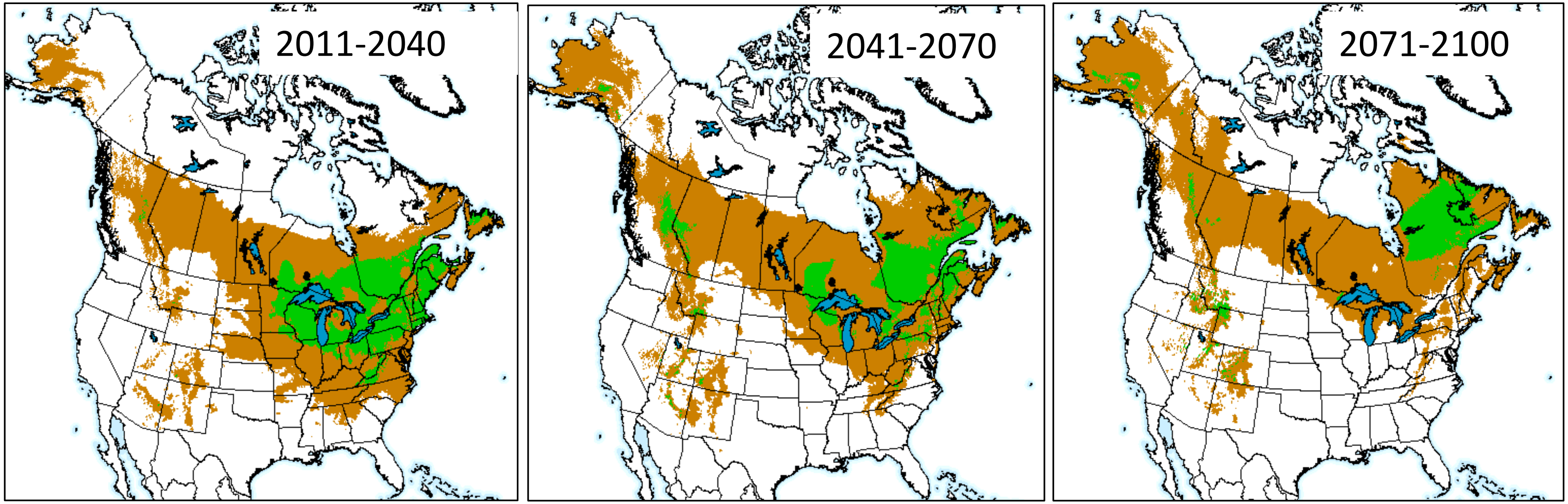
Natural Resou
Canada

But so is dryness…..



http://www.nrcan.gc.ca/forests/climate-change/forest-change/17772 (Ted Hogg and David Price)

Another worry: Climate habitat shifts eg *(Acer saccharum)*



- Over the past 50 years tree climate habitat has shifted ~60km
- If RCP8.5 close to correct by 2071-2100 average shift for 130 NA tree species >700km

Forum

2014

Change and Evolution in the Plant Hardiness Zones of Canada

DANIEL W. MCKENNEY, JOHN H. PEDLAR, KEVIN LAWRENCE, PIA PAPADOPOL, KATHY CAMPBELL, AND MICHAEL F. HUTCHINSON

We present 50-year updates for two plant hardiness models (maps), developed originally by Agriculture Canada and the US Department of Agriculture (USDA), that are widely used for plant selection decisions in Canada. The updated maps show clear northward shifts in

Global Change Biology

Global Change Biology (2011) 17, 2720–2730, doi: 10.1111/j.1365-2486.2011.02413.x

Revisiting projected shifts in the climate envelopes of North American trees using updated general circulation models

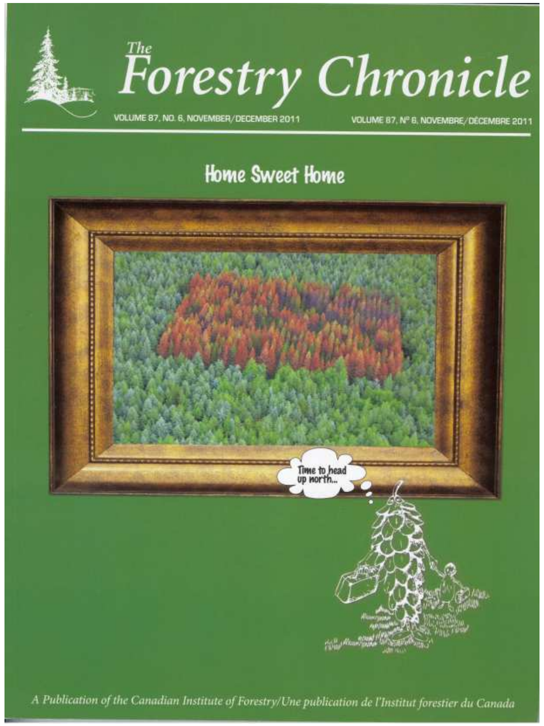
DANIEL W. McKENNEY*, JOHN H. PEDLAR*, RICHARD B. ROOD† and DAVID PRICE‡

Landscape Analysis and Applications Section, Canadian Forest Service, Great Lakes Forestry Centre, 1219 Queen Street E. Sault Ste Marie, ON, Canada P6A 2E5, †Department of Atmospheric, Oceanic and Space Sciences, University of Michigan, 2455 Hayward Street, Ann Arbor, Michigan 48109, USA, ‡Natural Resources Canada, Canadian Forest Service, Northern Forestry Centre, 5320 – 122nd Street, Edmonton, Alberta, Canada

Abstract

Global climate models are constantly being upgraded, but it is often not clear what these changes have on climate change impact projections. We used difference maps to directly compare downscaled projections of temperature and precipitation across North America for two versions (or generations) of three different Atmospheric-Ocean General Circulation Models (AOGCM)s. We found that AOGCM versions differed in their projections for the end of the current century by up to 4 °C for annual mean temperature and 60% for annual precipitation. To place these changes in an ecological context, we reanalyzed our work on shifts in tree climate envelopes (CEs) using the newer-generation

Assisted Migration in Canada



Contributors to the special collection of articles on

Assisted Tree Migration and Climate Change

Isabelle Aubin, Page 755
Tannis Beardmore, Pages 731, 745
Jean Beaulieu, Page 766
Marie-Eve Bonneau, Page 724
Stephen J. Colombo, Pages 755, 766
Anna Dabros, Page 724
Charles R. Drever, Page 755
Cornelia M. Garbe, Page 755
Daniel W. McKenney, Pages 755, 766
Jason S. McLachlan, Page 766
Christian Messier, Page 755
Elizabeth A. Nelson, Pages 724, 731
Gregory A. O'Neill, Page 766
John H. Pedlar, Pages 755, 766
Marc A. Saner, Page 755
Catherine Ste-Marie, Pages 724, 755, 776
Lisa Venier, Page 755
Adam M. Wellstead, Page 755
Richard Winder, Pages 731, 745, 755
Eve Witten, Page 755

NOVEMBER/DECEMBER 2011, VOL. 87, NO. 6 – THE FORESTRY CHRONICLE 723

Johnny Appleseed

- A CFS task group explored the state of AM in Canada
- Findings were summarized in a special issue of the Forestry Chronicle
- Five articles covered topics such as: ecological implications, species vulnerability assessments, ethical considerations, and implementation

Assisted Migration

- An evolving concept -

Topic	Forestry Context	Conservation Context
Objective	Maintaining forest productivity & ecosystem function	Maintaining biodiversity
Target Species	Major tree species	Species of conservation concern
Focal Unit	Populations (or provenances)	Species
Movement Logistics	Mostly within historical range	Mostly outside historical range
Potential Scope	Millions of hectares across N.A. each year	Likely small-scale projects
Feasibility	Many resources already in place	Much capacity-building required

Forum

Placing Forestry in the Assisted Migration Debate

JOHN H. PEDLAR, DANIEL W. McKENNEY, ISABELLE AUBIN, TANNIS BEARDMORE, JEAN BEAULIEU, LOUIS IVERSON, GREGORY A. O'NEILL, RICHARD S. WINDER, AND CATHERINE STE-MARIE

Assisted migration (AM) is often presented as a strategy to save species that are imminently threatened by rapid climate change. This conception of AM, which has generated considerable controversy, typically proposes the movement of narrowly distributed, threatened species to suitable sites beyond their current range limits. However, existing North American forestry operations present an opportunity to practice AM on a larger scale, across millions of hectares, with a focus on moving populations of widely distributed, nonthreatened tree species within their current range limits. Despite these differences (and many others detailed herein), these two conceptions of AM have not been clearly distinguished in the literature, which has added confusion to recent dialogue and debate. Here, we aim to facilitate clearer communication on this topic by detailing this distinction and encouraging a more nuanced view of AM.

Keywords: assisted migration, climate change, forestry, conservation, trees

Forestry vs Species Rescue AM

– Movement Logistics –

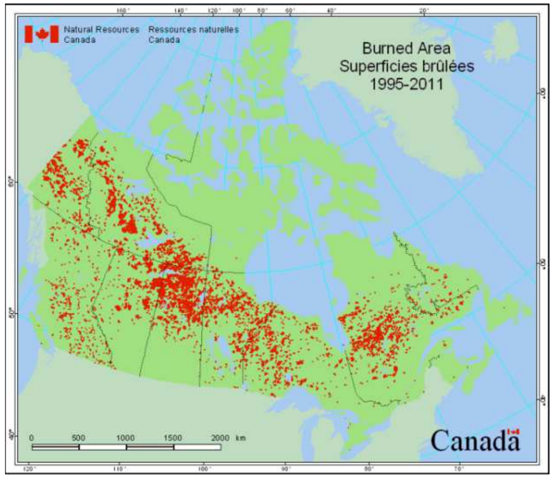
- Most commercial tree species span a wide climatic range
- The 18 species shown here occupy temp. and precip. ***ranges*** of 18 C and 1960 mm on average
- Climate migration distances being advocated in forestry AM are in the range of 1.5 to 3 C

Common Name	Scientific Name	Temperatures Occupied (C)	Precipitation Occupied (mm)
Sugar Maple	*Acer saccharum*	0.4 – 19.5	362 – 2127
American Beech	*Fagus grandifolia*	0.7 – 21.0	633 – 2082
Tamarack	*Larix laricina*	-7.3 – 10.3	292 – 1713
Sweetgum	*Liquidambar styraciflua*	6.7 – 22.7	876 – 1866
White Spruce	*Picea glauca*	-11.9 – 10.6	255 – 3358
Black Spruce	*Picea mariana*	-9.0 – 9.9	278 – 3570
Jack Pine	*Pinus banksiana*	-4.8 – 13.0	328 – 1623
Lodgepole Pine	*Pinus contorta*	-7.5 – 12.5	221 – 4185
Slash Pine	*Pinus elliottii*	13.3 – 23.7	1068 – 1745
Ponderosa Pine	*Pinus ponderosa*	-1.3 – 16.3	195 – 2292
Red Pine	*Pinus resinosa*	-0.4 – 13.5	423 – 1672
White Pine	*Pinus strobus*	-1.1 – 17.2	496 – 2141
Loblolly Pine	*Pinus taeda*	8.8 – 22.6	940 – 1904
Trembling Aspen	*Populus tremuloides*	-6.5 – 12.9	221 – 3503
Black Cherry	*Prunus serotina*	1.7 – 22.6	461 – 2187
Douglas Fir	*Pseudotsuga menziesii*	-3.5 – 16.0	195 – 3323
White Oak	*Quercus alba*	1.4 – 20.5	440 – 2104
Northern Red Oak	*Quercus rubra*	1.3 – 19.7	546 - 2130

Forestry vs Species Rescue AM

– Scope –

- ~ 1.5 million hectares reforested annually in Canada and US
- ~ 5 million hectares harvested or burned annually and allowed to regenerate naturally
- Should AM be extended into these areas?
- Species rescue projects likely at a much smaller scale



The State of Forestry AM in Canada

– British Columbia –

- In March 2009, British Columbia (BC) modified its seed transfer standards, allowing seed of most species in most regions to be moved up to 200 m higher in elevation
- In June 2010, policy was modified to allow western larch (Larix occidentalis Nutt.) to be moved slightly outside its existing range to climatically suitable locations
- A working group within the BC Ministry of Forests, Mines and Lands is currently working toward a climate-based seed transfer system

The State of Forestry AM in Canada

– Alberta –

- Seed transfer guidelines have been revised to extend current seed zone limits northward by up to 2° latitude and upslope by up to 200 m.
- Transfer functions have been developed for major timber species to inform further assisted migration efforts
- Non-native species that are anticipated to migrate naturally into Alberta are being explored; e.g., Ponderosa pine and Douglas-fir are currently being considered as replacements for lodgepole pine

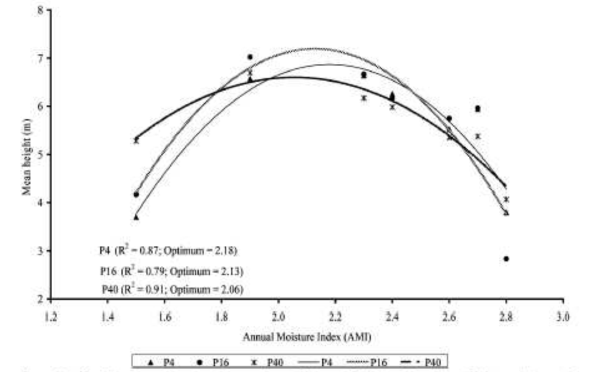


Figure 3. – Height response functions for a northern (P4), central (P16) and southern (P40) population and the predicted optimum AMI.

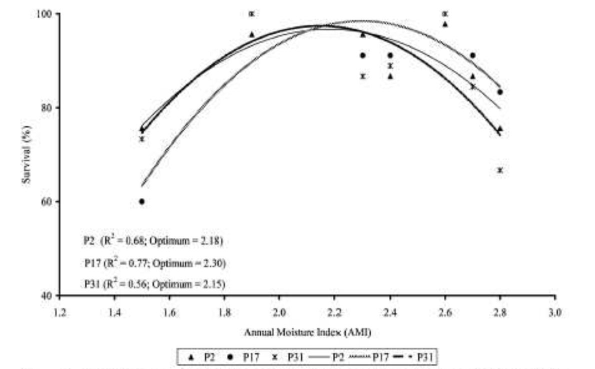


Figure 4. – Survival response function for a northern (P2), central (P17) and southern (P31) population and the predicted optimum AMI.

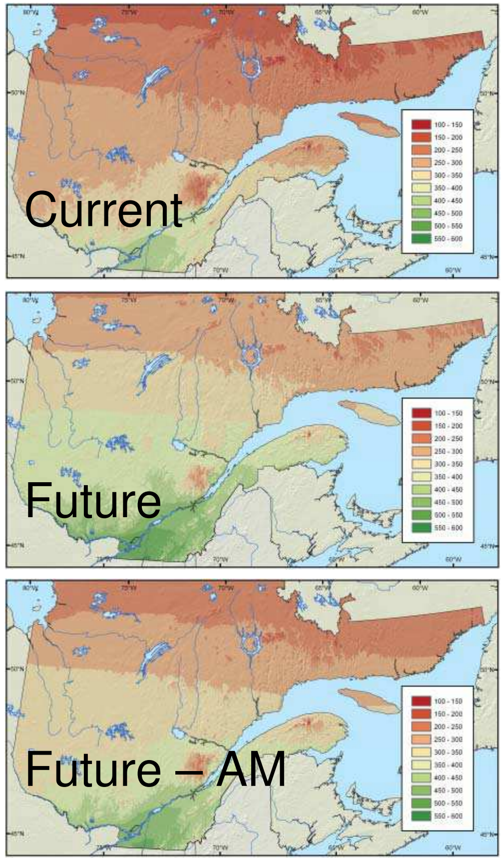
Source: Rweyongeza, D. M., Yang, R. C., Dhir, N. K., Barnhardt, L. K., & Hansen, C. C. (2007). Genetic variation and climatic impacts on survival and growth of white spruce in Alberta, Canada. ***Silvae Genetica***, ***56***(3/4), 117-127.

The State of Forestry AM in Canada

– Québec –

- Northern sites are being planted using a mixture of local and southern seed sources
- Transfer functions developed for major commercial tree species—black spruce, jack pine, and white spruce.
- Two seed transfer tools have been developed:
  - Optisource (Beaulieu 2009), generates maps that show relative risk of maladaptation associated with a given seed transfer
  - An application of the BioSim software (Régnière 1996) that combines biophysical site index, transfer function, and growth and yield models to estimate expected plantation yield for any seed source transferred to any location in the province

White Spruce Yield (m^3/ha)

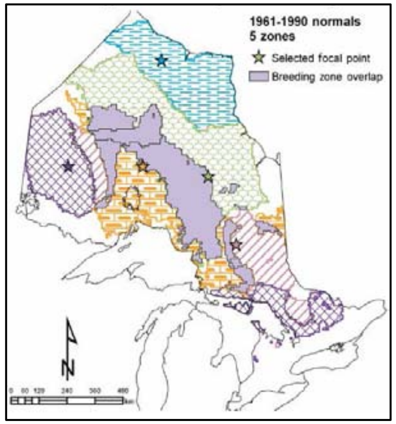


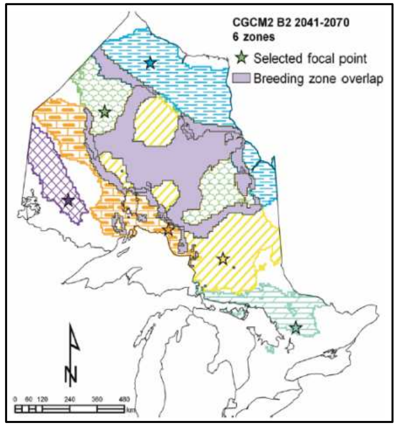
Source: Beaulieu, J. J., & Rainville, A. A. (2005). Adaptation to climate change: Genetic variation is both a short- and a long-term solution. ***Forestry Chronicle***, ***81***(5), 704-709.

The State of Forestry AM in Canada

– Ontario –

- Transfer functions have been developed for major commercial tree species—black spruce, jack pine, and white spruce.
- Growth trials and controlled environment studies have been initiated to explore how species and provenances will fare under changed climate
- Existing provenance studies are being consolidated and re-measured
- The general rule of matching seed source to current seed zone is still in place, but can be considered on a case-by-case basis





Source: A.M. Thomson, K.A. Crowe, and W.H. Parker. 2010. Optimal white spruce breeding zones for Ontario under current and future climates. Can. J. For. Res. 40: 1576–1587.

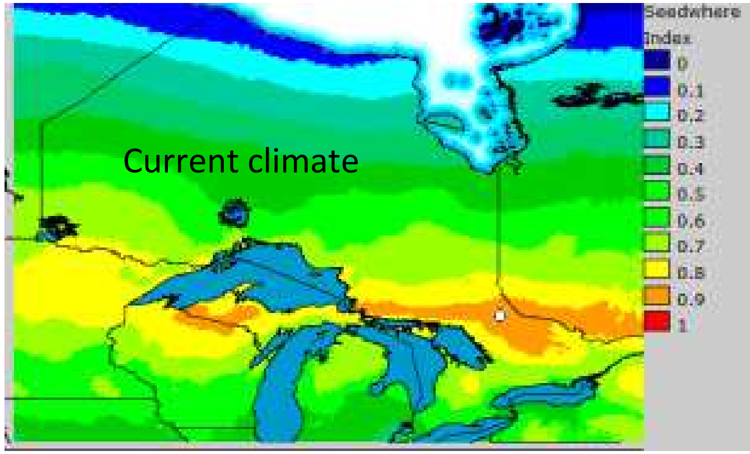
The State of Forestry AM in Canada

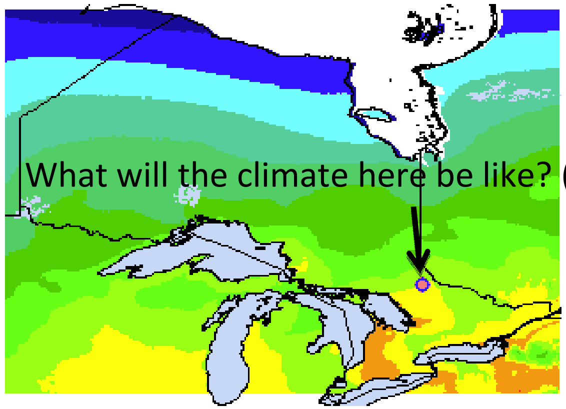
– Other Provinces –

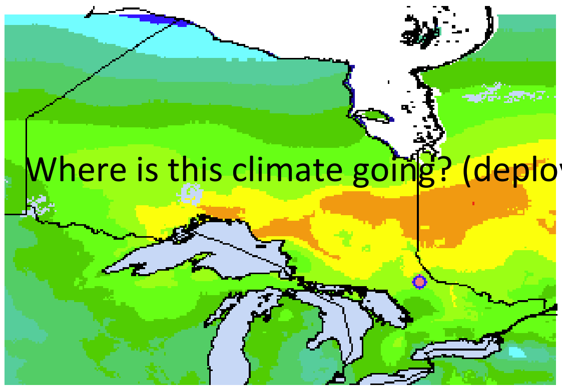
- Other provincial agencies, though not yet implementing AM, are actively engaged in:
  - AM-related dialogue
  - compiling existing provenance data
  - remeasuring established provenance trials
  - initiating new growth trials aimed at elucidating the growth potential of southern provenances

- SeedWhere -

- Seedwhere is a web application that identifies locations with climate similar to a point of interest – can help with the Assisted Migration problem
- employs a Gower index to calculate climate similarity
- can be used with any number of climate variables
- Can incorporate climate change scenarios
- can be used for both seed procurement and deployment







Digging a little deeper into AM….What is the cost/value of alternative seed sources under a changing climate?

- A sustainable, reforestation or restoration plan requires forests to be appropriately matched to future climates.

- Two kinds of decisions:
  (a) seed deployment
  (b) seed procurement

- Study compares forest regeneration using local, Seedwhere, and URF-based seed transfer decisions

- Test Question: Local seed, Seedwhere or a more advanced rule?

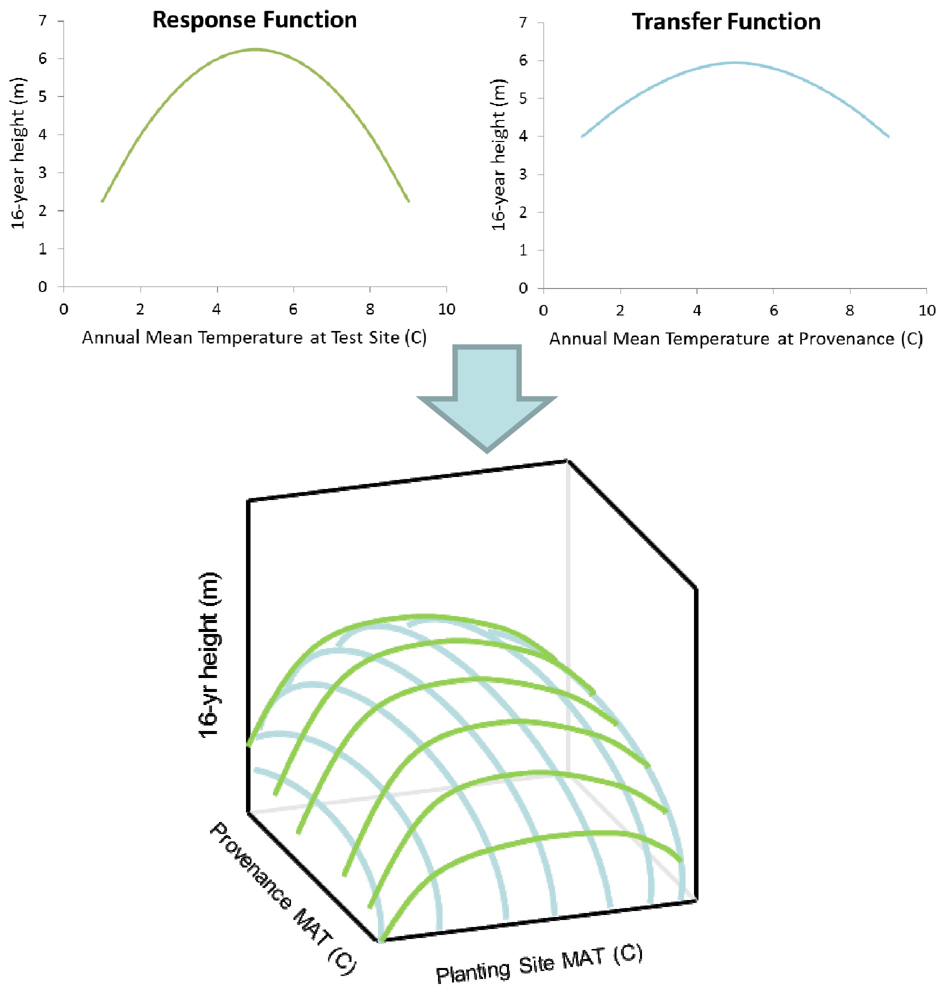
An economic analysis of seed source options under a changing climate for black spruce and white pine in Ontario, Canada

Daniel W. McKenney, John H. Pedlar, Jing Yang, Alfons Weersink, and Glenn Lawrence

Can. J. For. Res. **45**: 1248–1257 (2015) dx.doi.org/10.1139/cjfr-2015-0051

- Universal Response Functions -

- approach developed by Wang et al. (2010)
- combines traditional response functions and transfer functions into a single equation
- can (in principle) predict the growth of any provenance based on the climate at both the test site and the provenance site



URF Results

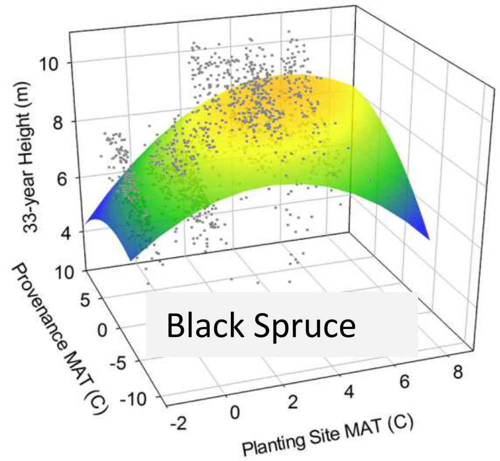
- both species showed a significant relationship with MAT (R^2 ~ 0.35; MAE ~ 12%, ~1m):

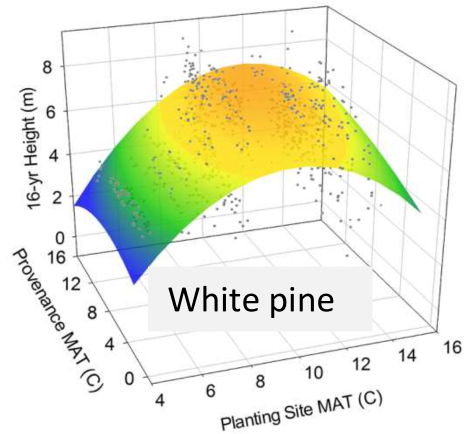
$$Ht_{33} = 7.29 + 0.568*MAT_s - 0.074*MAT_s^2 + 0.044*MAT_p - 0.015*MAT_p^2 + 0.031*MAT_s*MAT_p$$

$$Ht_{16} = -4.468 + 1.942*MAT_s - 0.093*MAT_s^2 + 0.270*MAT_p - 0.022*MAT_p^2 + 0.001*MAT_s^{2}*MAT_p^2$$

- showed strong response across test sites, with optimal MAT of ~4.5˚C for black spruce and ~11˚C for white pine (= strong 'environmental effect')

- weak response across provenances at a given test site (=weak 'genetic effect')





Yang, J., Pedlar, J.H., McKenney, D.W., and Weersink, A. 2015. The development of universal response functions to facilitate climate-smart regeneration of black spruce and white pine in Ontario, Canada. For. Ecol. Manage. **339**: 34–43. doi:10.1016/j.foreco.2014.12.001.

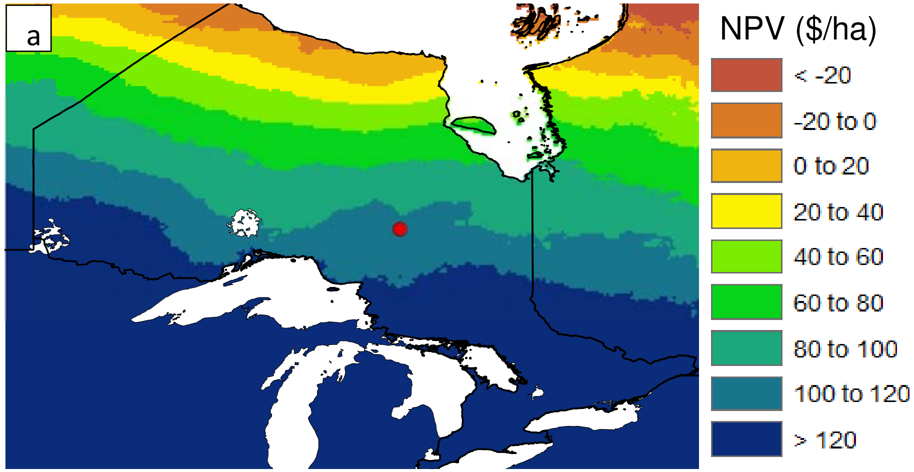
URF study
- Summary -

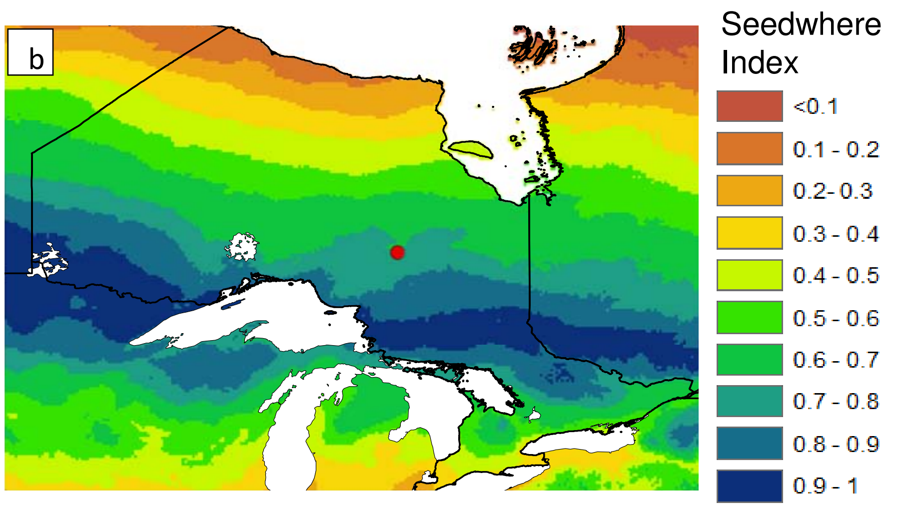
- Local seeds are not necessarily best
- Both species appear adapted to a central climatic optimum
  - 4.5ºC for black spruce and 11ºC for white pine
- Northern populations appear relatively well adapted to warming conditions
- Southern populations appear poorly adapted to warming conditions
- Now we can start to compare the economics of Local vs Seedwhere-based vs URFs seed source selections.

Black spruce seed PROCUREMENT for Hearst

Seedwhere Index Class	Net Present Value ($/ha)			Stand Volume (m^3/ha)		
	Min	Max	Mean	Min	Max	Mean
0.0-0.1	-38.5	-17.3	-24.2	113.1	122.2	119.2
0.1-0.2	-15.1	2.8	-4.1	123.2	130.9	127.9
0.2-0.3	4.9	123.2	21.9	131.8	183	139.2
0.3-0.4	23.8	128.4	72.6	140.0	185.2	161.1
0.4-0.5	43.2	131.2	87.7	148.4	186.4	167.6
0.5-0.6	59.2	132.3	98.8	155.3	186.9	172.4
0.6-0.7	73.8	132.3	99.8	161.6	186.9	172.8
0.7-0.8	88.3	131.2	107.5	167.9	186.4	176.2
0.8-0.9	99.6	128.3	115	172.8	185.2	179.4
0.9-1.0	109.4	123.7	116.9	177.0	183.2	180.2

Southern seed sources will like it in Hearst in the future….SeedWhere works!



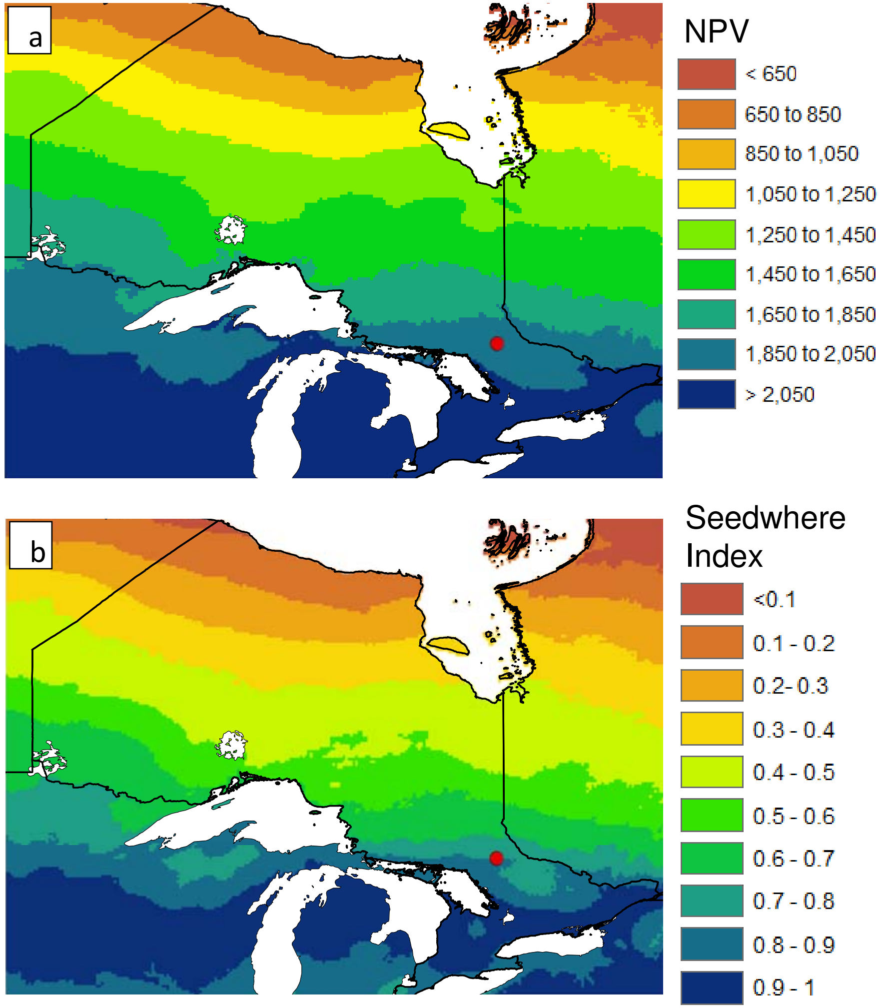


Notes: The price in this simulation model is assumed to set at $20/m^3, cost is set at $300/ha and discount rate is 4%; Each NPV is maximized at site through Faustman formula; IPCC RCP8.5 climate path

White pine seed PROCUREMENT for North Bay

Seedwhere Index Class	Net Present Value ($/ha)			Stand Volume (m^3/ha)		
	Min	Max	Mean	Min	Max	Mean
0.0-0.1	369.8	559.2	508.3	238	305.3	287.2
0.1-0.2	573.7	746.2	659.7	310.5	371.8	341.0
0.2-0.3	760.4	940.2	858.0	376.8	440.7	411.5
0.3-0.4	953.6	1110.0	1039.4	445.5	501.0	475.9
0.4-0.5	1122.6	1267.2	1192.5	505.5	556.9	530.3
0.5-0.6	1278.7	1419.8	1342.0	561.0	611.1	583.5
0.6-0.7	1430.0	1544.2	1485.7	614.7	655.3	634.5
0.7-0.8	1553.0	1878.4	1615.5	658.4	774.1	680.6
0.8-0.9	1665.0	1876.2	1765.1	698.2	773.3	733.8
0.9-1.0	1748.9	1855.0	1808.8	728.0	765.8	749.3

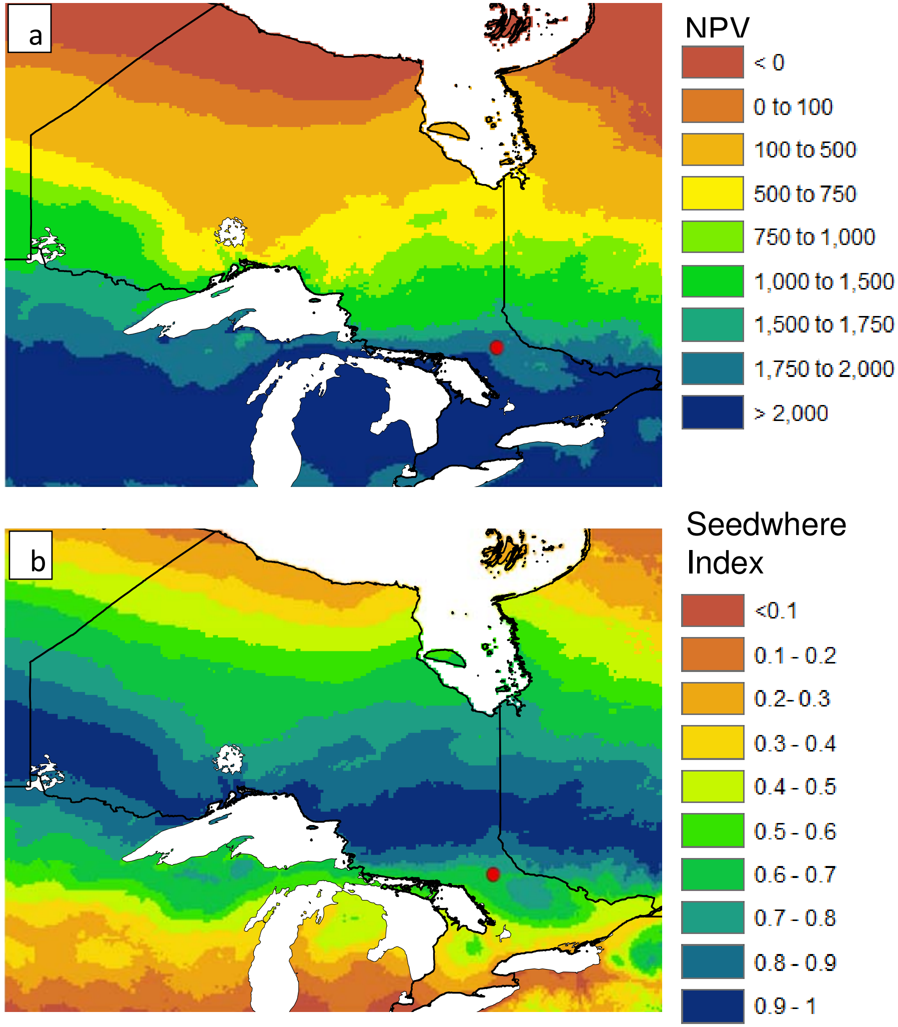
White pine seed sources will be fairly happy to move north …SeedWhere works again!



Notes: The price in this simulation model is assumed to set at $20/m^3$, cost is set at $300/ha and discount rate is 4%; Each NPV is maximized at site through Faustman formula

White pine seed DEPLOYMENT for North Bay

Seedwhere Index Class	Net Present Value ($/ha)			Stand Volume (m³/ha)		
	Min	Max	Mean	Min	Max	Mean
0.0-0.1	-200.3	1652.4	1540.5	139.9	570.2	537.5
0.1-0.2	-213.3	1749.5	1339.7	121.5	598.6	504.2
0.2-0.3	-175.4	1776.2	880.1	174.7	606.4	439.4
0.3-0.4	-113.2	1785.6	1004.5	261.9	741.1	499.1
0.4-0.5	-50.3	1785.6	839.8	295.5	741.1	536.6
0.5-0.6	27.0	1767.1	777.3	376.8	734.5	555.0
0.6-0.7	133.1	1721.0	826.9	390.1	718.1	558.3
0.7-0.8	263.6	1619.1	775.2	382.9	681.9	557.8
0.8-0.9	417.5	1478.7	853.8	384.6	633.0	527.3
0.9-1.0	648.5	1281.5	963.7	380.2	670.8	523.1



Notes: The price in this simulation model is assumed to set at $20/m³, cost is set at $300/ha and discount rate is 4%; Each NPV is maximized at site through Faustman formula

WARNING!!! White pine FROM North Bay does not want to go North …….prefers warmer climates than even this scenario suggests! Now what?

Conclusions

- Strong interest in AM in Canada and policy changes are happening in many provinces
- assisted population migration can likely help but not a magic bullet!
- “Range position” is another promising tool for the toolkit…see Pedlar & McKenney Nature Scientific Reports: Assessing the anticipated growth response of northern conifer populations to a warming climate (out this week!)