Dendroclimatic analysis of white pine (*Pinus strobus*) provenance trials across eastern North America including the United States and Canada

Sophan Chhin, Ronald Zalesny Jr.,
Bill Parker, John Brisette, Steve Colombo,
Pengxin Lu, Michael Ter-Mikaelian

West Virginia University

Forest Service U.S. Department of Agriculture

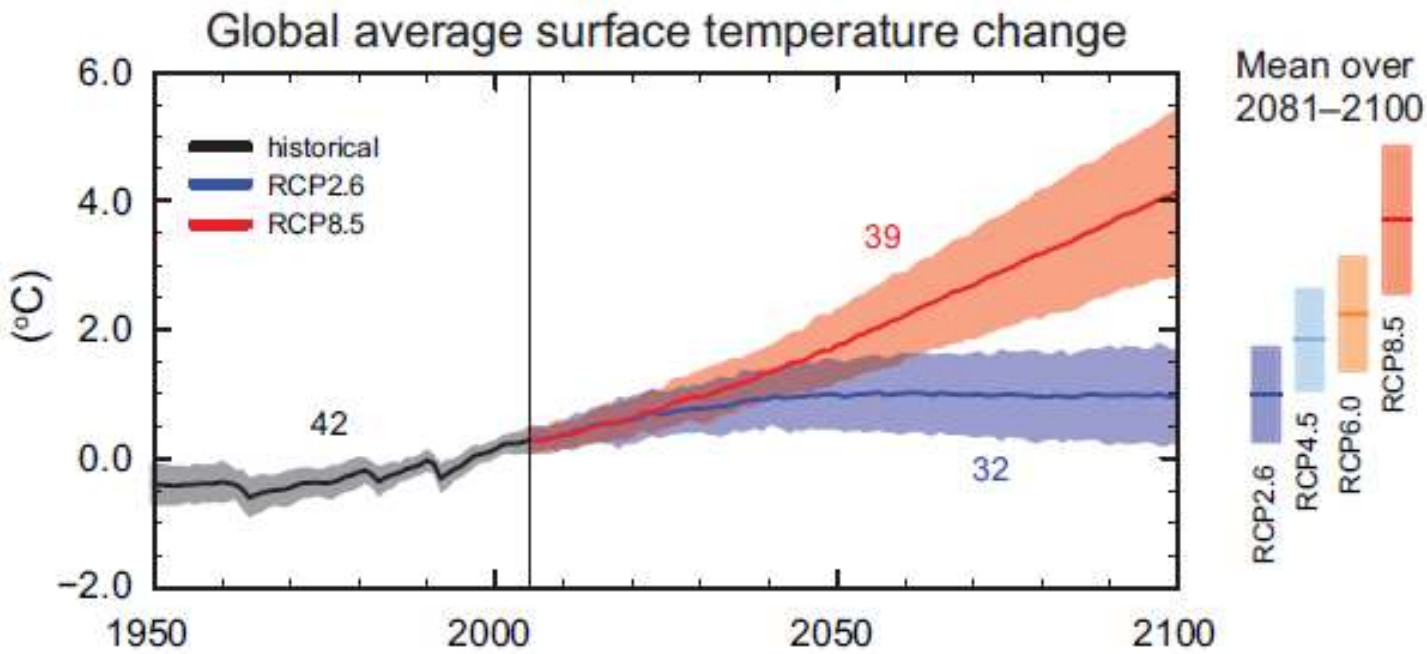
Ontario
Ministry of Natural Resources and Forestry

GFBI-FECS Joint Symposium 7 September 2017

Climate Change

Global Warming

- **1850-1900 →2003-2012: 0.78ºC increase**
- **Future projections: 0.3ºC – 4.8ºC increase by 2081-2100 relative to 1986-2005**



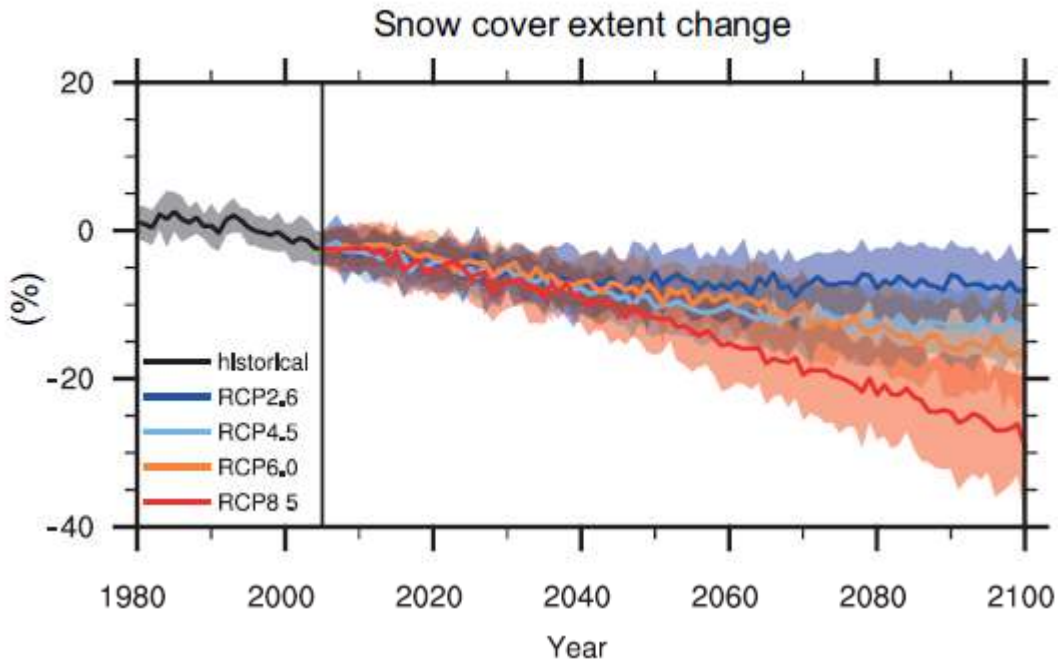
(IPCC 2013)

Scenarios

Climate Change

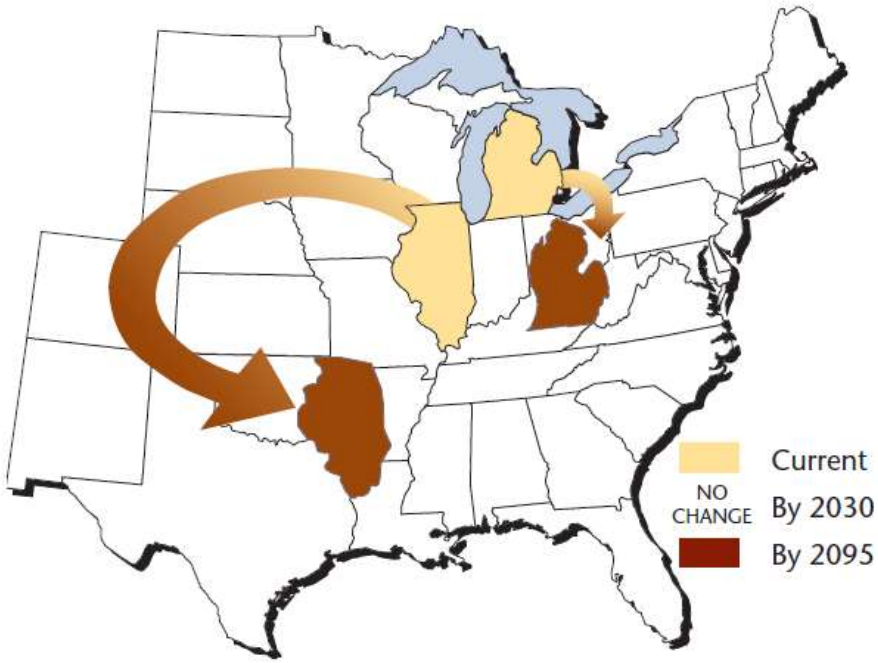
Precipitation Trends

- More uncertainty but summer precipitation generally will increase
- Increased summer precipitation could be negated by increases in evapotranspiration
- Snow cover expected to decline

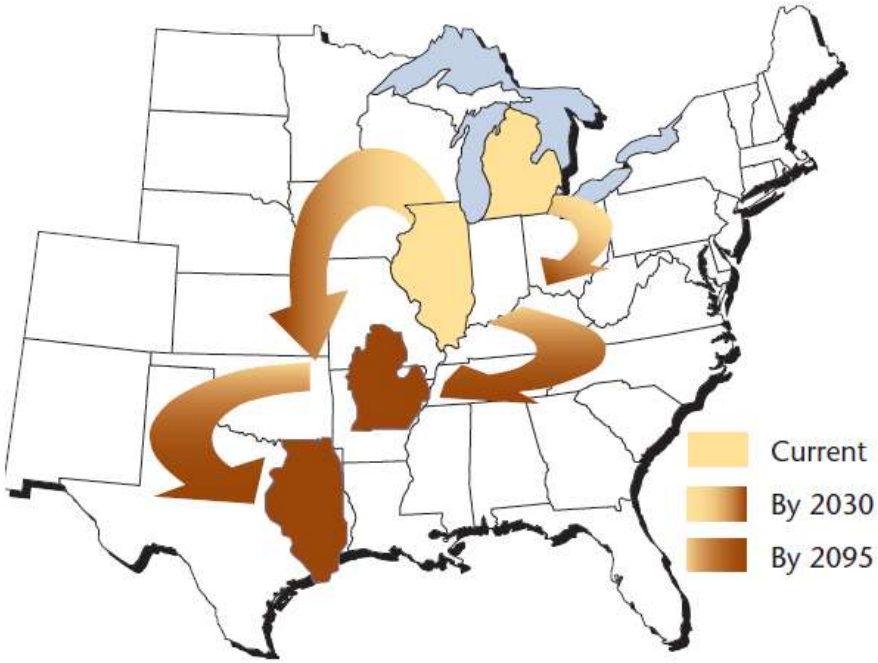


(IPCC 2013)

Changes in Regional Climate Conditions



Changing Winters (DJF average)
in Illinois and Michigan



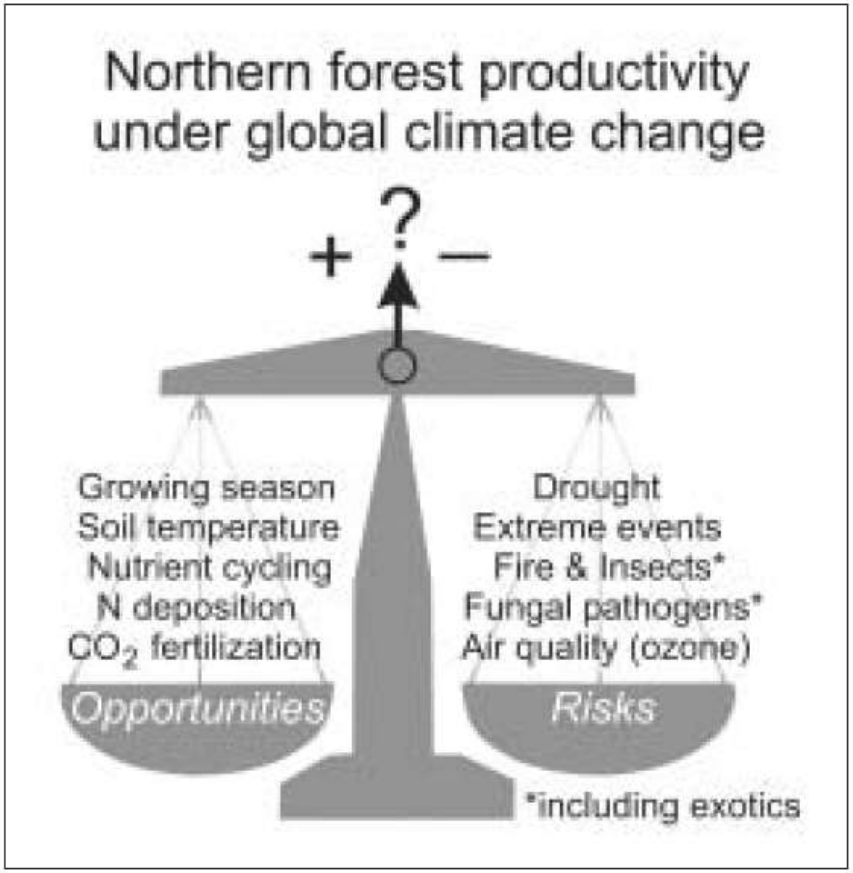
Changing Summers (JJA average)
in Illinois and Michigan

Union of Concerned Scientists (2003)

Climate Change

- **Impact of Climate on Forests**
  - **Northern regions**
  - **Northward expansion of forest communities**

- **Ecosystem resilience**
  - **Capacity of an ecosystem to absorb disturbance and undergo some degree of change but still maintain its essential functions and structure**



(Hogg & Bernier 2005)

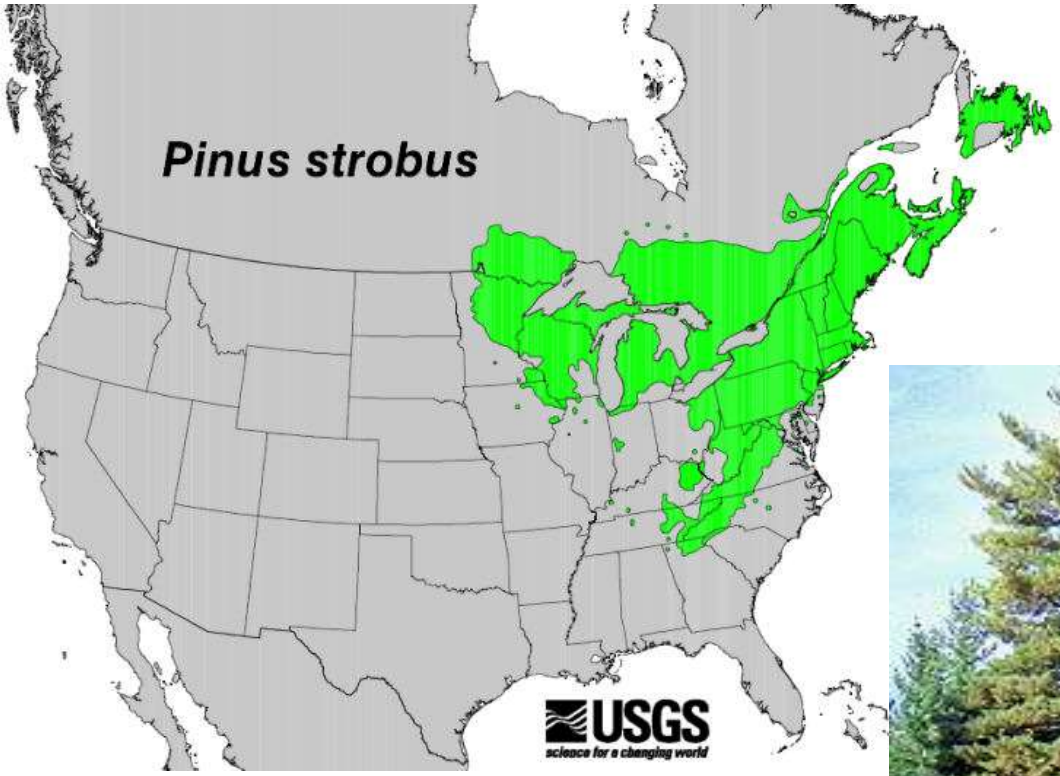
Adaptation to Climate Change

Adaptation framework

- Overall goal: Minimize the negative impacts of climate change and realize potential benefits
- Examples:
  - Human assisted migration of trees
  - Reforestation with drought tolerant genotypes through genetic tree improvement programs
- Challenge: Costs and climate forecast uncertainties
- Framework should start with monitoring and early detection of forest vulnerabilities to climatic stress

Eastern White Pine (*Pinus strobus* L.)

- Range
  - Eastern U.S. and Canada close to the Great Lakes
  - Prefer cool and humid climate



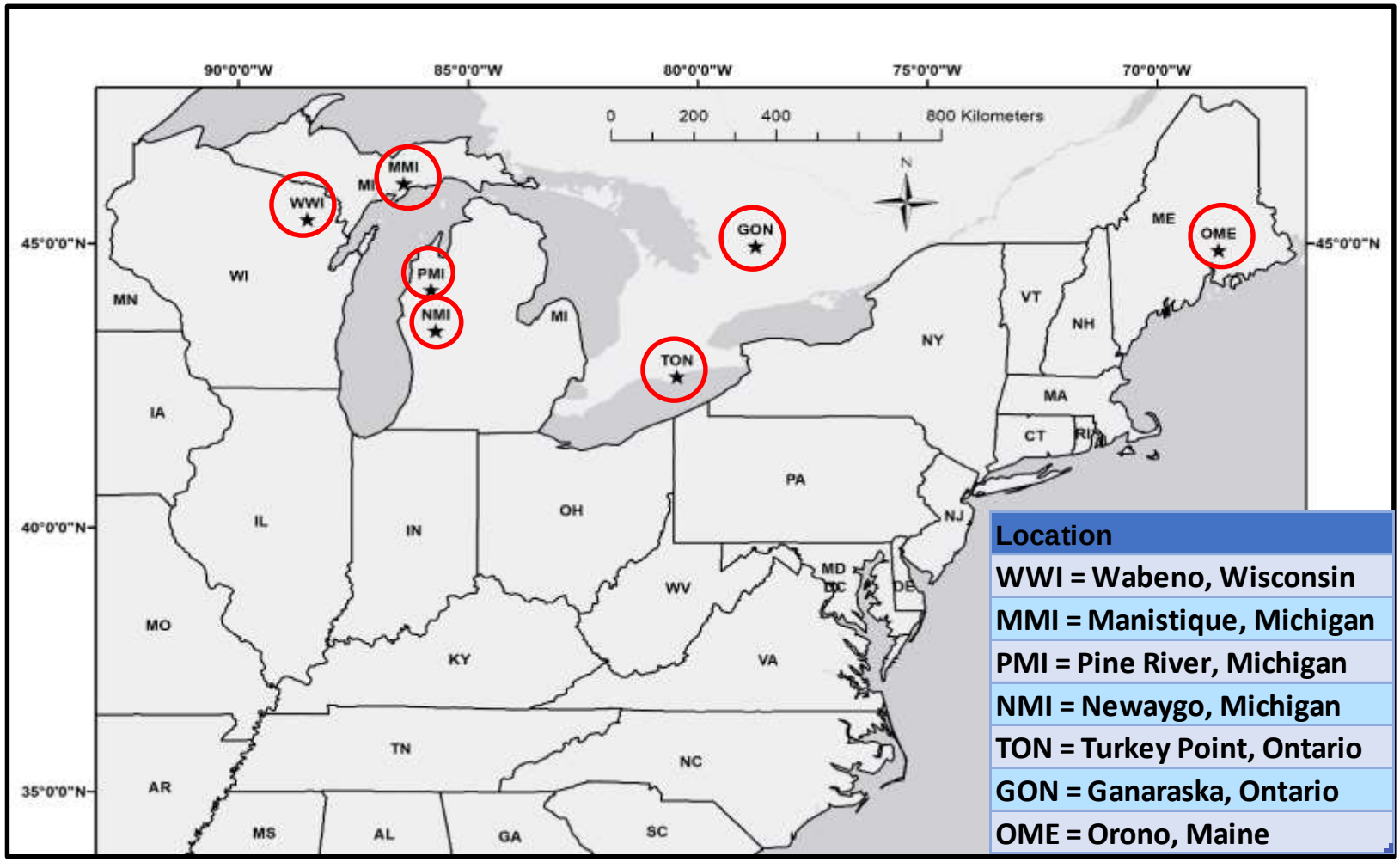
Research Objectives

Objectives and General Approach

- **The main objective of the study was to examine the climatic sensitivity of eastern white pine (*Pinus strobus* L.) provenances throughout the portion of its native distribution in eastern North America**
- **A dendroclimatic approach was used to examine sensitivity to climate in a genetic provenance study**

Study Area

- Eastern North America: United States and Canada

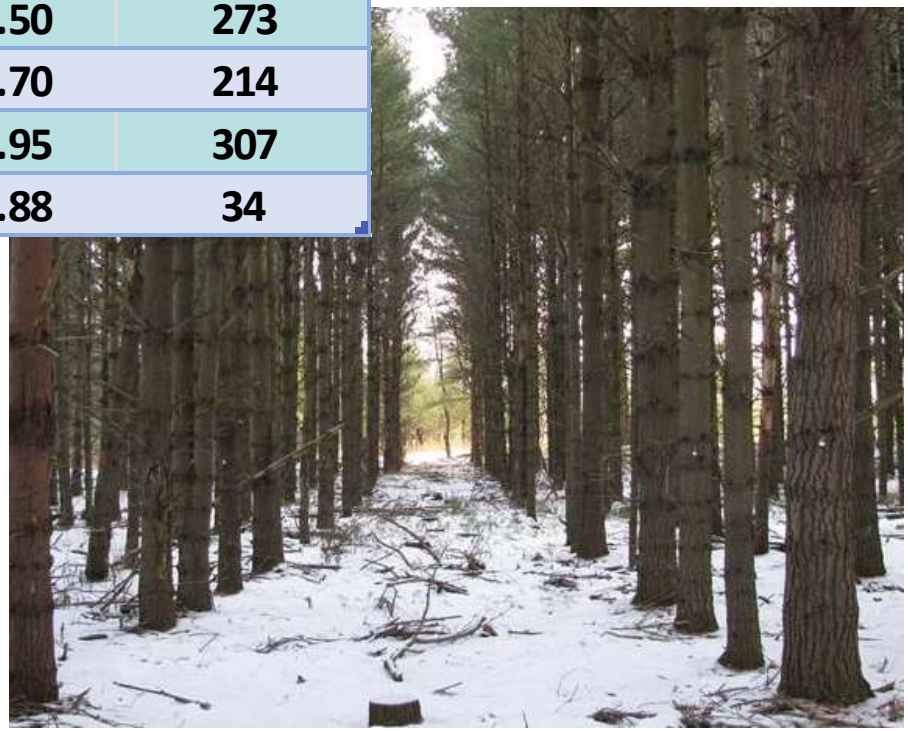


Location
WWI = Wabeno, Wisconsin
MMI = Manistique, Michigan
PMI = Pine River, Michigan
NMI = Newaygo, Michigan
TON = Turkey Point, Ontario
GON = Ganaraska, Ontario
OME = Orono, Maine

Field Sampling Design

- 7 trial site locations

Location	Longitude	Latitude	Elevation
Wabeno, Wisconsin	-88.50	45.40	438
Manistique, Michigan	-86.40	46.00	232
PineRiver, Michigan	-85.80	44.20	268
Newaygo, Michigan	-85.70	43.50	273
TurkeyPoint, Ontario	-80.45	42.70	214
Ganaraska, Ontario	-78.73	44.95	307
Orono, Maine	-68.65	44.88	34



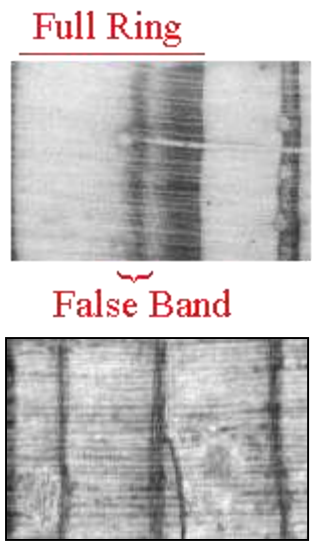
Field Sampling Design

- 13 seed source locations

Seed Source	Longitude	Latitude	Elevation	CAN Seed Source #	Population #	US Seed Source #
Union, Georgia	-84.05	34.77	876	1	272	1633
Greene, Tennesse	-82.80	36.00	625	2	273	1634
Monroe, Pennsylvania	-75.42	41.08	585	3	274	1640
Franklin, New York	-74.30	44.40	702	4	275	1639
Penobscot, Maine	-68.60	44.90	33	5	276	1638
Ashland, Ohio	-82.30	40.80	394	6	277	1632
Allamakee, Iowa	-91.50	43.30	350	7	278	1624
Cass, Minnesota	-94.50	47.40	393	8	279	1622
Forest, Wisconsin	-88.90	45.80	500	9	280	1623
Lunenburg, Nova Scotia	-64.60	44.40	95	10	281	1637
Pontiac, Quebec	-77.00	47.40	366	11	282	1635
Algoma, Ontario	-82.60	46.40	365	12	283	1636
Newaygo, Michigan	-85.70	43.50	273	13	345	1670

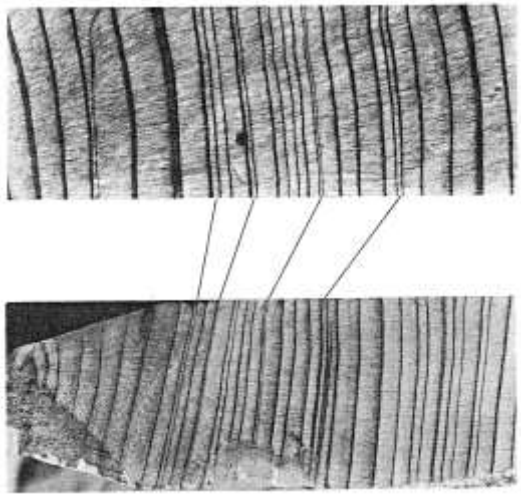
Dendrochronology

- Sanding
- Crossdating
  - False rings
  - Missing rings
- Ring Measurement
  - Image analysis
  - Stage micrometer



Locally Absent

(http://www.ltrr.arizona.edu/)

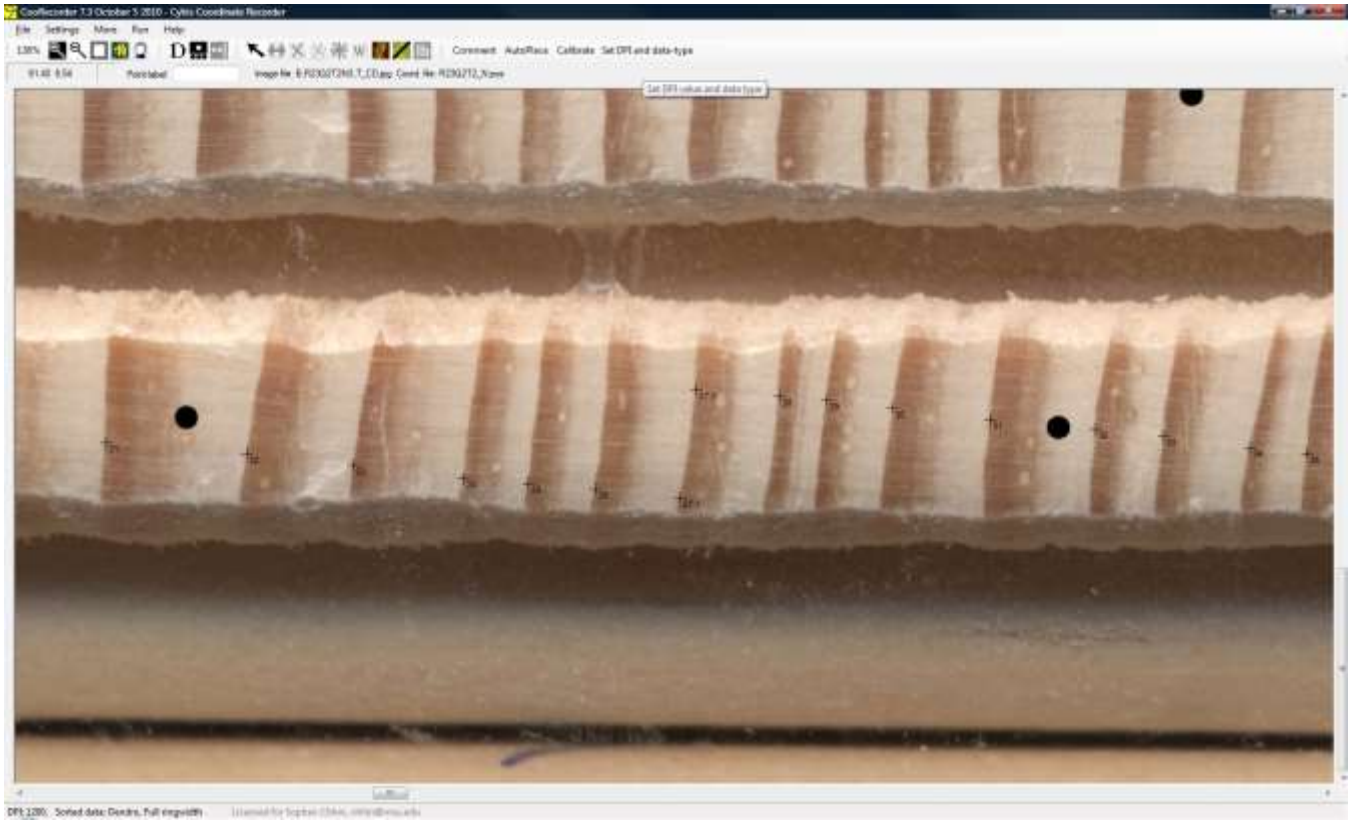


(Stokes & Smiley 1996)

Dendrochronology

Ring Measurement

- Image analysis (WinDendro and CooRecorder)
- Stage micrometer (Velmex)

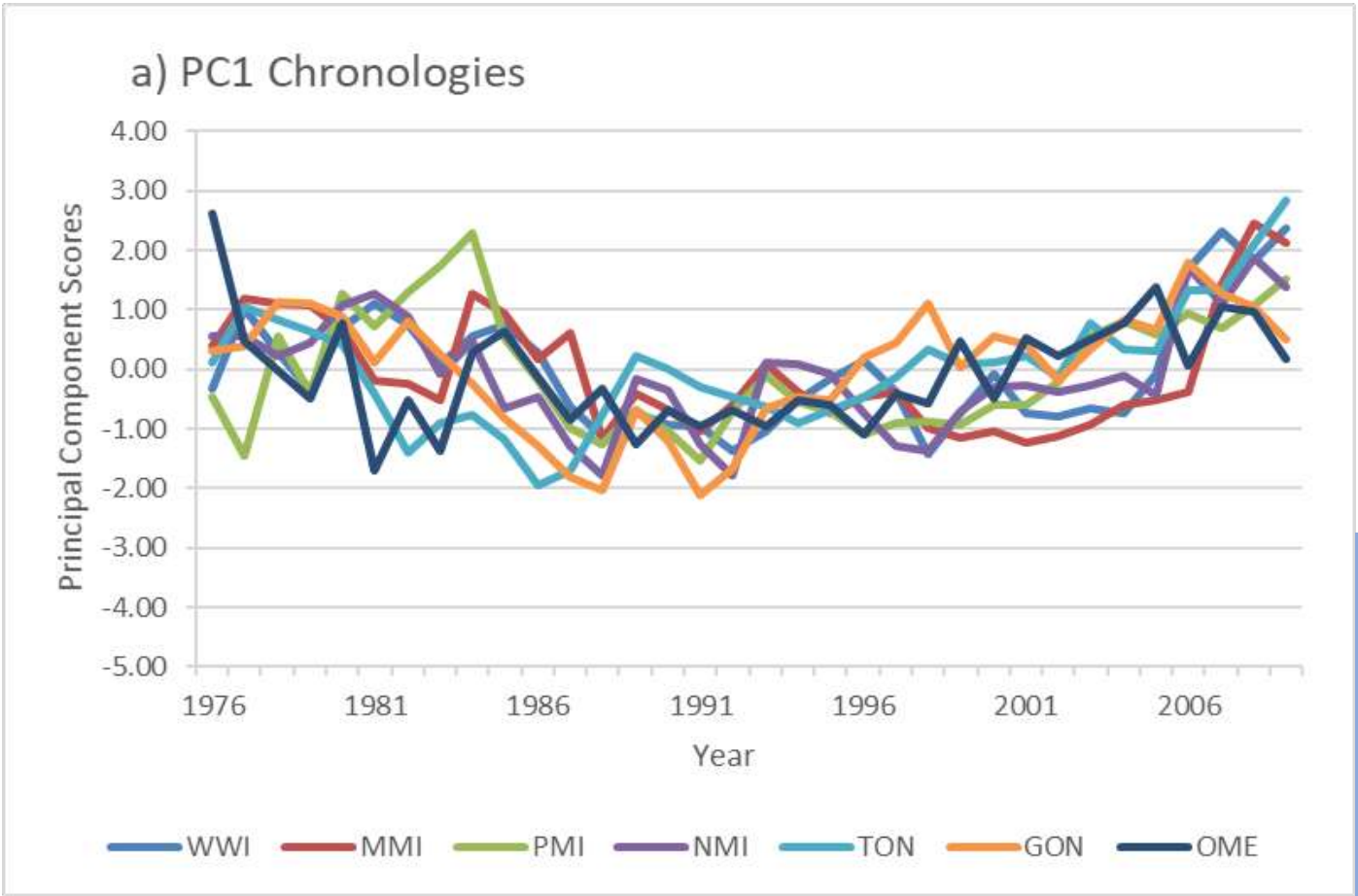


Principal Components Analysis

Trial Site Location	Explained Variance PC1 (%)	Explained Variance PC2 (%)
Wabeno, WI	31.9	11.5
Manistique, MI	52.8	32.0
Pine River, MI	46.6	43.0
Newego, MI	52.1	33.8
Turkey Point, ON	41.8	26.1
Ganaraska, ON	58.8	29.1
Orono, ME	41.2	46.7

Principal Components Analysis

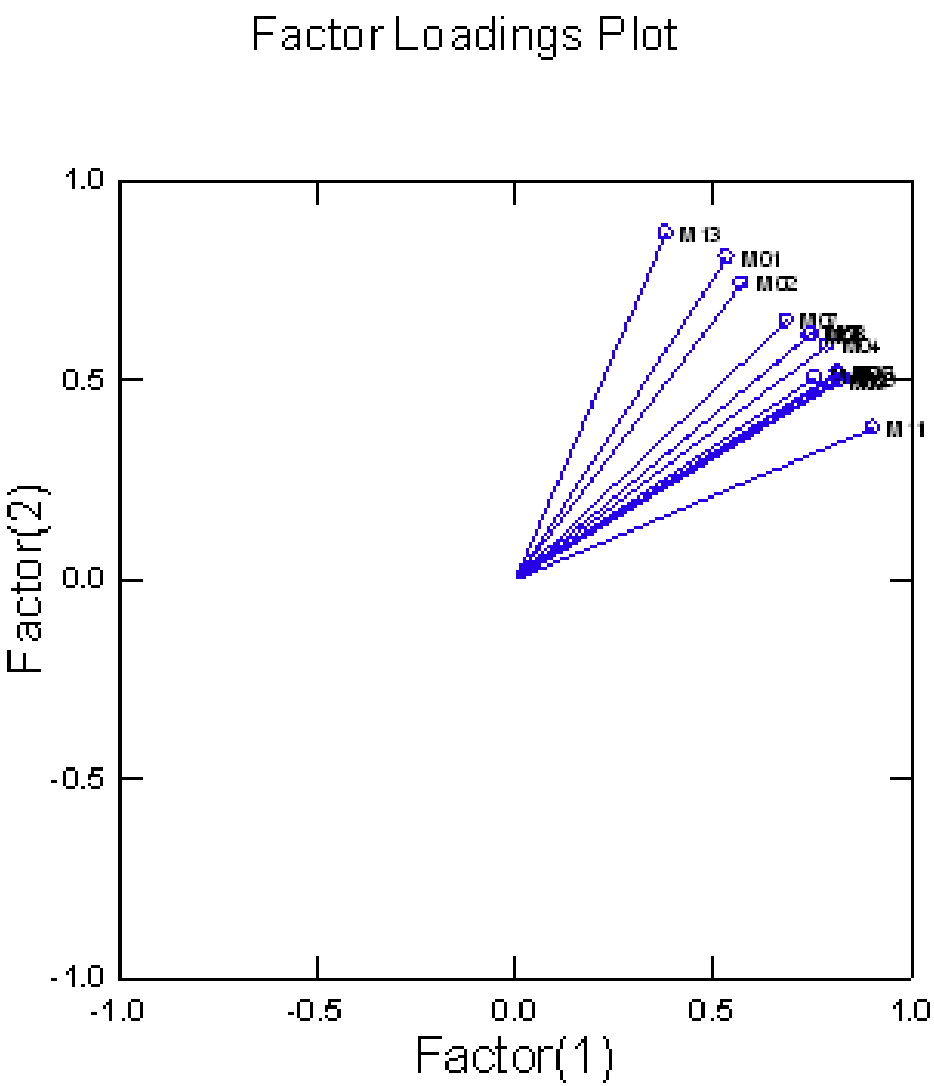
- **Year scores of principal component axes used to examine similar responses to climate across all seed sources at each trial site location**



Location
WWI = Wabeno, Wisconsin
MMI = Manistique, Michigan
PMI = Pine River, Michigan
NMI = Newaygo, Michigan
TON = Turkey Point, Ontario
GON = Ganaraska, Ontario
OME = Orono, Maine

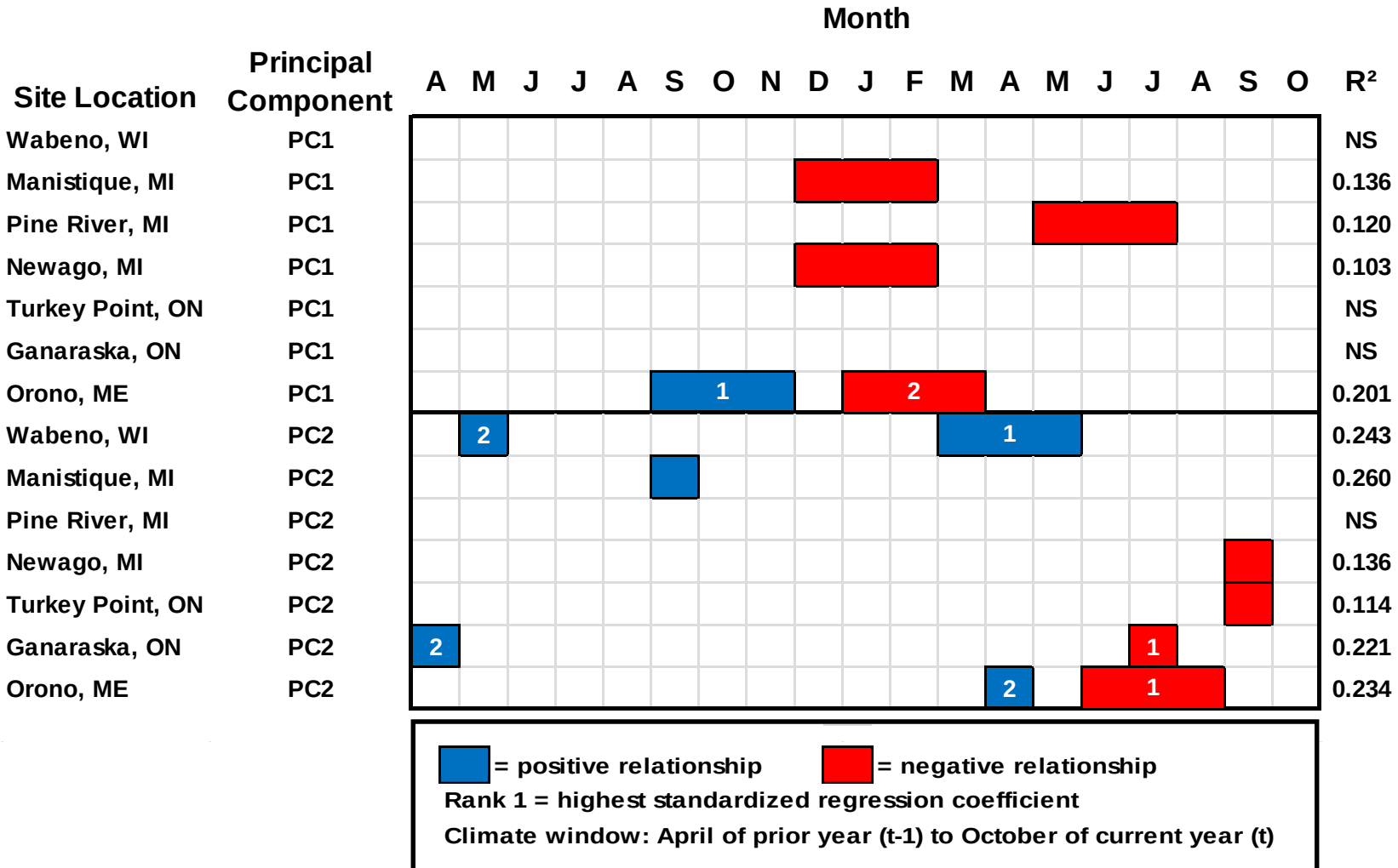
Principal Components Analysis

- **Loadings of seed sources on principal component axes used to examine differences in climatic response between the seed sources at each trial site location**



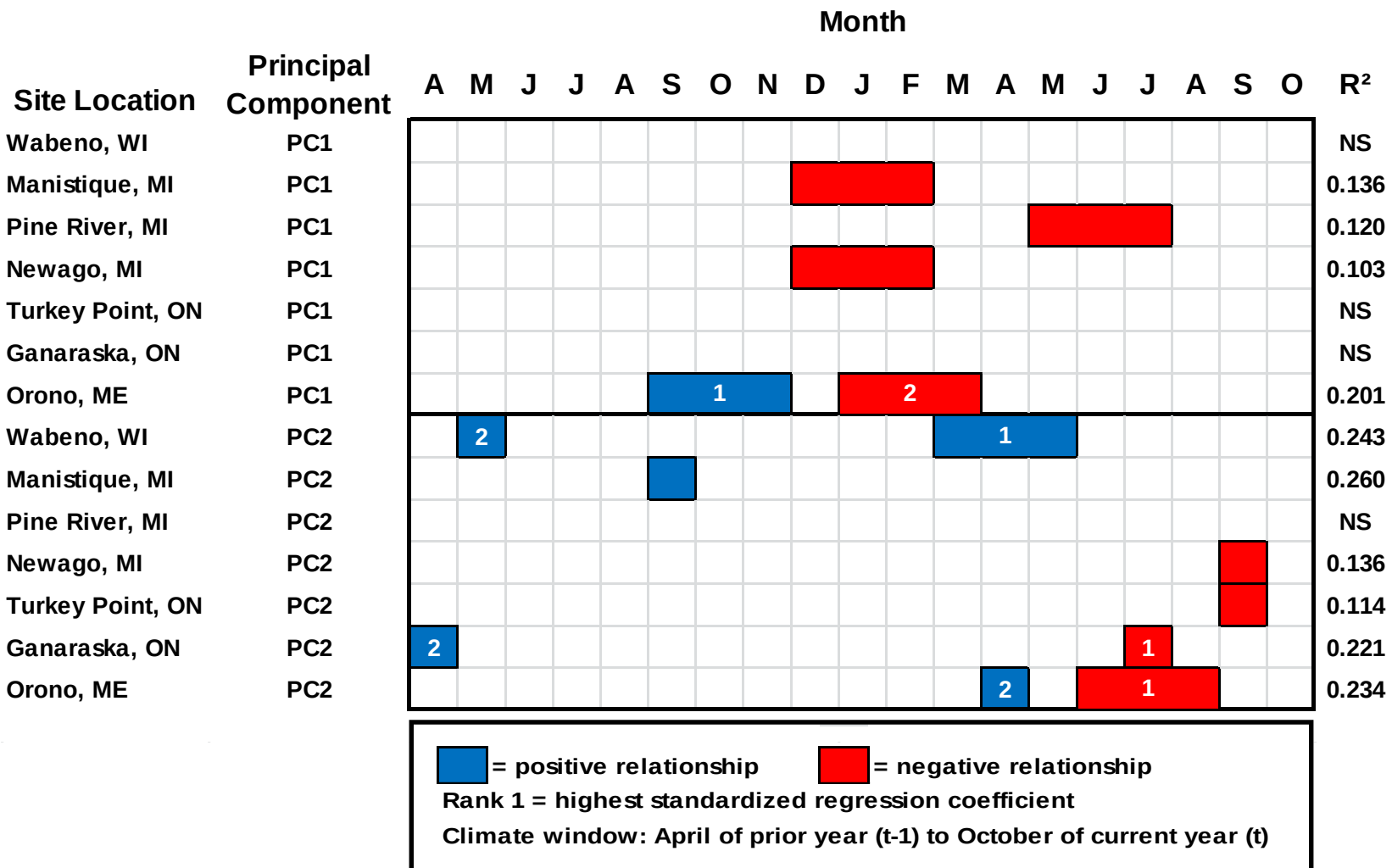
Dendroclimatic Analysis

- **Response of year scores of PC1 and PC2 to maximum temperature**
  - **High temperature stress in the winter and summer**



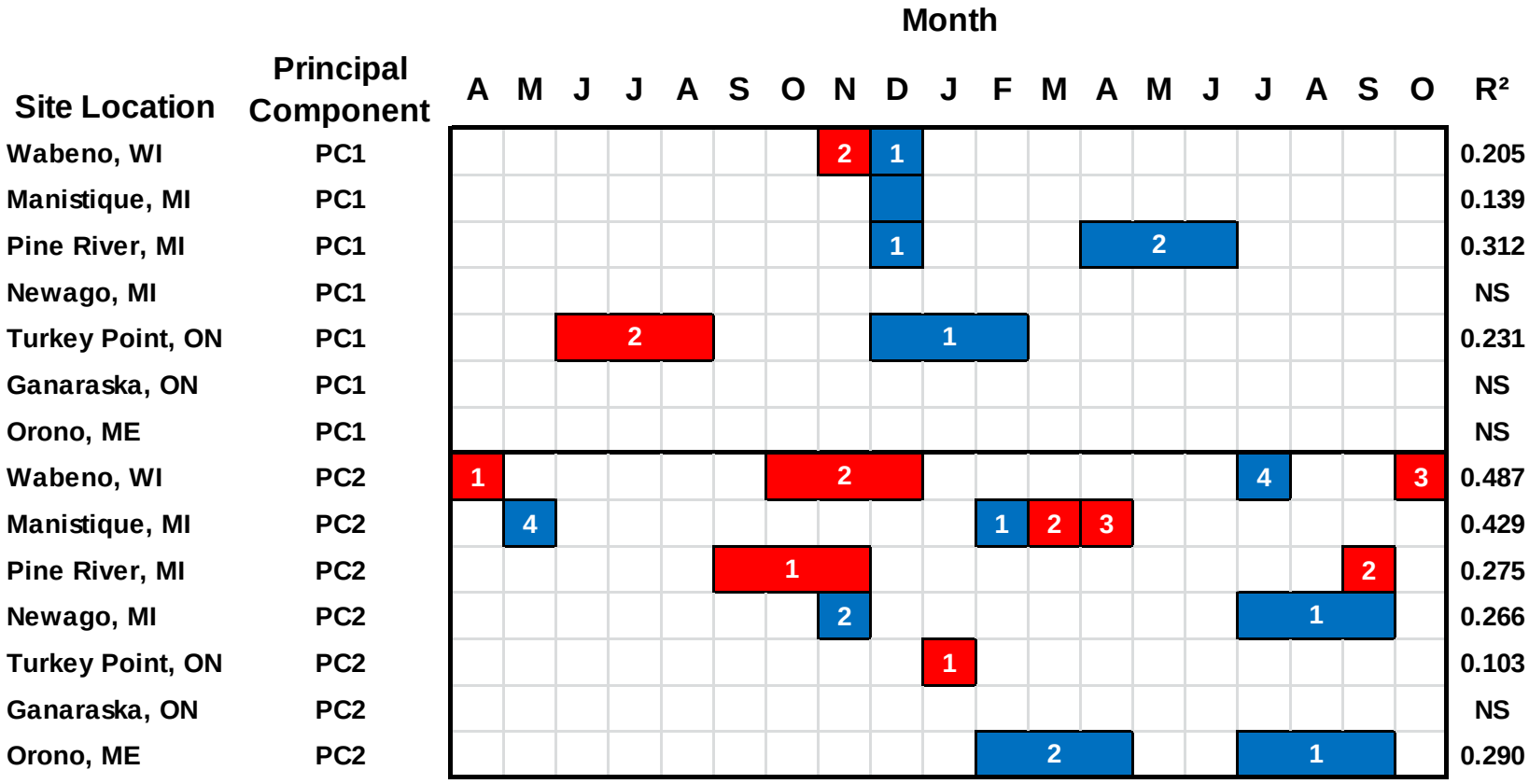
Dendroclimatic Analysis

- **Response of year scores of PC1 and PC2 to maximum temperature**
  - **Cold temperature stress in the spring and fall**



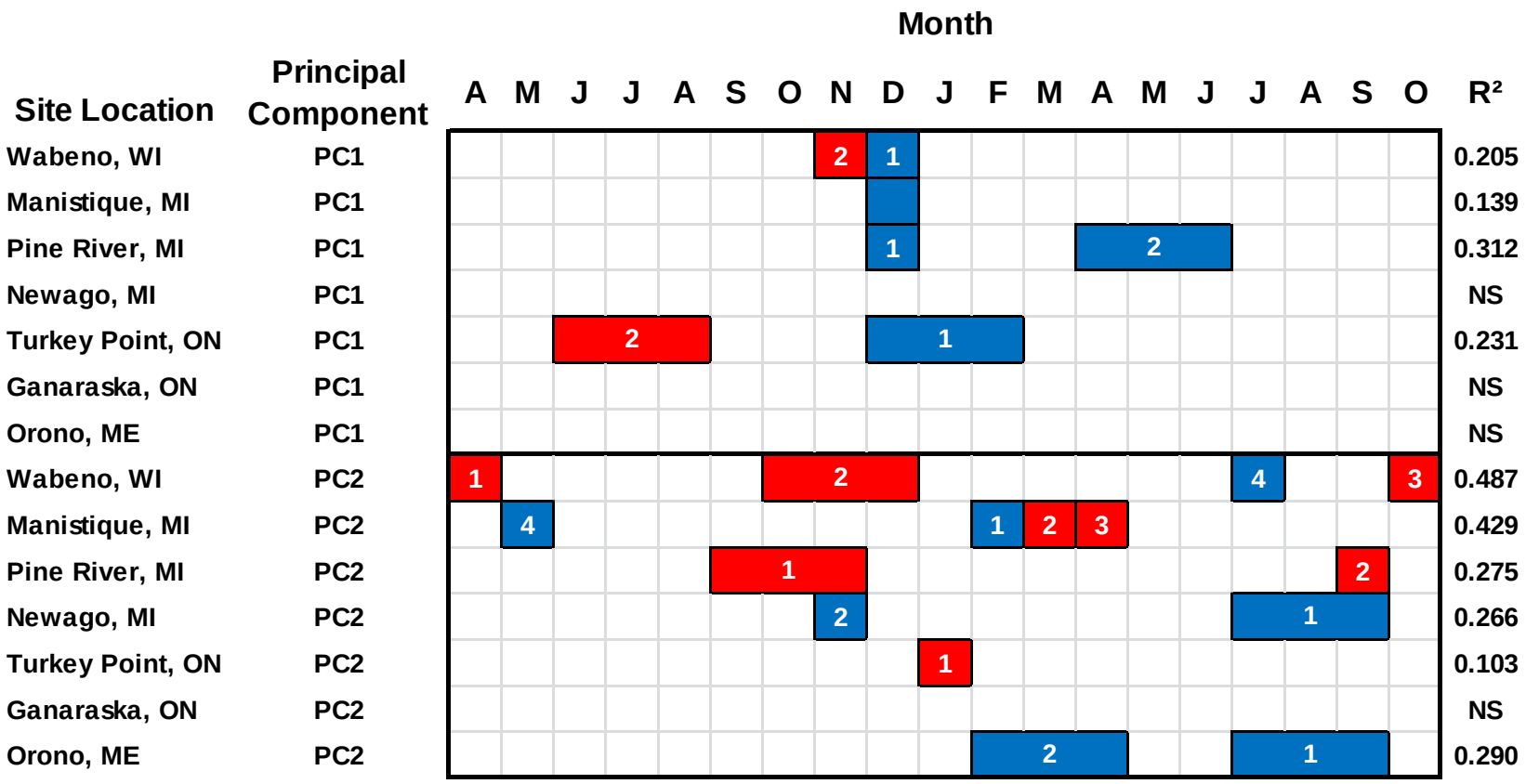
Dendroclimatic Analysis

- **Response of year scores of PC1 and PC2 to climate moisture index**
  - **Beneficial effects of higher winter snowfall**



Dendroclimatic Analysis

- **Response of year scores of PC1 and PC2 to climate moisture index**
  - **Summer moisture stress**



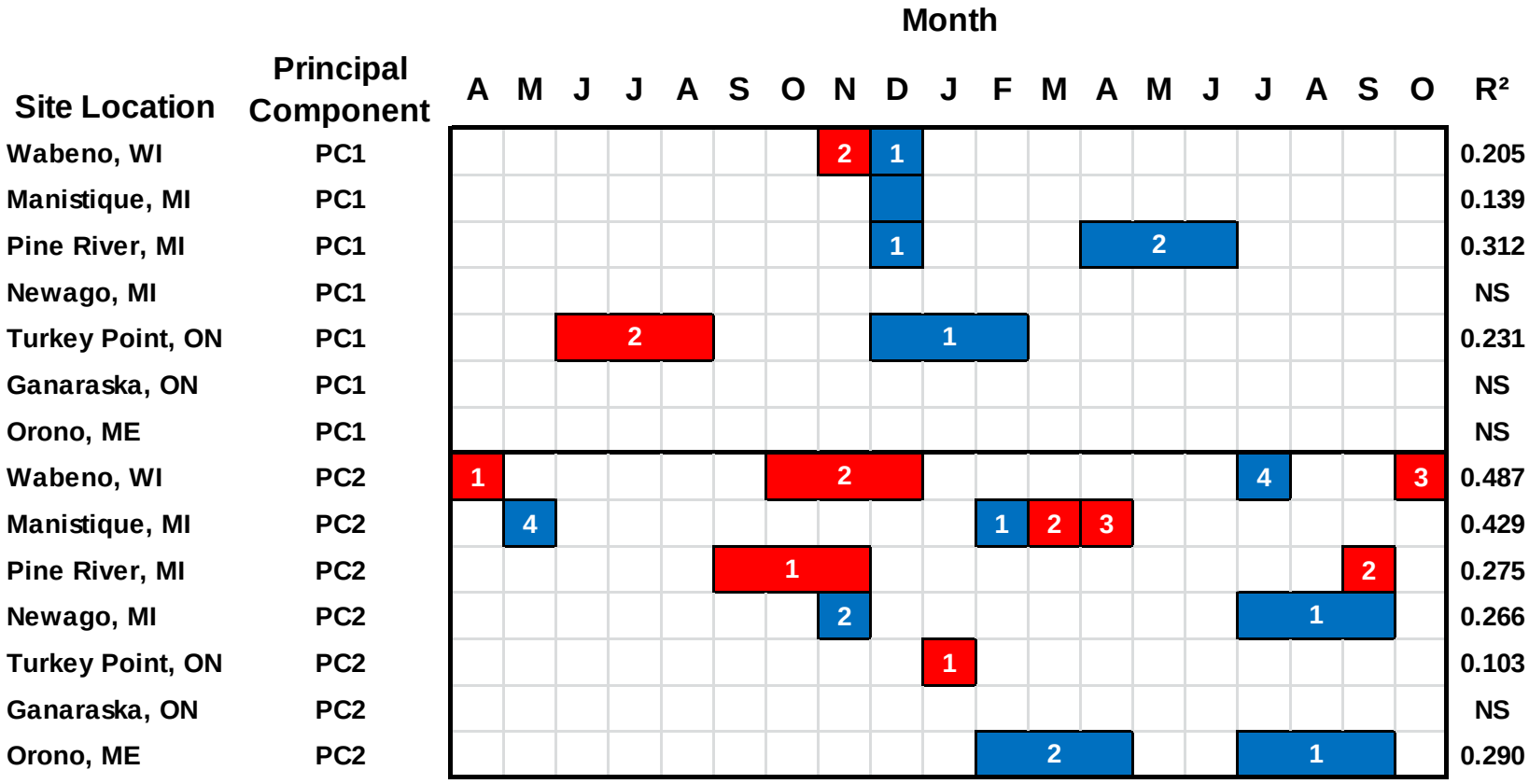
= positive relationship = negative relationship

Rank 1 = highest standardized regression coefficient

Climate window: April of prior year (t-1) to October of current year (t)

Dendroclimatic Analysis

- **Response of year scores of PC1 and PC2 to climate moisture index**
  - **Storm related damage in the spring and fall**



Dendroclimatic Analysis

- **Correlations between seed source loadings and bioclimatic parameters**

Bioclimatic Parameter	Wabeno, WI	Manistique, MI	PineRiver, MI	Newaygo, MI	TurkeyPoint, ON	Ganaraska, ON	Orono, ME
1. Annual mean temperature (AMT)	0.367	0.156	**0.544***	-0.032	-0.233	-0.286	-0.018
2. Mean diurnal range (MDR)	**-0.736***	-0.324	-0.352	0.357	**-0.664***	-0.112	-0.294
3. Isothermality (ISO)	0.11	**0.731***	0.082	**-0.713***	0.028	-0.161	-0.294
4. Temperature seasonality (TSCV)	**0.643***	**0.566***	0.275	**-0.552***	**0.531***	0.182	0.119
5. Max temperature of warmest period (TWP)	**-0.780***	-0.368	-0.39	0.343	**-0.580***	-0.21	-0.28
6. Min temperature of coldest period (TCP)	-0.121	0.137	0.258	-0.238	**-0.699***	-0.28	-0.119
7. Temperature annual range (TAR)	0.391	0.361	0.014	-0.404	**0.758***	0.175	0.109
8. Mean temperature of wettest quarter (TWetQ)	0.182	**0.776***	0.116	**-0.637***	0.077	-0.042	-0.249
9. Mean temperature of driest quarter (TDQ)	**0.654***	**0.505***	0.308	**-0.517***	**0.531***	0.182	0.119
10.Mean temperature of warmest quarter (TWarmQ)	**0.819***	0.066	0.418	0.042	**0.531***	0.385	0.427
11.Mean temperature of coldest quarter (TCQ)	**0.725***	0.335	**0.643***	0.035	0.182	**0.594***	0.273

*** = significant Spearman rank correlation coefficient ($p < 0.05$)**

Dendroclimatic Analysis

- **Correlations between seed source loadings and bioclimatic parameters**

Bioclimatic Parameter	Wabeno, WI	Manistique, MI	PineRiver, MI	Newaygo, MI	TurkeyPoint, ON	Ganaraska, ON	Orono, ME
12.Annual precipitation (AP)	**0.725***	-0.082	0.346	0.091	**0.636***	0.322	0.441
13.Precipitation of wettest period (PWP)	**0.709***	0.198	**0.637***	0.077	0.175	**0.622***	0.273
14.Precipitation of driest period (PDP)	**0.676***	-0.088	0.291	0.091	**0.692***	0.273	0.427
15.Precipitation seasonality (PSCV)	**0.654***	0.33	**0.637***	-0.07	-0.182	**0.524***	-0.035
16.Precipitation of wettest quarter (PWetQ)	**0.714***	-0.038	0.357	0.056	**0.678***	0.21	0.427
17.Precipitation of driest quarter (PDQ)	-0.388	**-0.721***	-0.165	**0.630***	-0.326	-0.13	0.186
18.Precipitation of warmest quarter (PWarmQ)	0.47	**0.580***	0.193	-0.476	**0.580***	0.217	0.028
19.Precipitation of coldest quarter (PCQ)	0.484	**0.659***	0.203	**-0.545***	0.448	0.259	-0.091

*** = significant Spearman rank correlation coefficient ($p < 0.05$)**

Summary

- **The key dendroclimatic relationships revealed in this study include sensitivity to:**
  - **High temperature stress in the winter and summer**
  - **Cold temperature stress in the spring and fall (i.e., beginning and end of the growing season)**
  - **Beneficial effects of higher winter snowfall**
  - **Summer moisture stress**
  - **Storm induced damage in the spring and fall**

Summary

- **Temperature related bioclimatic parameters were responsible for differences in radial growth between the seed sources at 5 of the 7 the trial site locations situated closer to the influences of the Great Lakes region.**
- **Future projected changes in climate including warmer winters and increased storm activity may pose a significant challenge to management of the genetic resources of white pine.**
- **Expected future increases in the length of the growing season could potentially help offset the negative aspects of climate change.**

Acknowledgements

Field & Lab Assistance: N. Eskelin, K. Finley, K. Minnix, I. Allen

Funding: US Forest Service

Contact Info: sophan.chhin@mail.wvu.edu