

What role does changing climate play in reforestation decisions?



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Overview: Reforestation management recommendations under changing climate

- **Consider** conservation of genetic diversity in anticipation of climate change impacts
- **Consider** matching species and seed source with the expectation of changing climate.

Overview: Available Tools

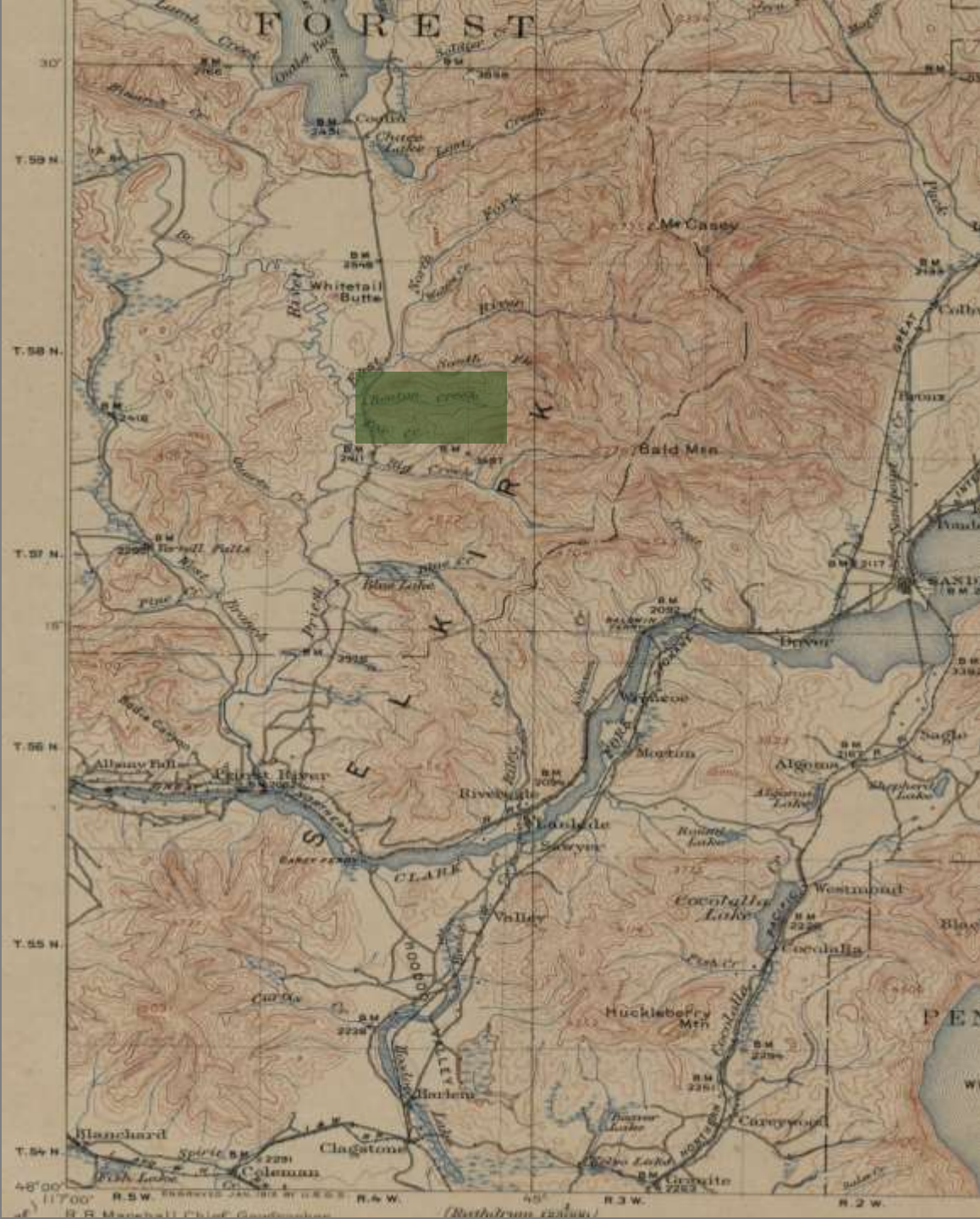
Websites:

- Climate Estimates, Climate Change and Plant Climate Relationships – VT
- Climate-Forest Vegetation Simulator
- Seed Selection Tool

Overview

Focus on a few key ecological genetic concepts:

- 1911 Ponderosa Pine Pioneer Plantation
- Historic and Local Climate Context



Priest River Experimental Station, Est. 1911

Purpose: Research to inform management decisions.







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EVIDENCES OF RACIAL INFLUENCE IN A 25-YEAR
TEST OF PONDEROSA PINE

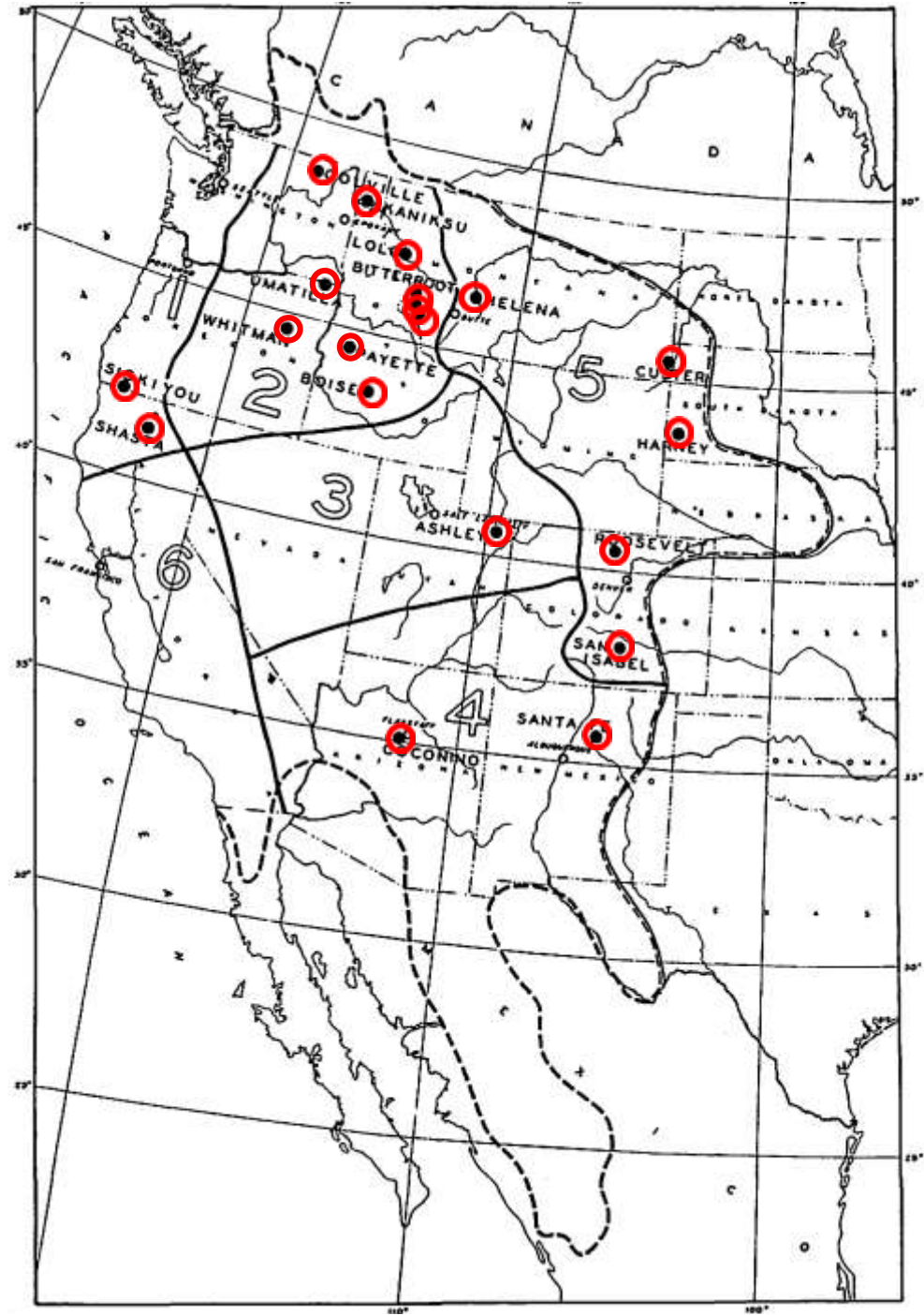
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P. H. WIDMAN
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(Pages 11-18)



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LAND-GRANT COLLEGES AND UNIVERSITIES

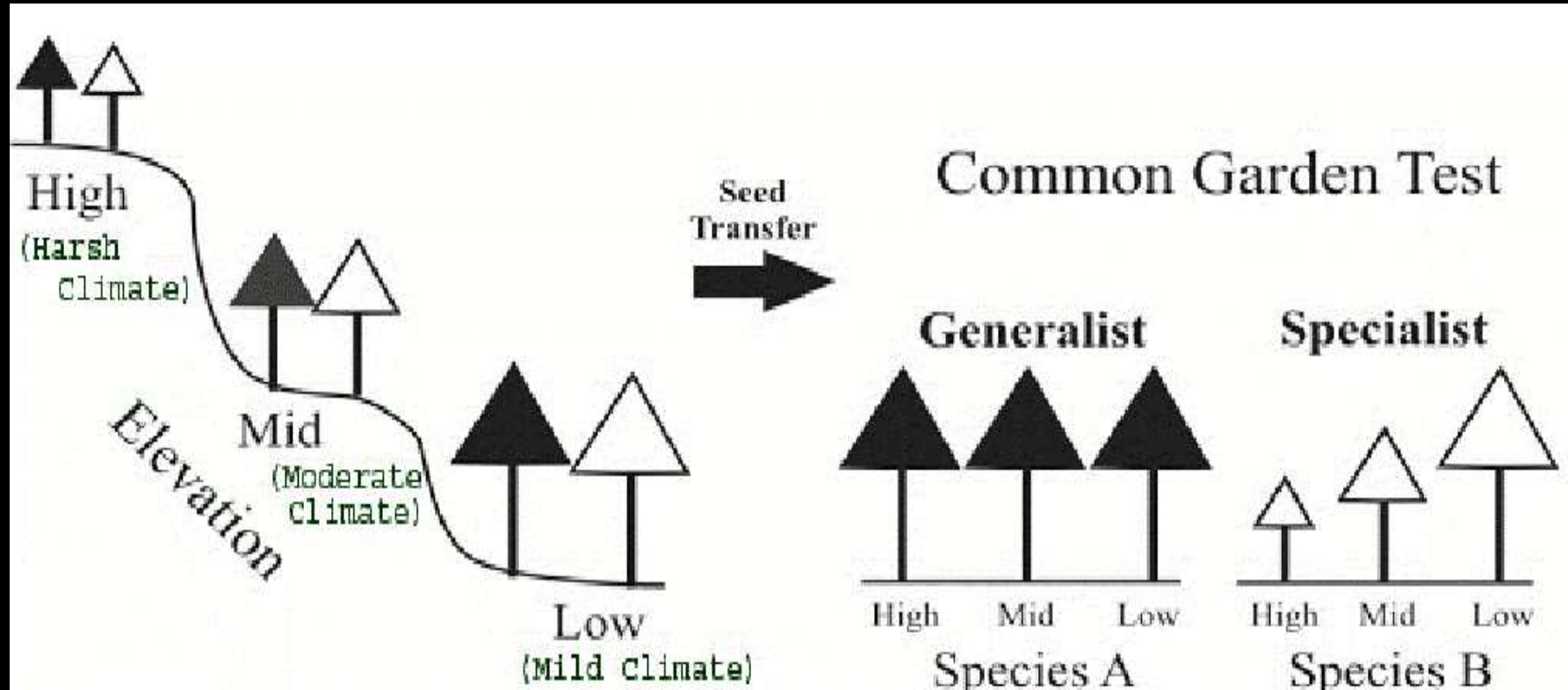
Squillace and Silen, 1962



Concepts

$$P = G \times E$$

$$P = G \times E$$

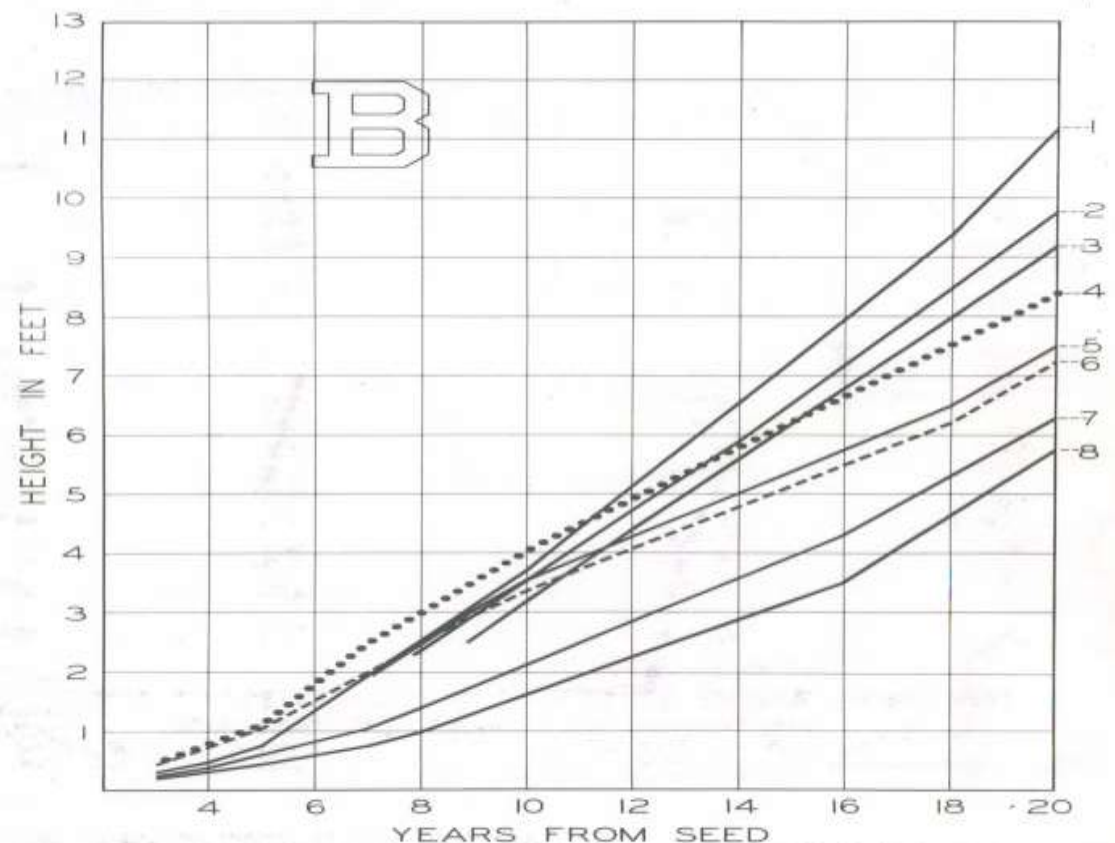
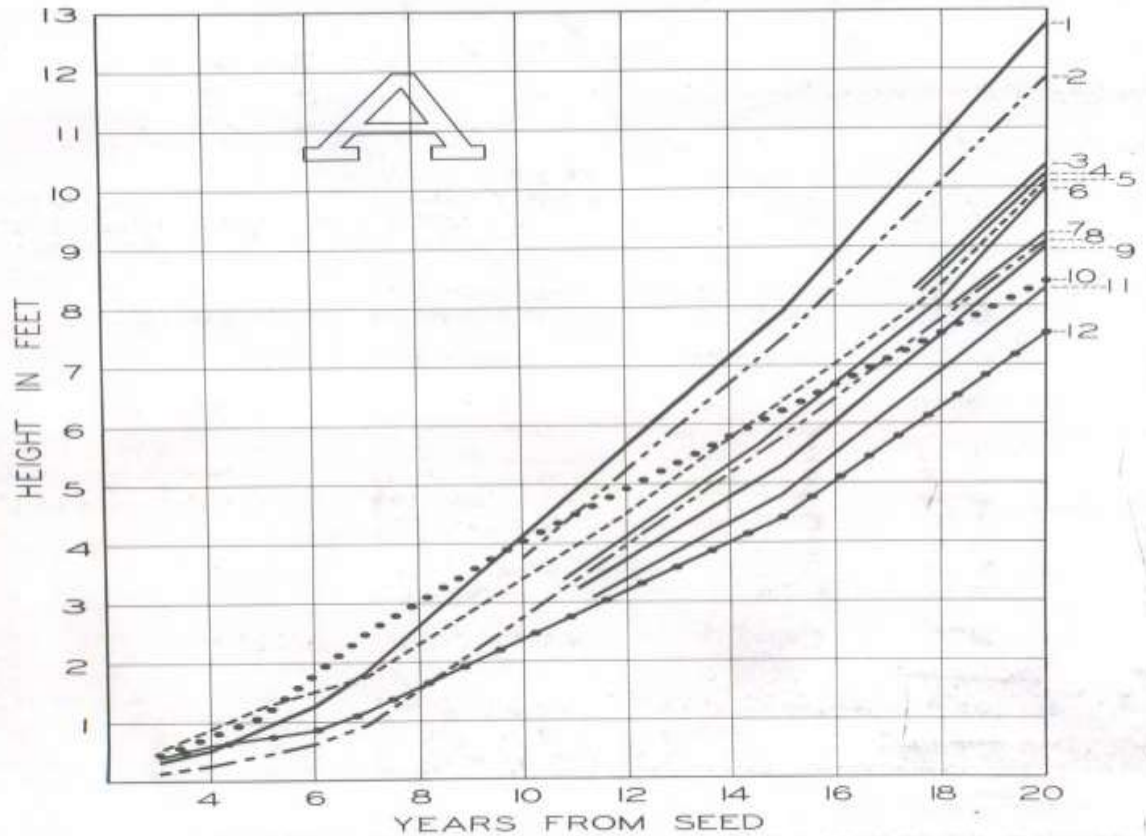


- Common garden experiments are used to assess adaptive genetic structure and evolutionary response



Payette June 5, 1912	Coconino May 10, 1912	Santa Fe May 3, 1915	Lolo May 2, 1916	Bitterroot 7,200 feet May 29, 1917	
Coeur d'Alene Oct. 6, 1911 (excluded)	Custer Oct. 6, 1911	Ashley May 13, 1915	Kaniksu May 2, 1916	Bitterroot 4,000 feet May 31, 1917	
Helena Oct. 14, 1911	San Isabel Oct. 14, 1911	Roosevelt June 5, 1912	Bitterroot 5,000 feet May 13, 1915	Siskiyou May 3, 1916	Harney May 2, 1916
Shasta May 13, 1915 (excluded)	Umatailla Nov. 18, 1911	Whitman May 13, 1916	Boise May 13, 1915	Colville May 13, 1915	Unknown Origin April 29, 1916 (excluded)

FIGURE 3.—Arrangement of progeny plots, and dates of first planting. The large plots are 50 by 50 feet and the small ones 25 by 50 feet.



1 LOLO
2 BITTERROOT 4000
3 BITTERROOT 5000
4 COLVILLE

5 UMATILLA
6 KANIKSU
7 PAYETTE
8 BITTERROOT 7200

9 SISKIYOU
10 COCONINO
11 BOISE
12 WHITMAN

1 HELENA
2 HARNEY
3 CUSTER

4 COCONINO
5 SAN ISABEL
6 ROOSEVELT

7 SANTA FE
8 ASHLEY

Figure 3.--Relative height growth of progenies, by years.

Age 12, 20, 50 and 80 years

- Survival
- Height
- Volume



No. 270752 Source of seed experiment on Priest River Experimental Forest. Ponderosa Pine stand grown from Helena seed. July-August, 1932.



No. 270756 Source of seed experiment on Priest River Experimental Forest. Ponderosa Pine stand grown from Pecos seed. July-August, 1932.













United States
Department of
Agriculture

Forest Service

Intermountain
Forest and Range
Experiment Station
Ogden, UT 84401

General Technical
Report INT-159

December 1983



Climate of Priest River Experimental Forest, Northern Idaho

Arnold I. Finklin



United States
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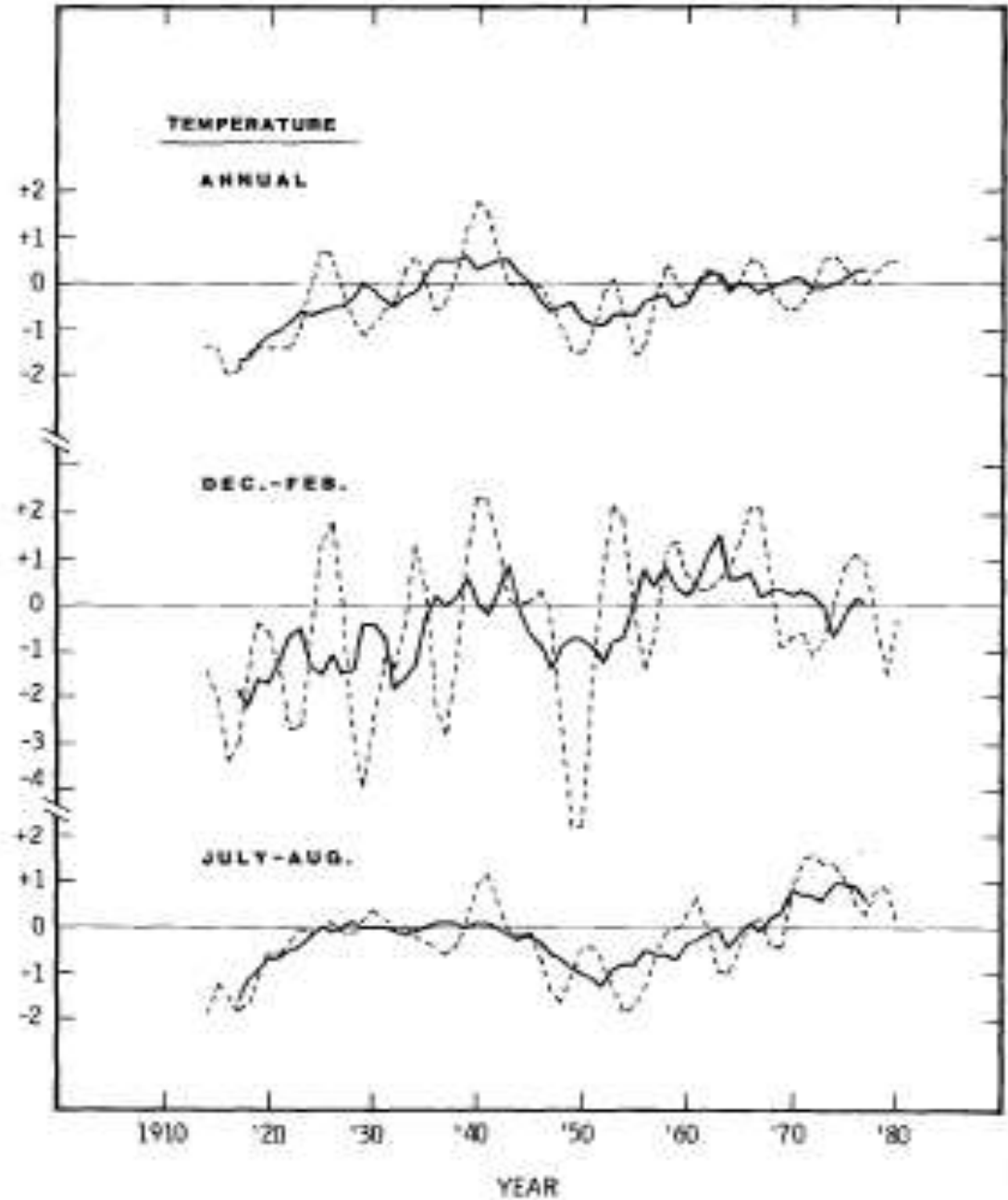


Climate of Priest River Experimental Forest, Northern Idaho

Arnold I. Finklin

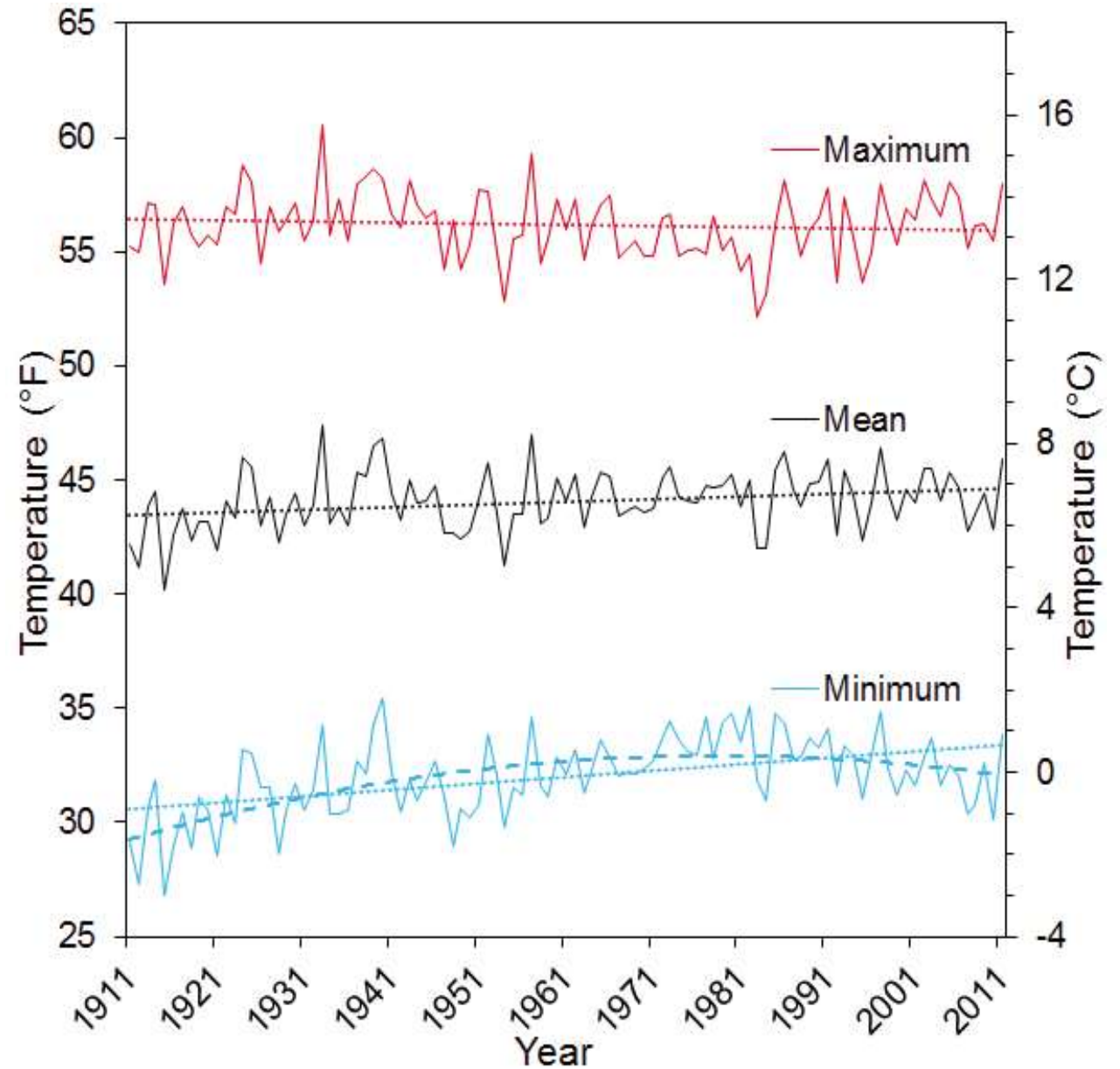


DEPARTURE, °F, FROM 1931-1980, AVERAGE TEMPERATURE

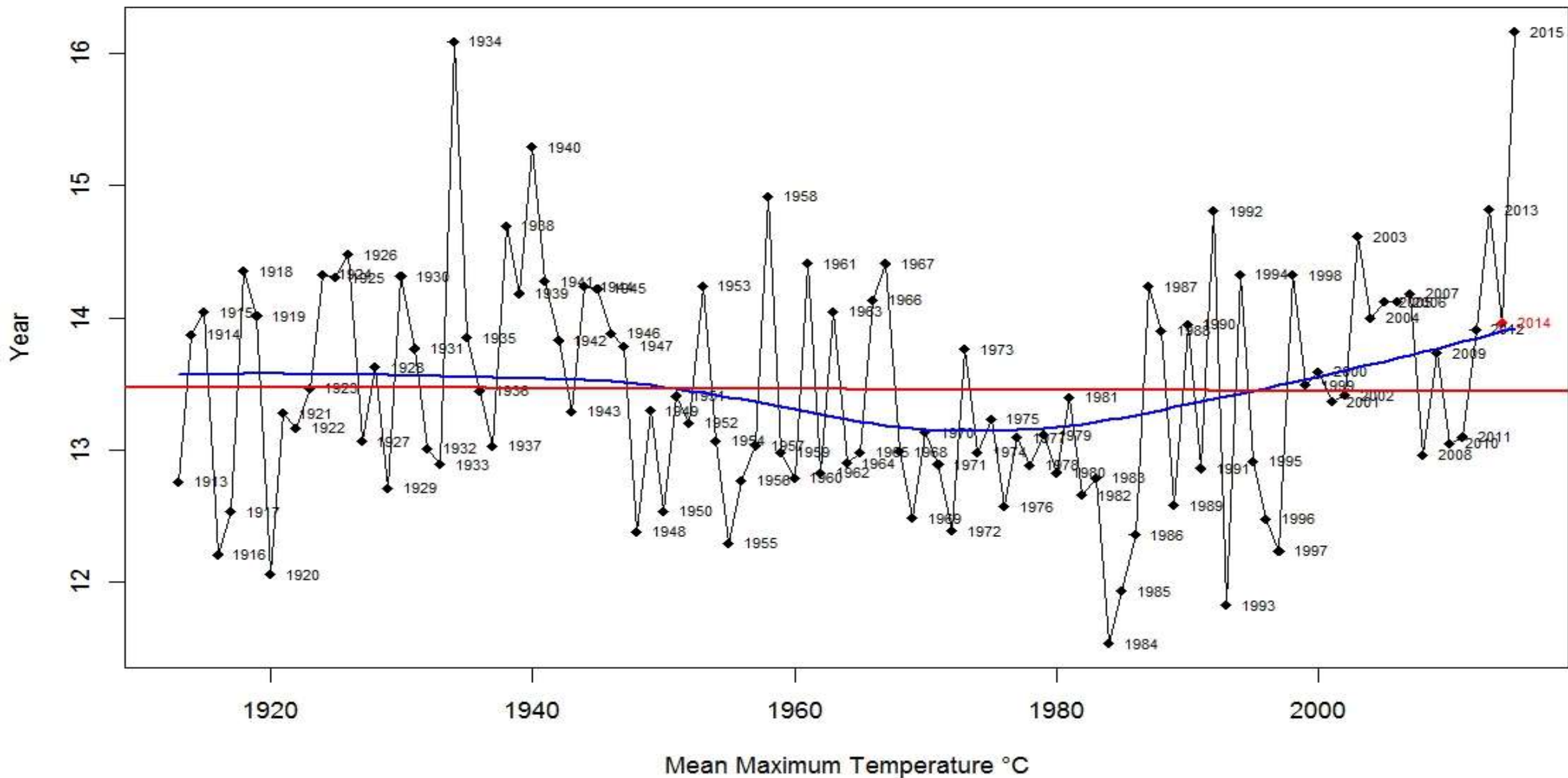


Climate, Snowpack, and Streamflow of Priest River Experimental Forest, Revisited

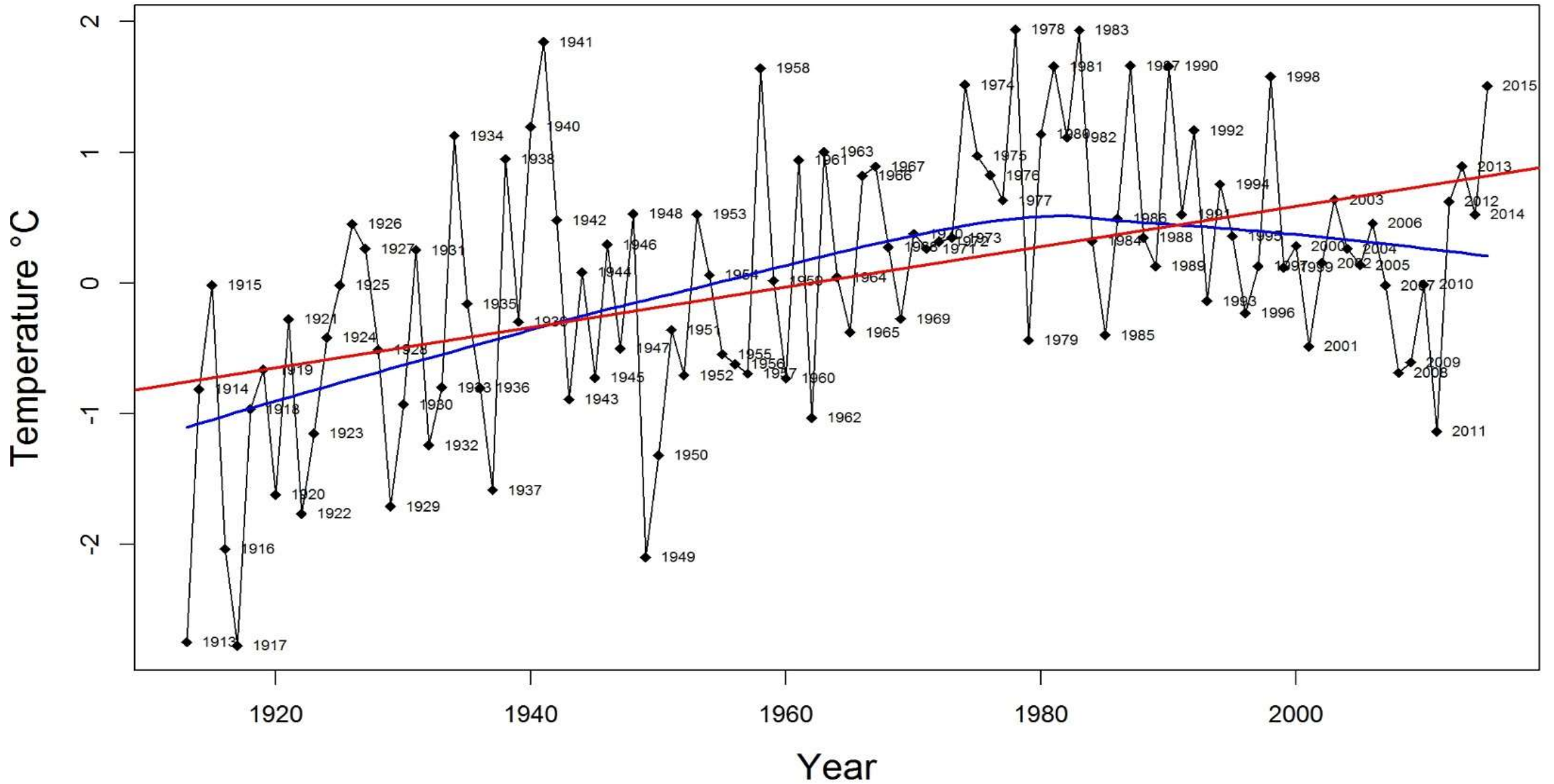
Wade T. Tinkham
Robert Denner
Russell T. Graham



Mean Maximum Temperature at PREF by Water Year

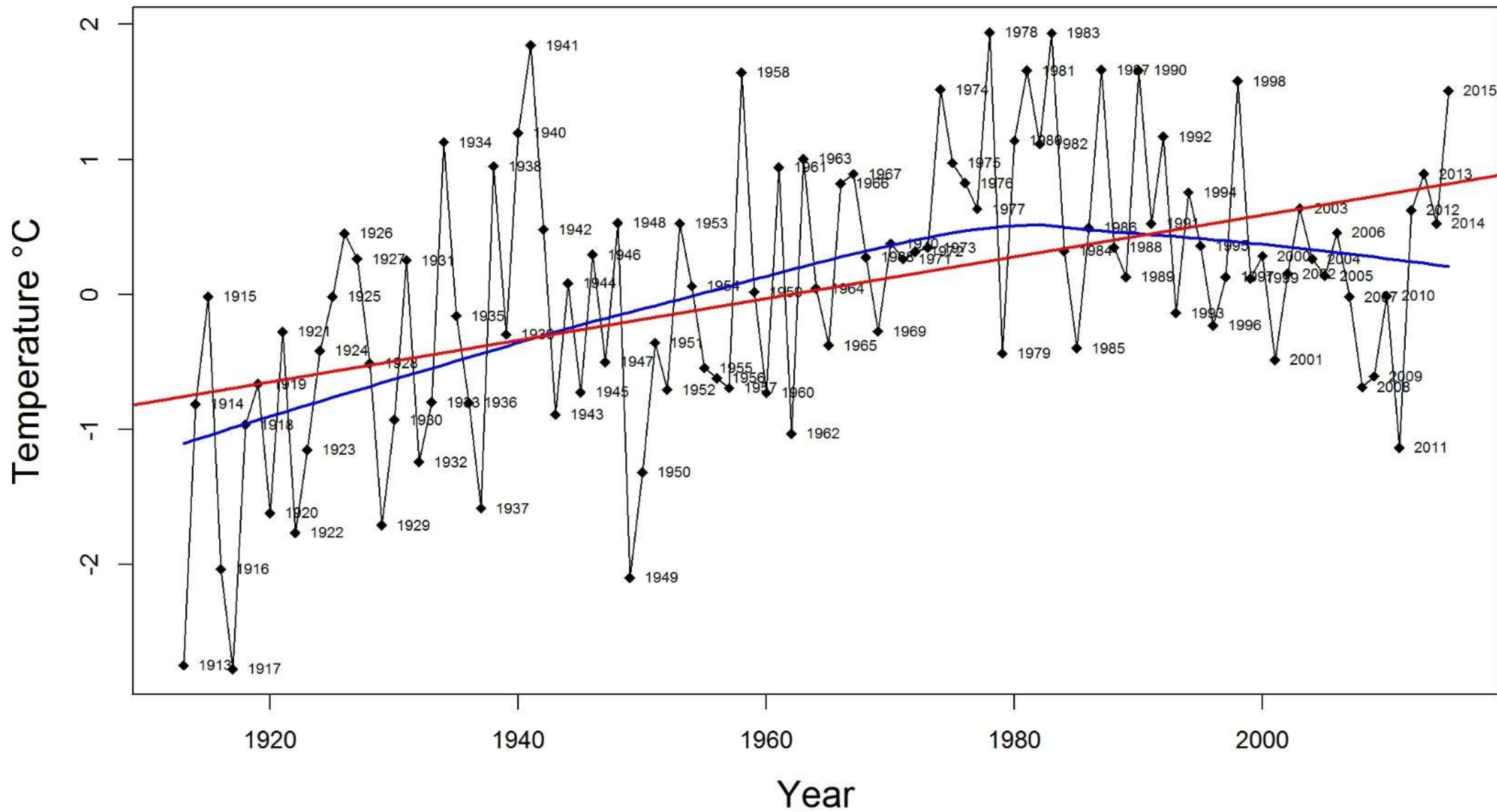


Mean Minimum Temperature at PREF by Water Year

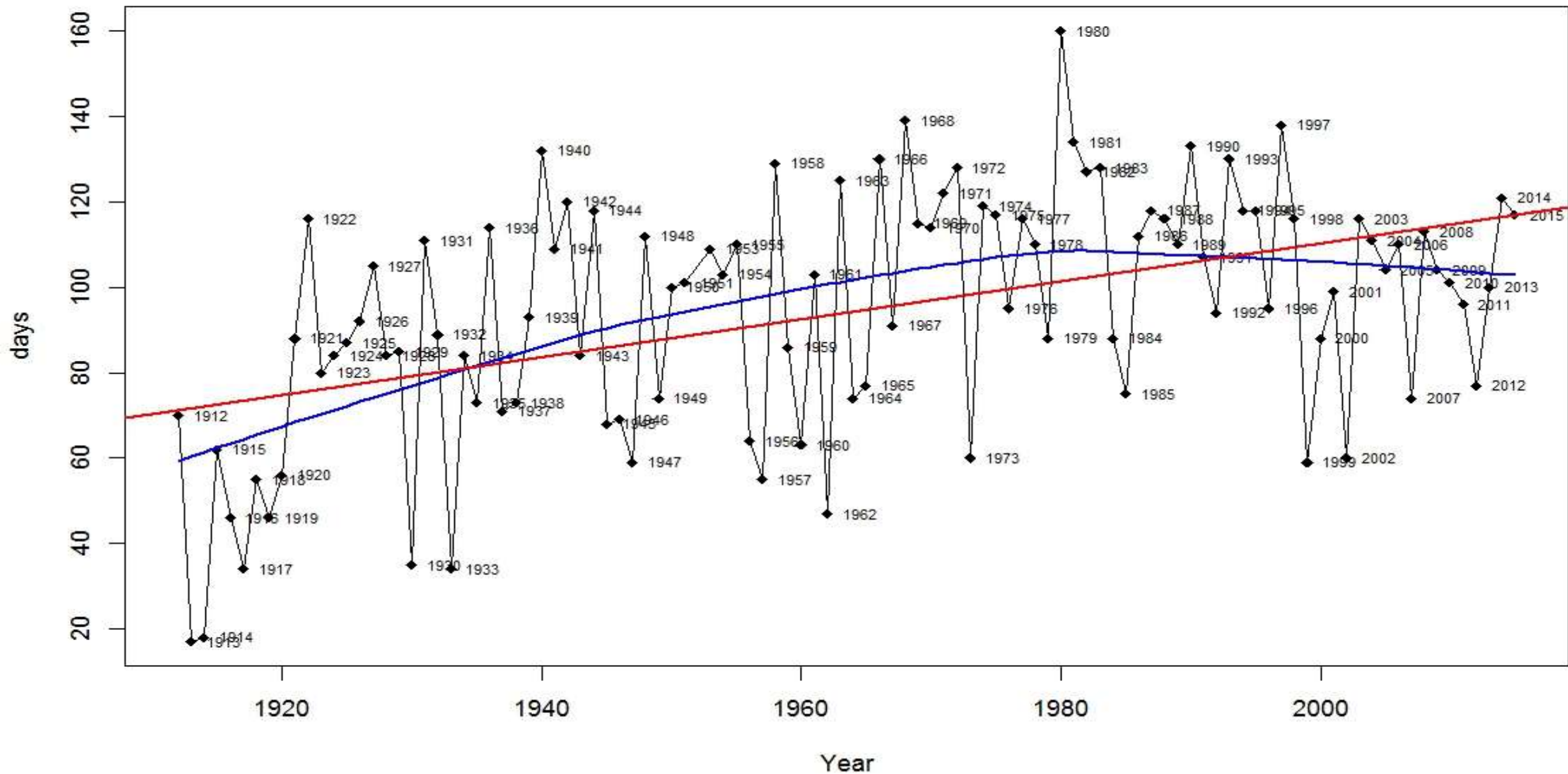




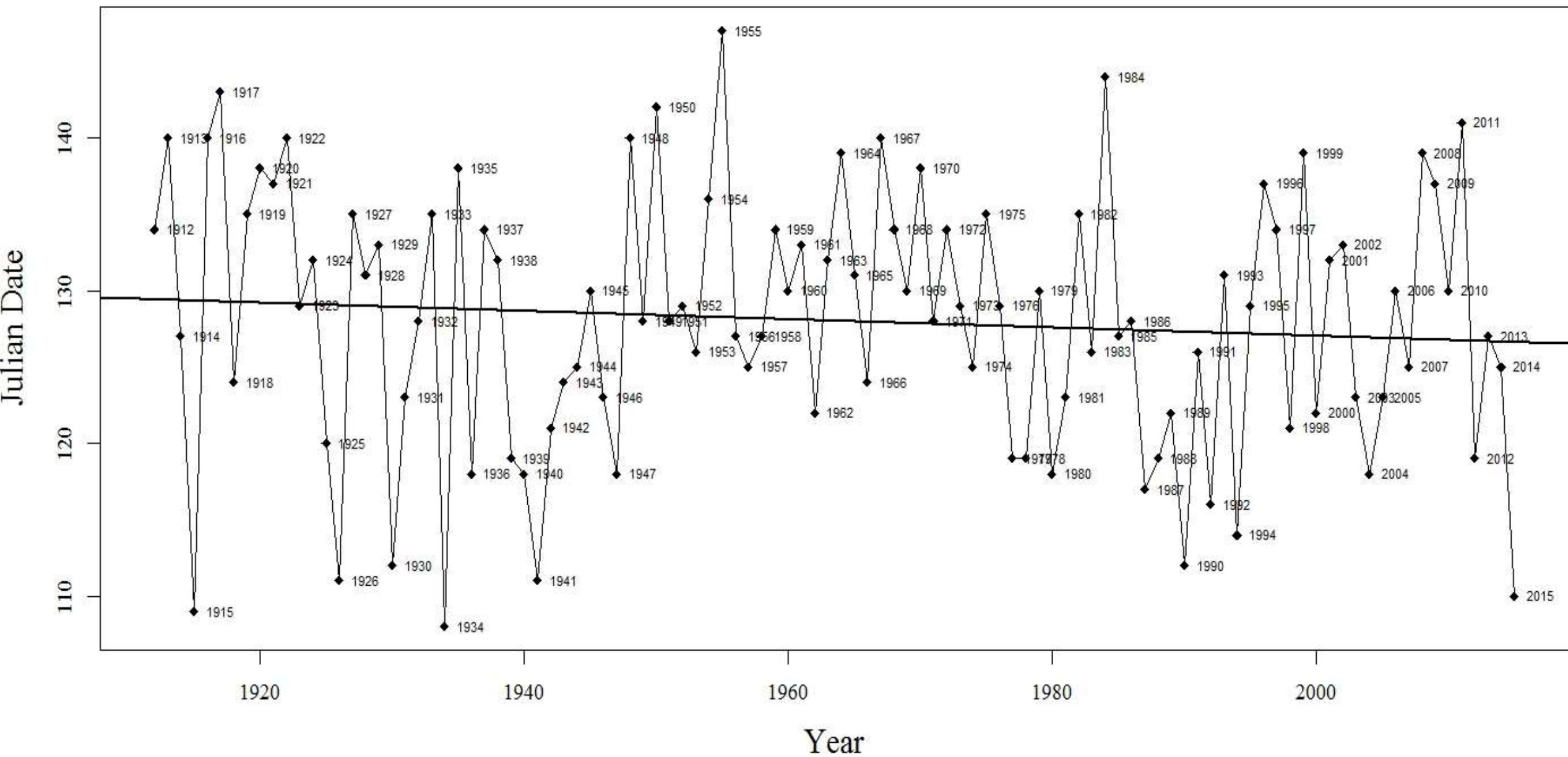
Mean Minimum Temperature at PREF by Water Year



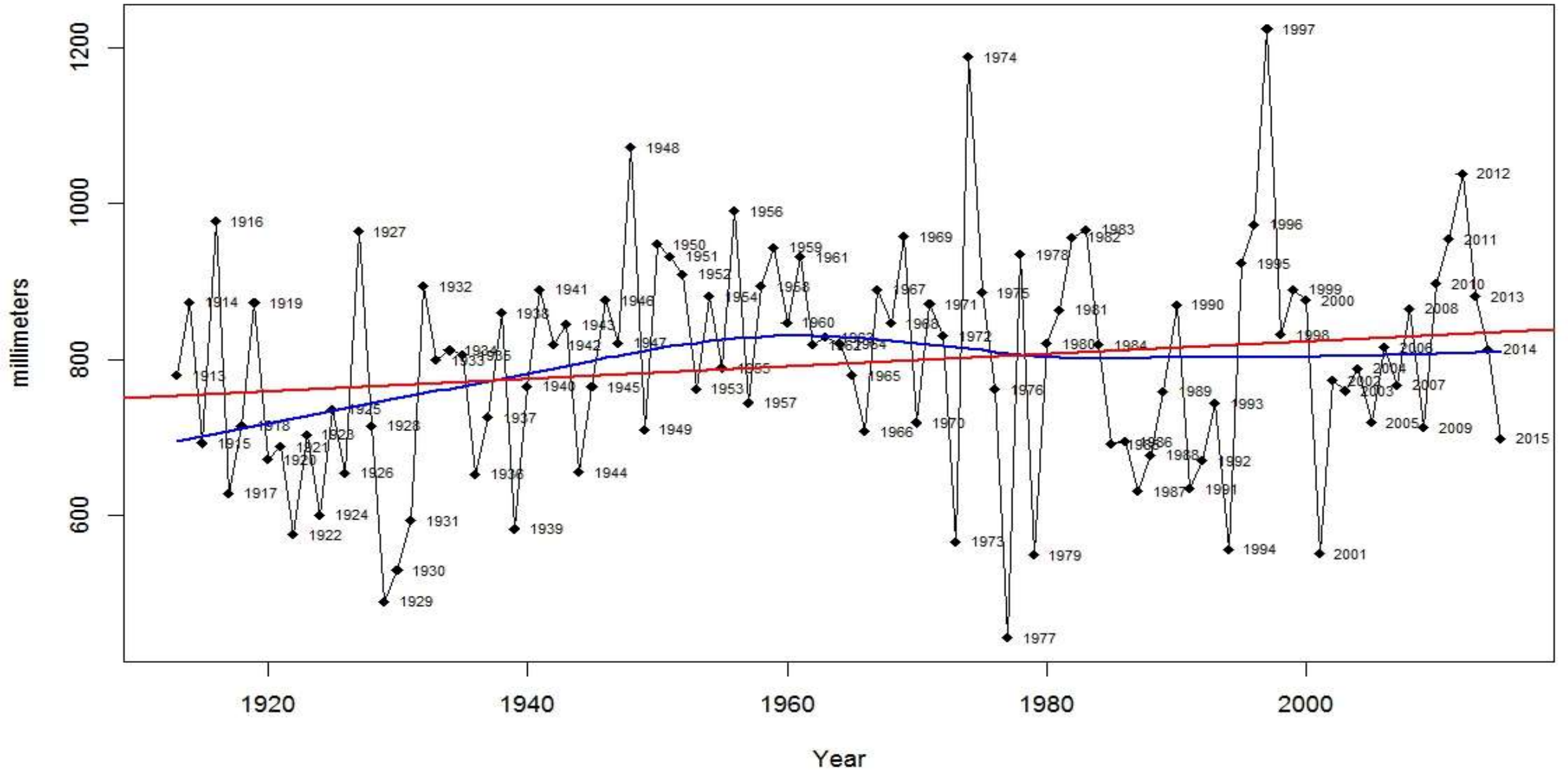
Frost Free Period at PREF



D100 at PREF



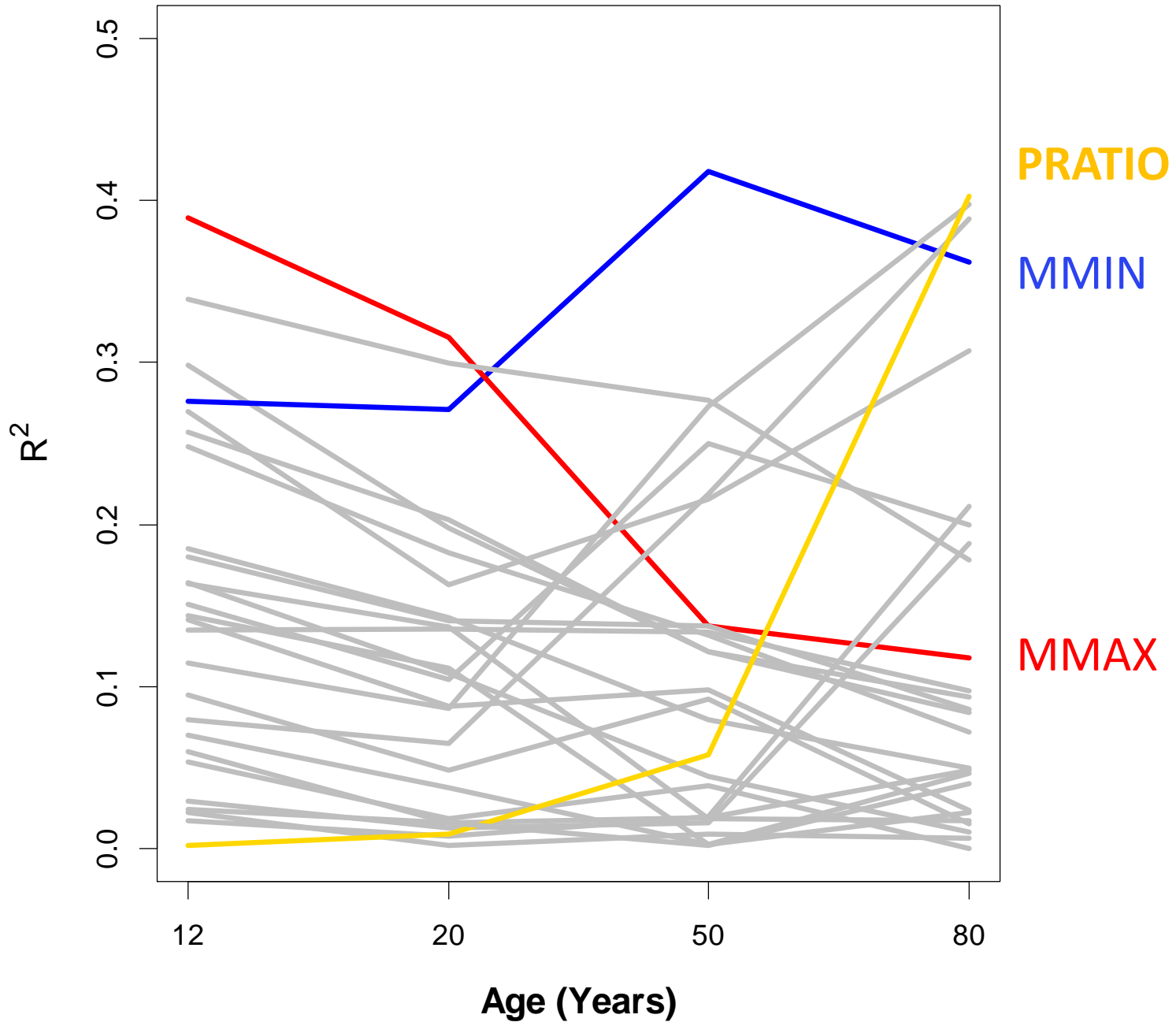
Annual Total Precipitation at PREF by Water Year



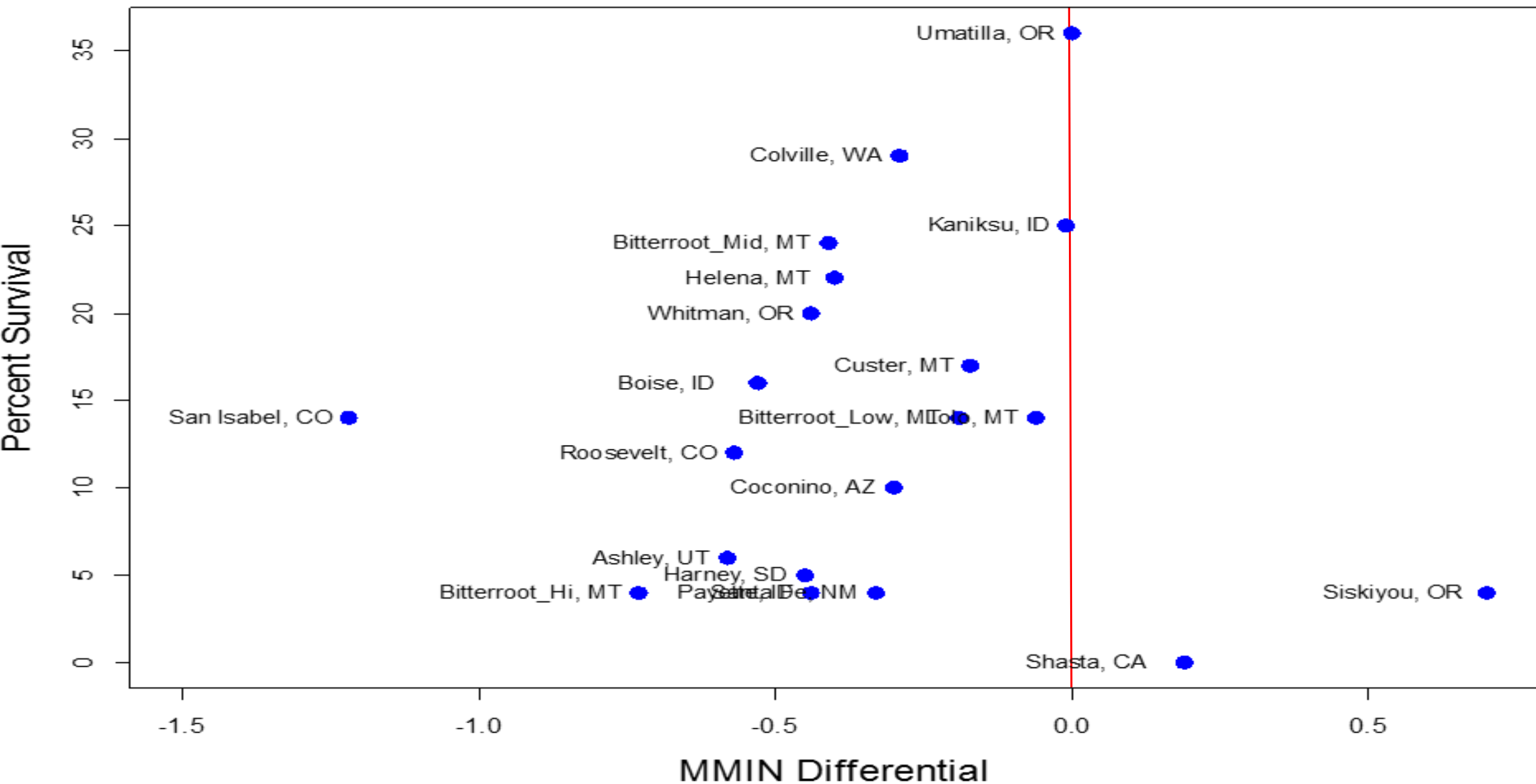
Annual Temperature	
Mean annual temperature	MAT
Temperature: Warmth	
Mean annual maximum temperature	MMAX
Mean temperature in the warmest month	MTWM
Degree-days > 5°C (based on mean monthly temperature)	DD5
Degree-days > 5°C accumulating within the frost-free period	GSDD5
Temperature: Coldness	
Mean annual minimum temperature	MMIN
Mean temperature in the coldest month	MTCM
Degree-days < 0°C (based on mean monthly temperature)	DD0
Degree-days < 0°C (based on mean minimum monthly temperature)	MMINDD0
Seasonal Temperature: Balance and Timing	
Temperature differential between mean warmest and coldest months	TDIFF
Julian date the sum of degree-days > 5°C reaches 100	D100
Julian date of the last freezing date of spring	SDAY
Julian date of the first freezing date of autumn	FDAY
Length of the frost-free period (days)	FFP
Timing of Annual Precipitation	
Mean annual precipitation	MAP
Growing season precipitation, April to September	GSP
Spring precipitation: (April+May)	SPRP
Summer precipitation: (July+August)	SMRP
Winter precipitation: (November+December+January +February)	WINP
Precipitation: Seasonal Balance	
Ratio of growing season precipitation to total precipitation, gsp/map	PRATIO
Interaction of Temperature and Precipitation	
Annual dryness index, dd5/map	ADI
Summer dryness index, gsdd5/gsp	SDI
Adi*mmindd0	ADIMMINDD0
Summer dryness index, gsdd5/gsp	SDIMMINDD0

- 26 Derived climate variables

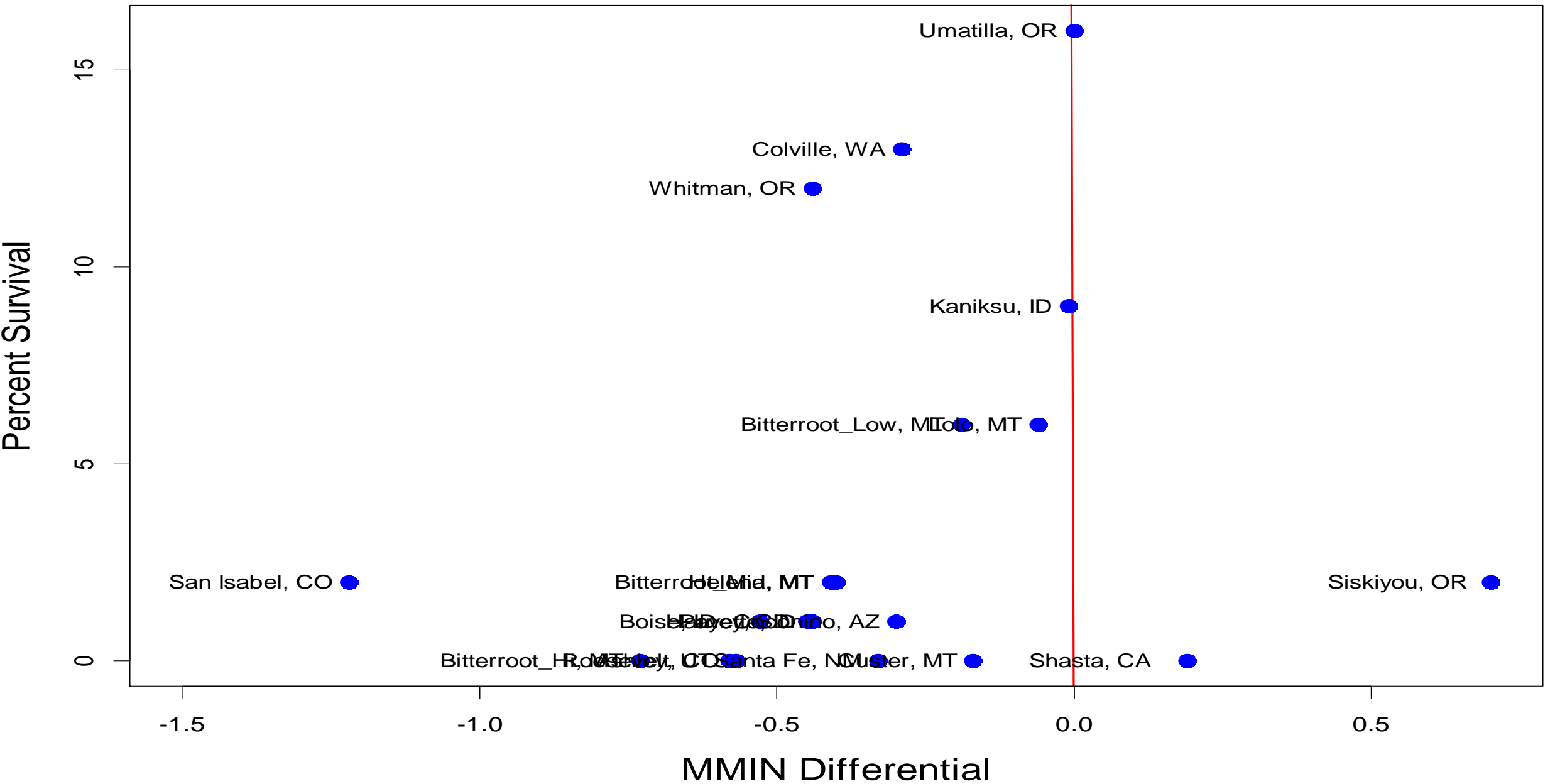
% Survival and Climate of Seed Origin



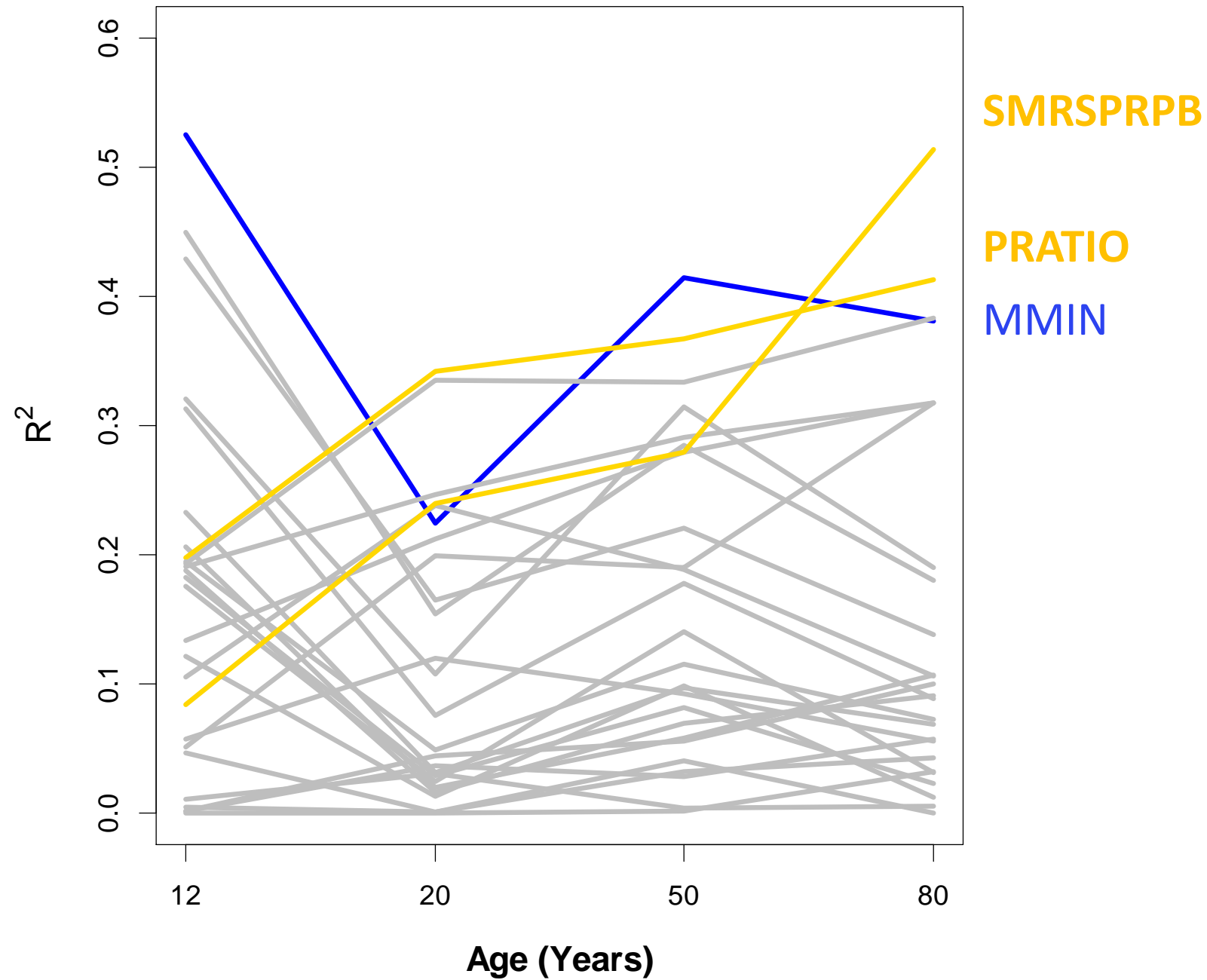
MMIN Differential of Seed Origin and Study Site vs. Survival at 50 years



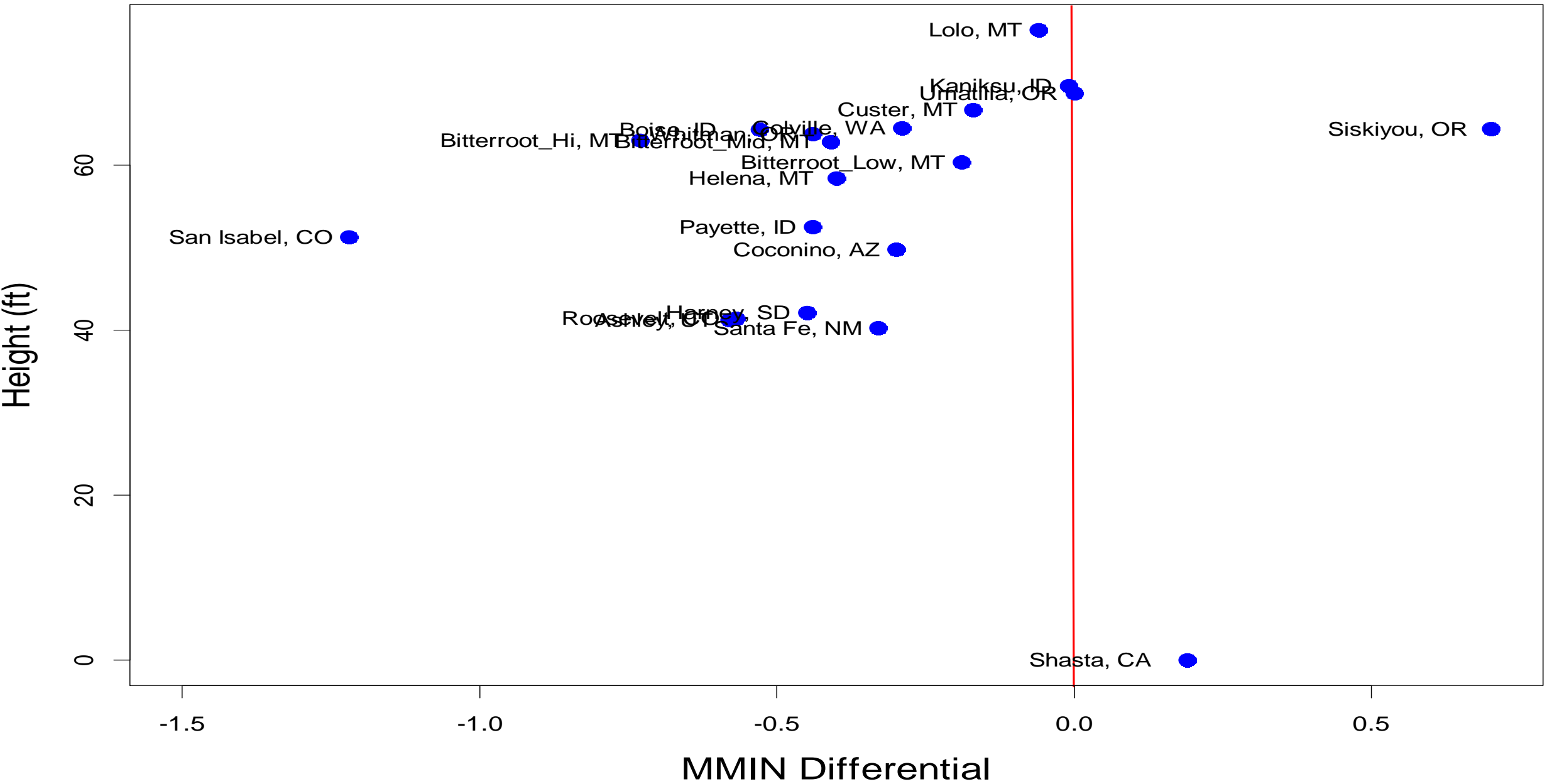
MMIN Differential of Seed Origin and Study Site vs. Survival at 80 years



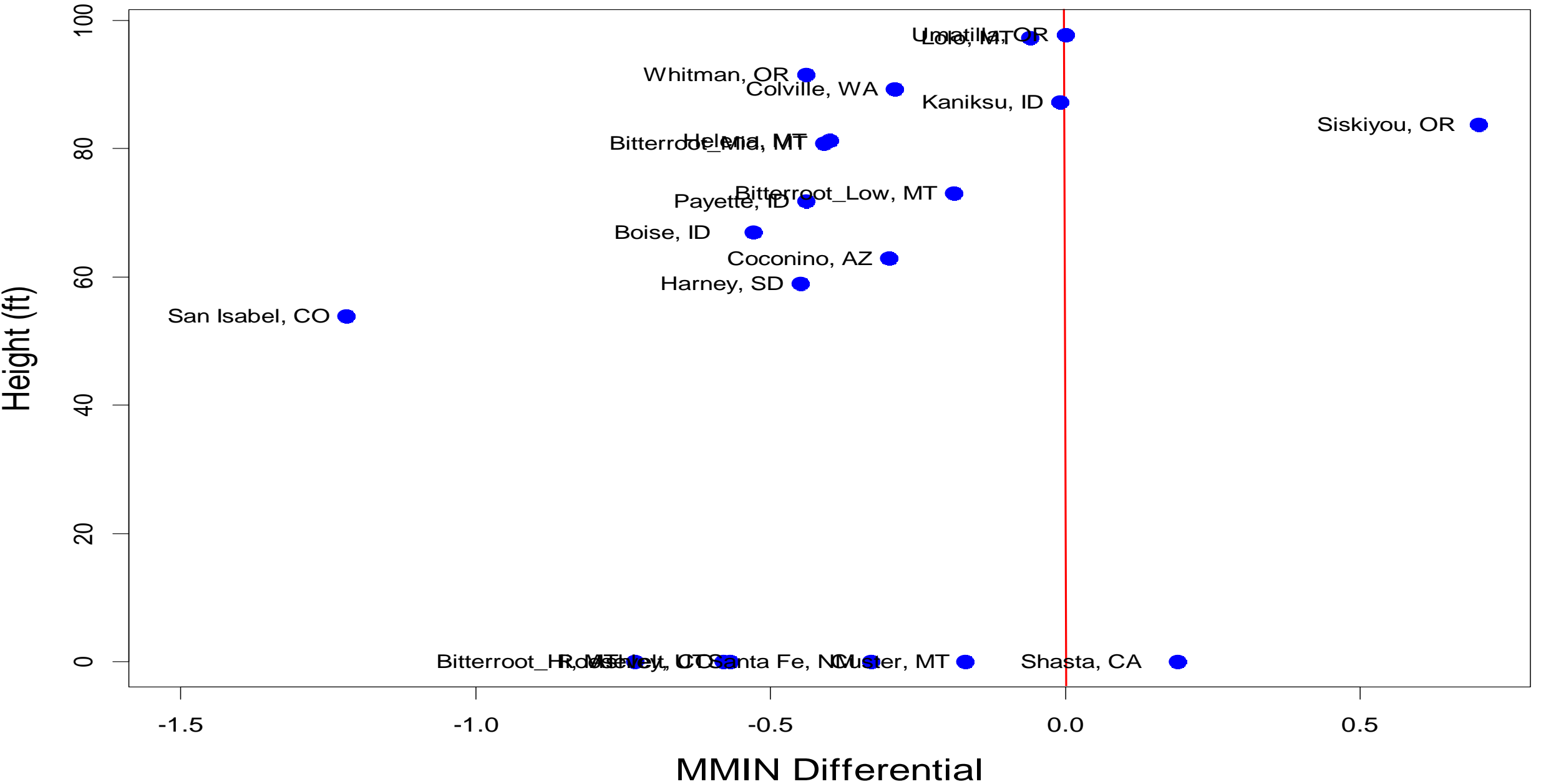
Mean Height and Climate of Seed Origin



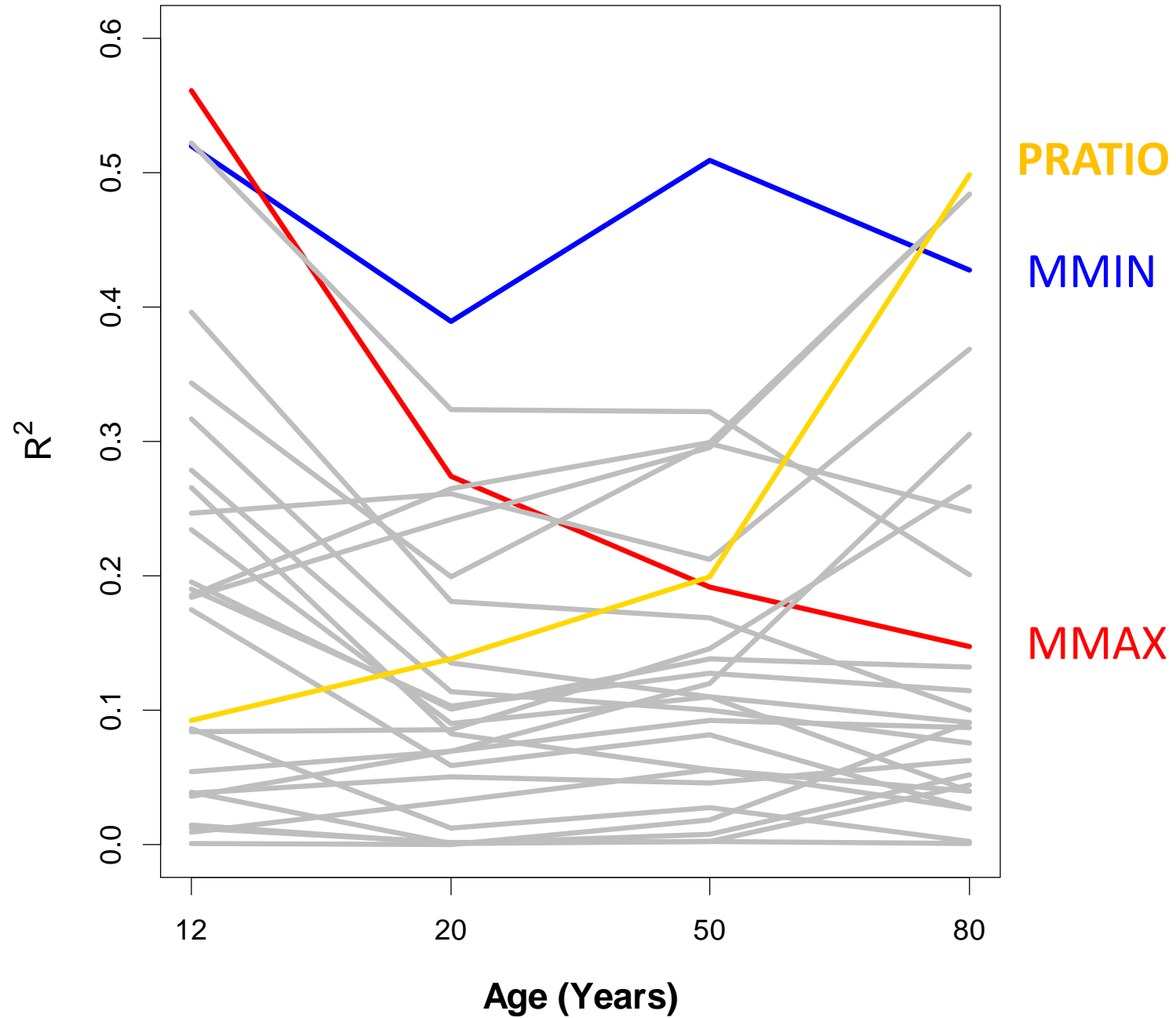
MMIN Differential of Seed Origin and Study Site vs. Height at 50 years



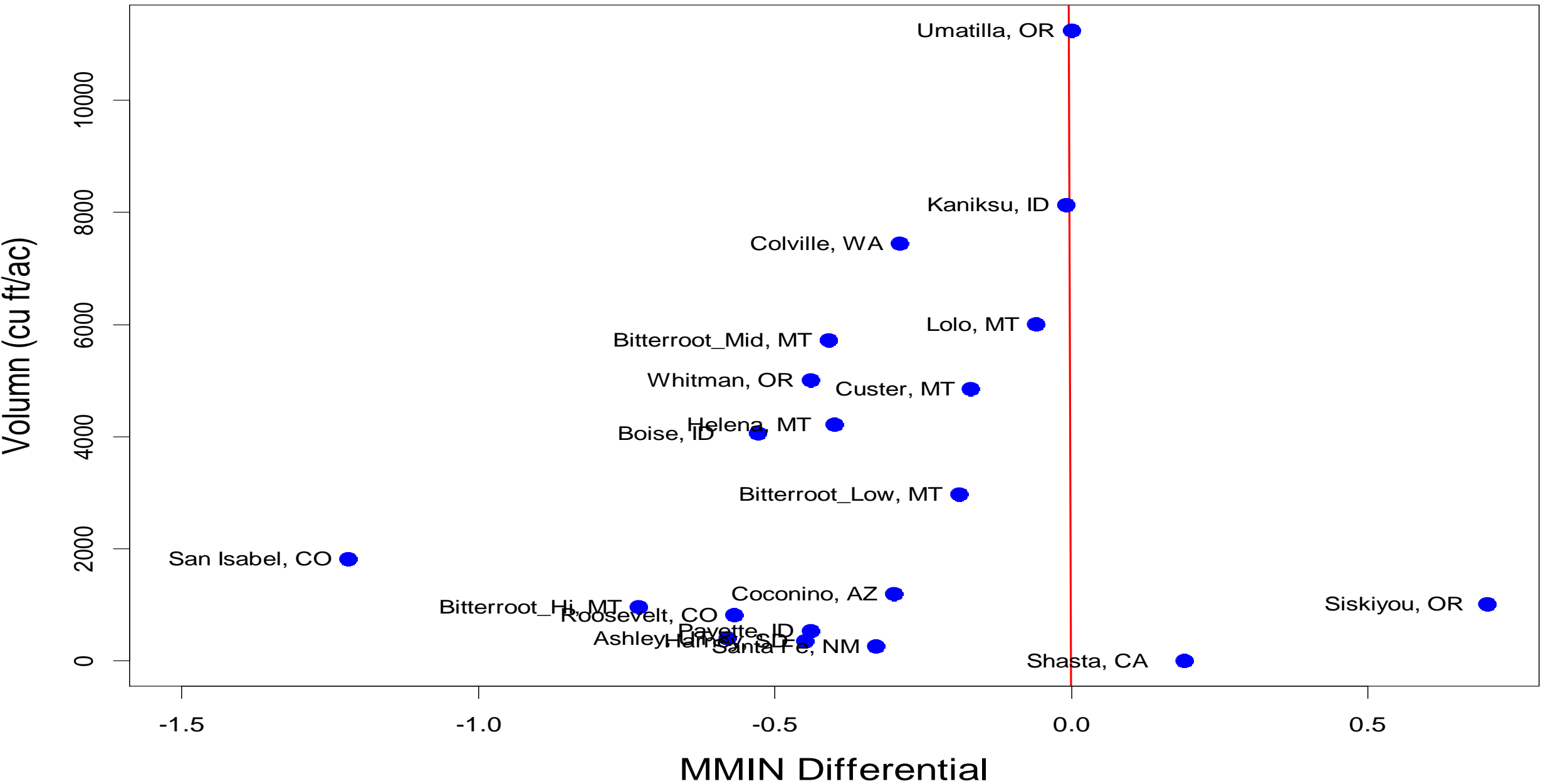
MMIN Differential of Seed Origin and Study Site vs. Height at 80 years



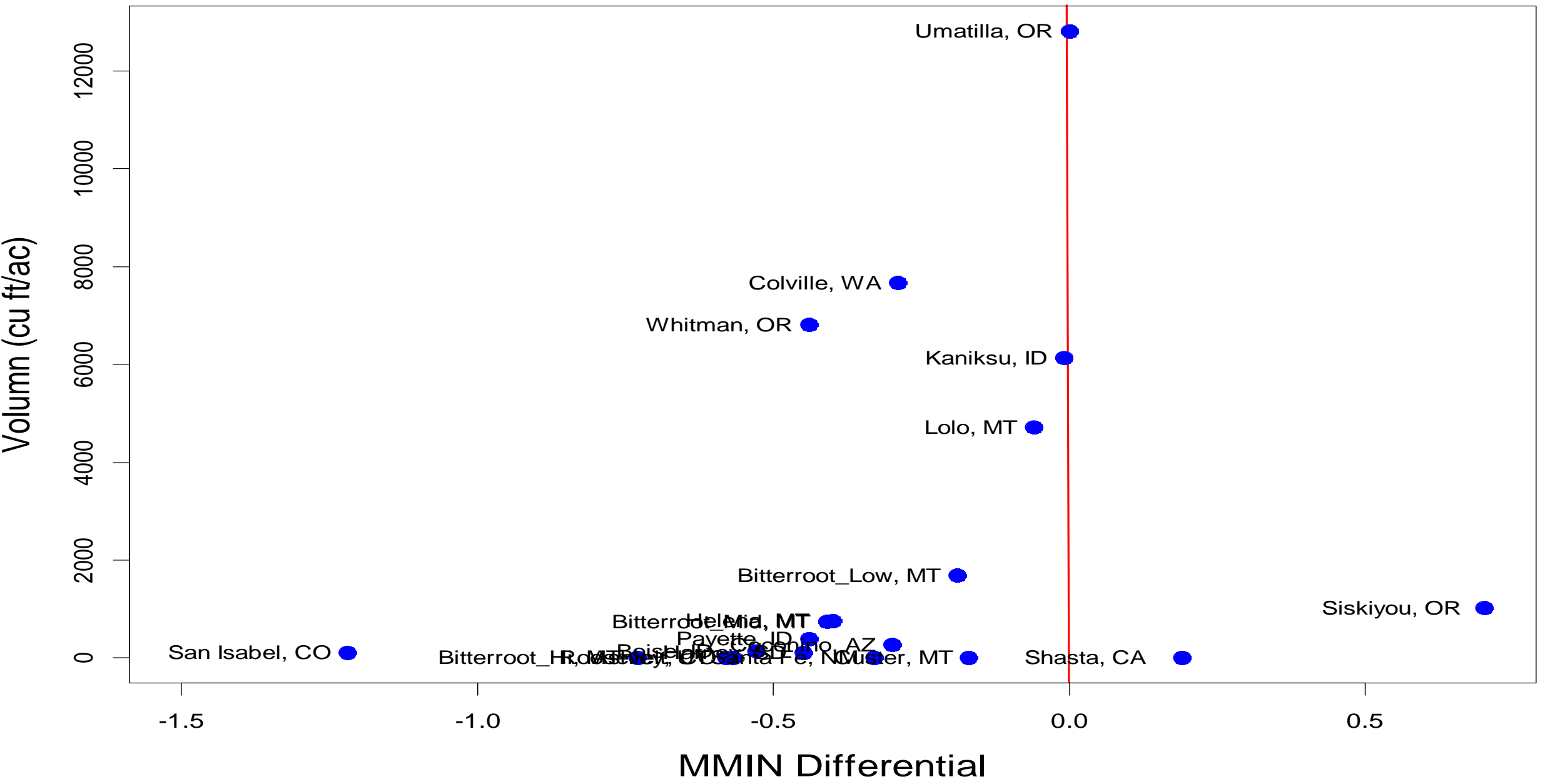
Volume/Acre and Climate of Seed Origin



MMIN Differential of Seed Origin and Study Site vs. Volumn at 50 years



MMIN Differential of Seed Origin and Study Site vs. Volumn at 80 years





Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco



Comparative genetic responses to climate in the varieties of *Pinus ponderosa* and *Pseudotsuga menziesii*: Clines in growth potential

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ARTICLE INFO

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Available online 29 March 2014

Keywords:
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Geneecology
Mixed effects models
Provenance tests

ABSTRACT

Height growth data were assembled from 10 *Pinus ponderosa* and 17 *Pseudotsuga menziesii* provenance tests. Data from the disparate studies were scaled according to climate similarities of the provenances to provide single datasets for 781 *P. ponderosa* and 1193 *P. menziesii* populations. Mixed effects models were used for two sub-specific varieties of each species to describe clines in growth potential associated with provenance climate while accounting for study effects not eliminated by scaling. Variables related to winter temperatures controlled genetic variation within the varieties of both species. Clines were converted to climatypes by classifying genetic variation, using variation within provenances in relation to the slope of the cline to determine climatype breadth. Climatypes were broader in varieties of *P. ponderosa* than in *P. menziesii* and were broader for varieties inhabiting coastal regions of both species than for varieties from interior regions. Projected impacts of climate change on adaptedness used output from an ensemble of 17 general circulation models. Impacts were dependent on cline steepness and climatype breadth but implied that maintaining adaptedness of populations to future climates will require a redistribution of genotypes across forested landscapes.

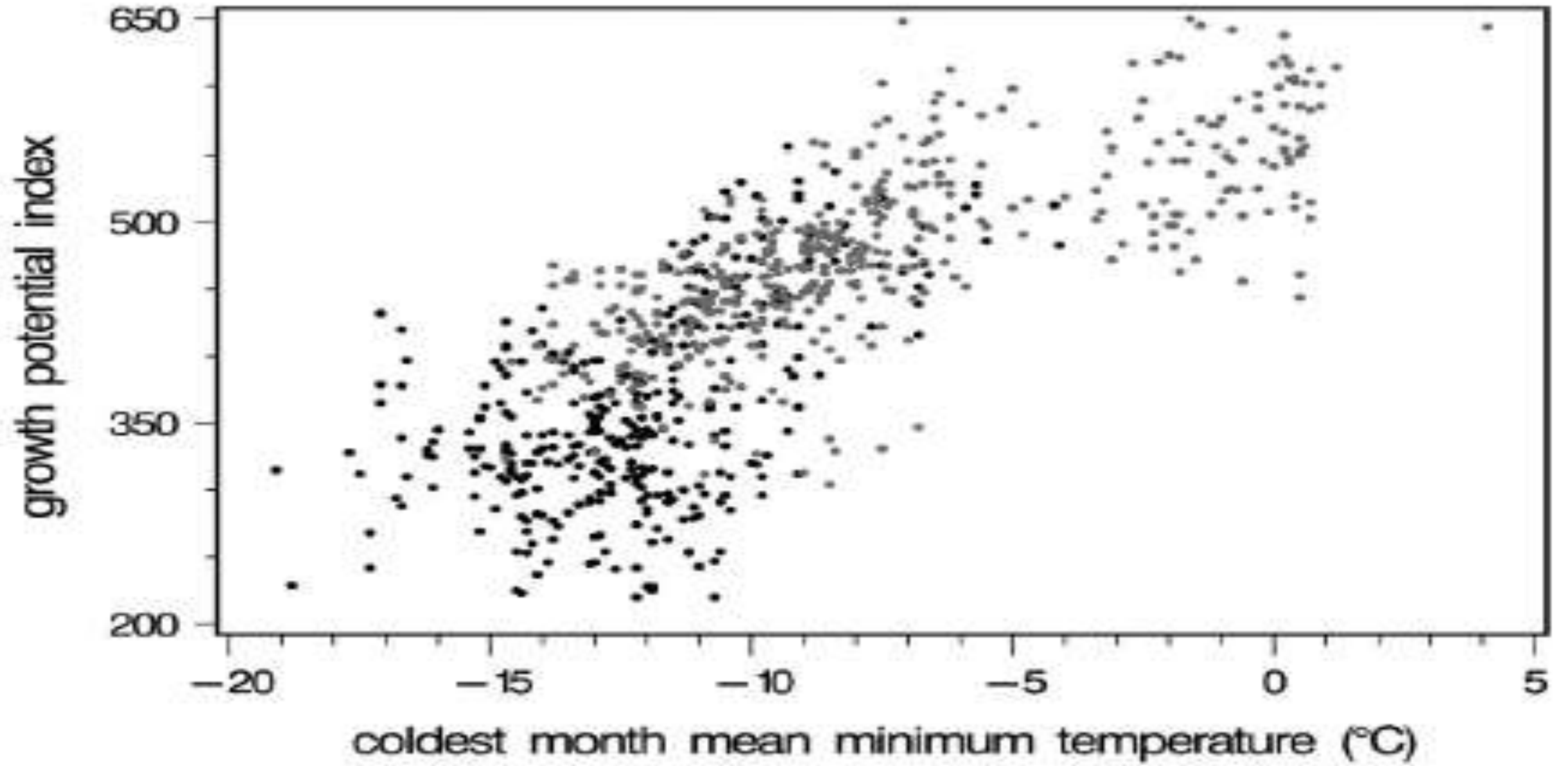
Published by Elsevier B.V.

1. Introduction

From the earliest (e.g., Kempff, 1928; Munger and Morris, 1936) to more recent (Burdon and Low, 1991; St Clair et al., 2005), provenance tests have demonstrated extensive genetic differentiation among populations of *Pinus ponderosa* and *Pseudotsuga menziesii*

et al., 1967). Subsequent tests, addressing regional genetic effects within varieties, repeatedly illustrated genetic differences among populations for traits controlling growth, phenology, cold hardiness (e.g., Callahan and Liddicoet, 1961; Wells, 1964; Campbell, 1979) and tolerances to pests (e. g., Burdon and Low, 1991; Stanhan, 1980; McDermott and Robinson, 1989). In this paper

- MMINNDDO
- 10 Studies
 - Age 3 -22 years old
 - 38 – 138 population



Key Points

- Climate maladaptation is expressed as decreased health and productivity.
- Cold hardiness should be considered when moving populations from warmer to colder contemporary climates.
- Species that are more finely attuned to climate variation (specialist) are at greater risk of maladaptation under changing climate

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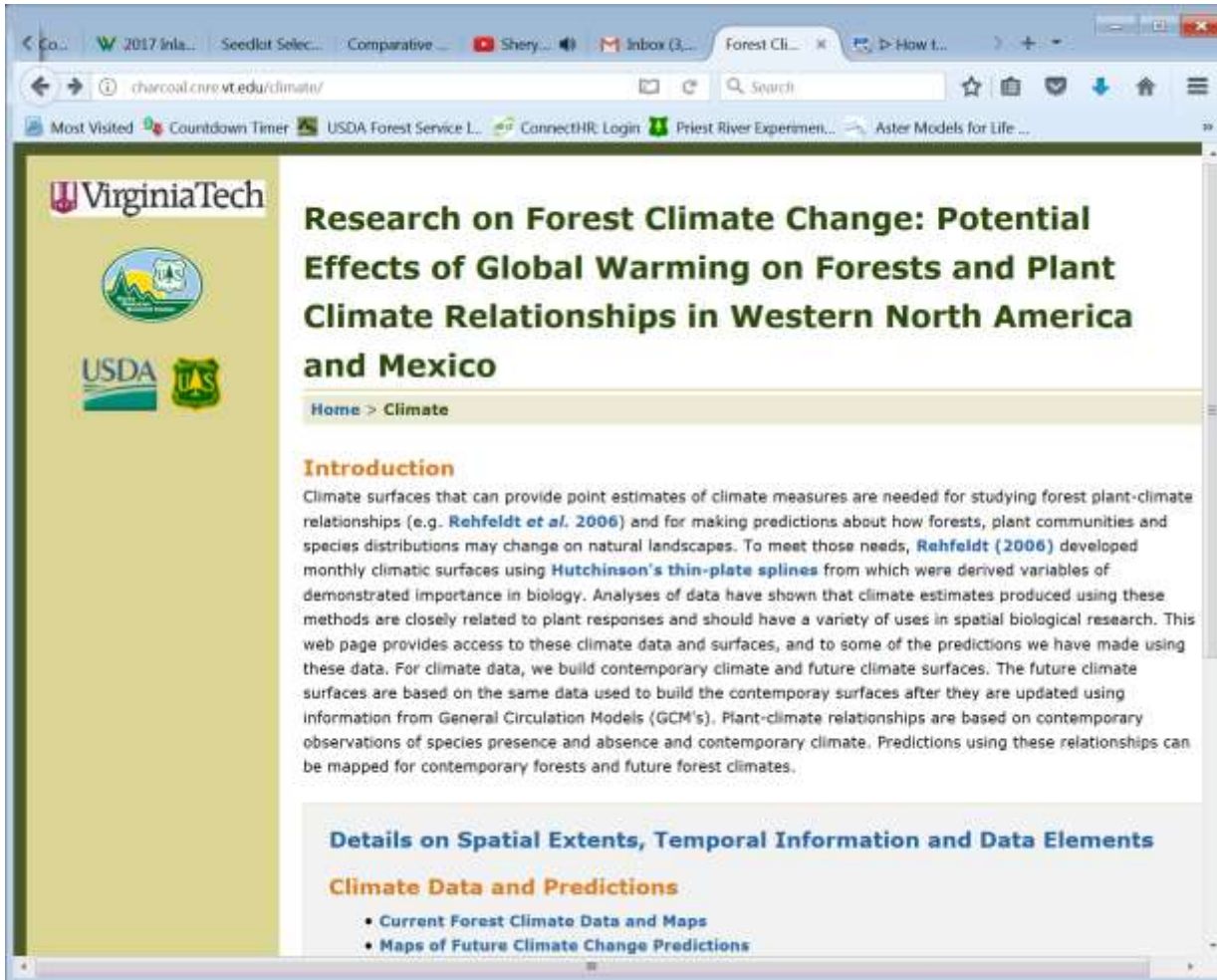


Reforestation Management Recommendations Under Changing Climate

- **Consider** conservation of genetic diversity in anticipation of impacts of changing climate
- **Consider** matching species and seed sources with expected future climates.

<http://charcoal.cnre.vt.edu/climate/>

- Nicholas Crookston, USDA Forest Service Ret.



The screenshot shows a web browser window displaying the website <http://charcoal.cnre.vt.edu/climate/>. The page features the Virginia Tech logo and the USDA logo. The main heading is "Research on Forest Climate Change: Potential Effects of Global Warming on Forests and Plant Climate Relationships in Western North America and Mexico". Below the heading, there is a navigation menu with "Home > Climate". The "Introduction" section discusses the need for climate surfaces for studying forest plant-climate relationships and mentions the work of Rehfeldt (2006) and Hutchinson's thin-plate splines. The "Details on Spatial Extents, Temporal Information and Data Elements" section includes links for "Climate Data and Predictions", "Current Forest Climate Data and Maps", and "Maps of Future Climate Change Predictions".

VirginiaTech

USDA

Research on Forest Climate Change: Potential Effects of Global Warming on Forests and Plant Climate Relationships in Western North America and Mexico

Home > Climate

Introduction

Climate surfaces that can provide point estimates of climate measures are needed for studying forest plant-climate relationships (e.g. Rehfeldt *et al.*, 2006) and for making predictions about how forests, plant communities and species distributions may change on natural landscapes. To meet those needs, Rehfeldt (2006) developed monthly climatic surfaces using Hutchinson's thin-plate splines from which were derived variables of demonstrated importance in biology. Analyses of data have shown that climate estimates produced using these methods are closely related to plant responses and should have a variety of uses in spatial biological research. This web page provides access to these climate data and surfaces, and to some of the predictions we have made using these data. For climate data, we build contemporary climate and future climate surfaces. The future climate surfaces are based on the same data used to build the contemporary surfaces after they are updated using information from General Circulation Models (GCM's). Plant-climate relationships are based on contemporary observations of species presence and absence and contemporary climate. Predictions using these relationships can be mapped for contemporary forests and future forest climates.

Details on Spatial Extents, Temporal Information and Data Elements

Climate Data and Predictions

- [Current Forest Climate Data and Maps](#)
- [Maps of Future Climate Change Predictions](#)

Climate FVS

US FOREST SERVICE Forest Vegetation Simulator

Climate-FVS

The Forest Service Mission is to "Sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations."

"The Nation's forests and grasslands provide clean water, scenic beauty, biodiversity, outdoor recreation, natural resource-based jobs, forest products, renewable energy and carbon sequestration. Climate change is one of the greatest challenges to sustainable management of forests and grasslands and to human well-being that we have ever faced, because rates of change will likely exceed many ecosystems' capabilities to naturally adapt. Without fully integrating consideration of climate change impacts into planning and actions, the Forest Service can no longer fulfill its mission." (Forest Service Strategic Framework for Responding to Climate Change (2008))(PDF, 294 KB)

"Climate change is expected to have pronounced ecological consequences in forested ecosystems. Projected impacts encompass a broad range of effects: the evolution of novel plant associations, shifts in the spatial distribution of tree species, redistribution of populations adapted to local climates, and in site index. Several studies, in fact, have been unanimous in predicting widespread disruption of native ecosystems from the change in climate being portrayed by numerous General Circulation Models." (Crookston and others (2010, p. 1198))(PDF, 695 KB)

The Climate Extension to the Forest Vegetation Simulator (Climate-FVS) provides forest managers a tool for considering the effects of climate change on forested ecosystems. The original Forest Vegetation Simulator (FVS) components predict performance in the absence of climate change. To accommodate the effects of climate change, Climate-FVS modifies these components rather than replacing them with new climate estimators. In this respect, the primary intrinsic components of FVS and its empirical heritage remain intact. The core tree growth, mortality, and regeneration components in FVS are modeled as functions of site capacity, tree size, and competition. The measures of site capacity rely on direct observations of biological indicators such as site index. In the base FVS model, there is an assumption that site capacity does not change over time. With the introduction of Climate-FVS, there is now the ability to use information regarding climate change to affect site capacity and estimate the effects on tree growth, mortality, and regeneration potential.

Growth is affected when climate conditions at a given location change in relation to the optimal climate conditions within which the species or population is known to grow and thrive. Mortality is affected when the climate in an

Climate-FVS Webinar Video
[Introduction to Climate-FVS in the Western U.S.](#) - video and audio recording of the March 10, 2011, webinar.

Poster
[Effects of and responses to climate change on National Forests: Addressing Climate Change in the Forest Vegetation Simulator](#) (PDF, 724 KB)

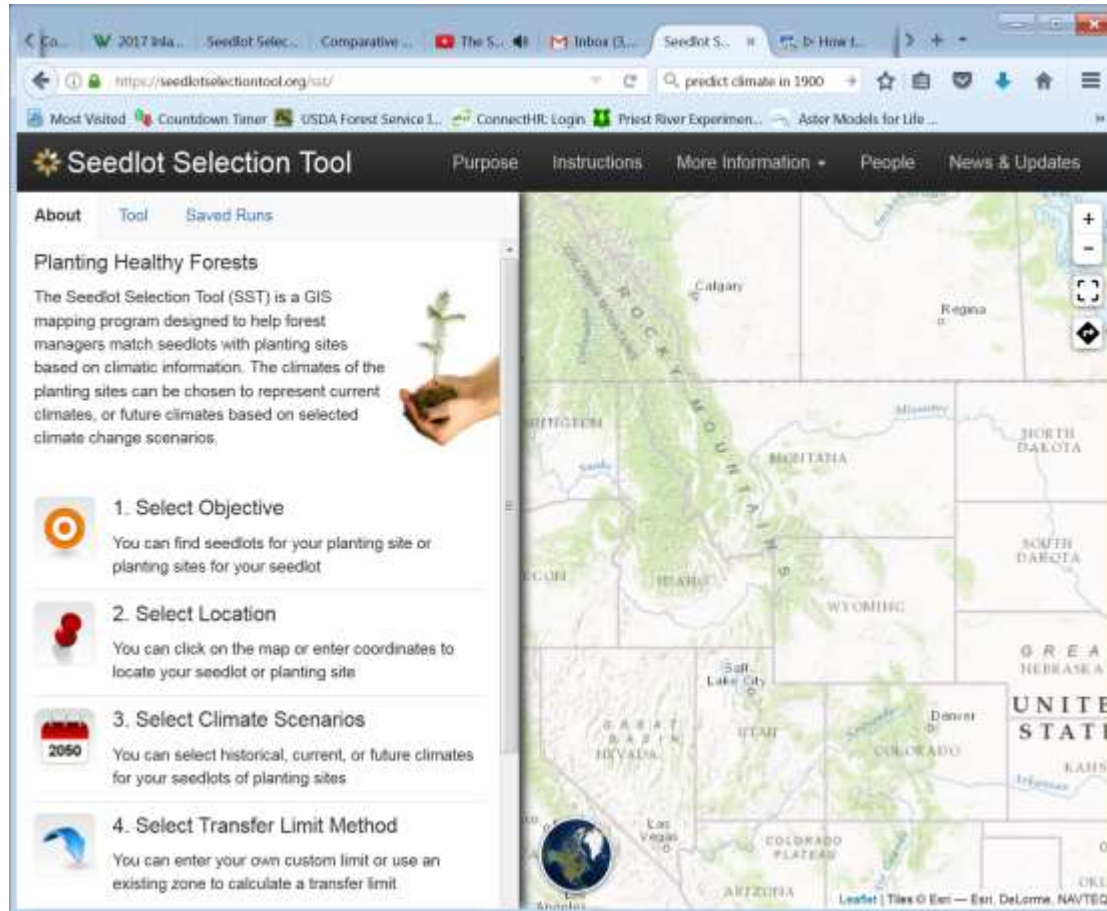
US Forest Service
Forest Management Service Center
2150 Centre Avenue, Bldg. A
Fort Collins, CO 80526-1891

Please [contact us](#) with questions or comments regarding this website.

USA.gov
Government • Made Easy

- Nicholas Crookston, USDA Forest Service Ret.

<https://seedlotselectiontool.org>



The screenshot shows the Seedlot Selection Tool website. The browser address bar displays <https://seedlotselectiontool.org/>. The page title is "Seedlot Selection Tool" with navigation links for Purpose, Instructions, More Information, People, and News & Updates. The main content area is titled "Planting Healthy Forests" and includes a description: "The Seedlot Selection Tool (SST) is a GIS mapping program designed to help forest managers match seedlots with planting sites based on climatic information. The climates of the planting sites can be chosen to represent current climates, or future climates based on selected climate change scenarios." Below this is a list of four steps: 1. Select Objective, 2. Select Location, 3. Select Climate Scenarios, and 4. Select Transfer Limit Method. A map of the United States is visible on the right side of the page, showing the Rocky Mountain region.

- Glenn Howe, Oregon State University
- Brad St.Clair, USDA Forest Service
- Dominique Bachelet, Conservation Biology Institute

<http://www.torreyaguardians.org/assisted-migration.html>

- Connie Barlow



The screenshot shows a web browser window displaying the website www.torreyaguardians.org/assisted-migration.html. The page features a green header with the website's name and a main title in orange: "Assisted Migration (Assisted Colonization, Managed Relocation, Translocation) and Rewilding of Plants and Animals in an Era of Rapid Climate Change". Below the title, there is an "EDITOR'S NOTE" in green text, followed by a paragraph in black text explaining the site's purpose. A section titled "The FORESTRY section" is also present, along with a note from the volunteer editor, Connie Barlow, urging authors to remove paywall barriers. At the bottom, there is a list of key themes and papers.

[www.TorreyGuardians.org](http://www.torreyaguardians.org)

Assisted Migration (Assisted Colonization, Managed Relocation, Translocation) and Rewilding of Plants and Animals in an Era of Rapid Climate Change

EDITOR'S NOTE: This **annotated and linked list of online-accessible papers, articles, and news reports** on assisted migration (aka: **assisted colonization** / colonisation, translocation, managed relocation, facilitated migration, and "neo-natives") aims to further professional and popular understanding of **the substance and history of debate and actions** regarding one of the most significant developments in conservation biology, forestry, and natural resources management. This lengthy list is **continually updated**; entries are ordered by topic, with longer excerpts given for papers of high academic importance, insight into shifting conservation values, expansive treatment of the issue, and provision of background understanding.

The **FORESTRY** section differs from the **CONSERVATION BIOLOGY** section in that foresters are accustomed to "managing" landscape so there has been little debate about *whether* to engage in assisted migration (which is their preferred term). Rather, the focus is on species-by-species details of how to accomplish it. For readers focused on forestry in the USA, go directly to the excerpts here of the Assisted Migration subsection of a 289-page (77 scientist contributors) **2016 technical report of the U.S. Forest Service**.

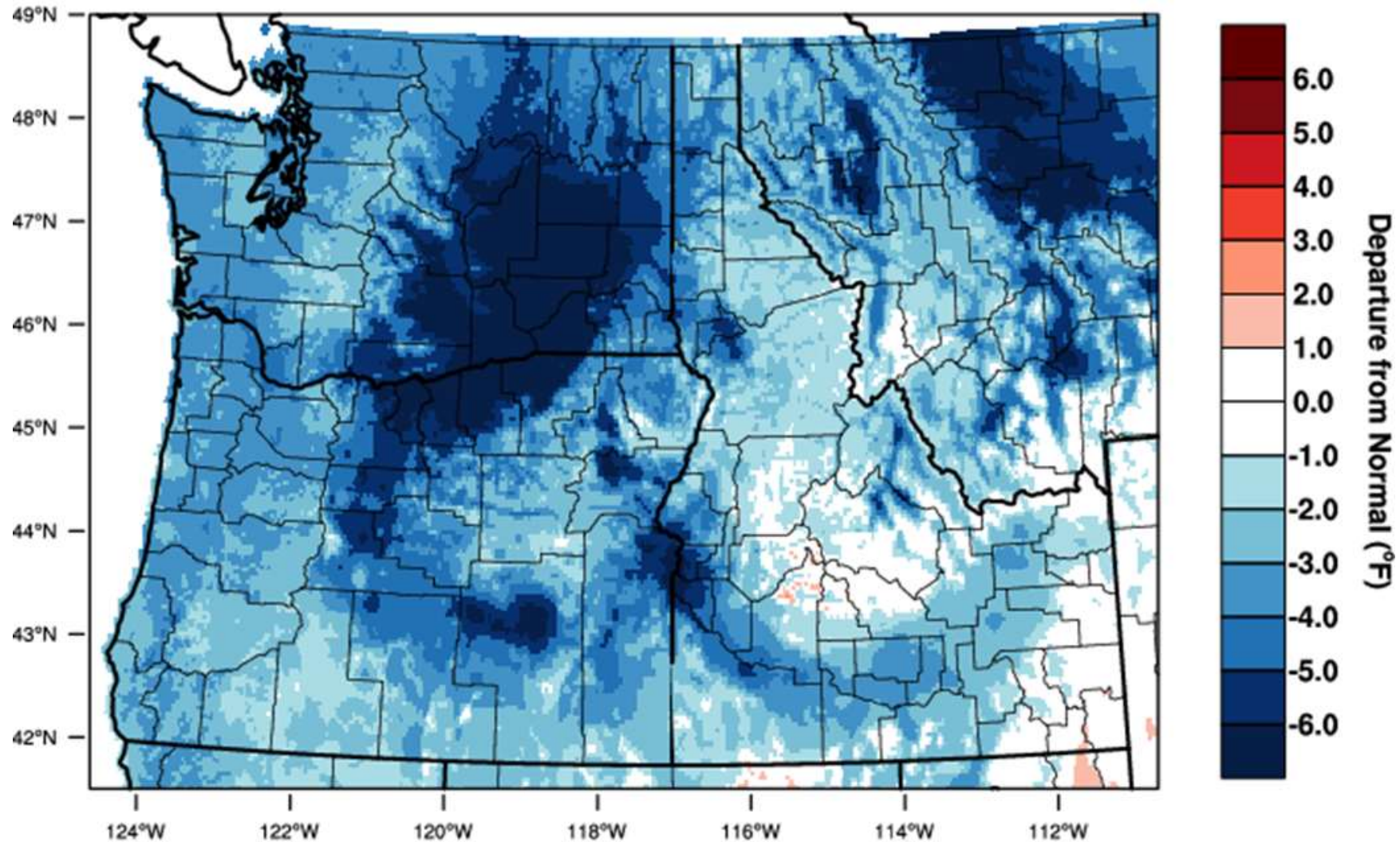
Note: The volunteer editor and webmaster, **Connie Barlow** (founder of Torreya Guardians), urges authors, agencies, and publishers to **remove paywall barriers**. Contributions, such as those listed below, to improve **climate adaptation** methods must become freely available to researchers, managers, and citizen activists in all nations and to the public at large.

Click to advance to each theme (or do an internal "Find" for a topic or year of your choice).

- **Key Charts and Papers** (short list for all to begin here)
- **Society, Values, and Communications** (incl. Science & Society field)
- **Ethics, Law, and History**
- **Urban Ecology Assisted Migration** (emphasis on trees)
- **Paleoecology, Paleobiology, and Biogeography** (focus on Pleistocene range shifts as guidance for assisted migration)

Pacific Northwest - Mean Temperature

December-February 2017 Departure from 1981-2010 Normal



WestWide Drought Tracker - U Idaho/WRCC Data Source - PRISM (Prelim), created 2 MAR 2017

See: <https://climateinw.wordpress.com/2017/03/06/winter-wont-end/>