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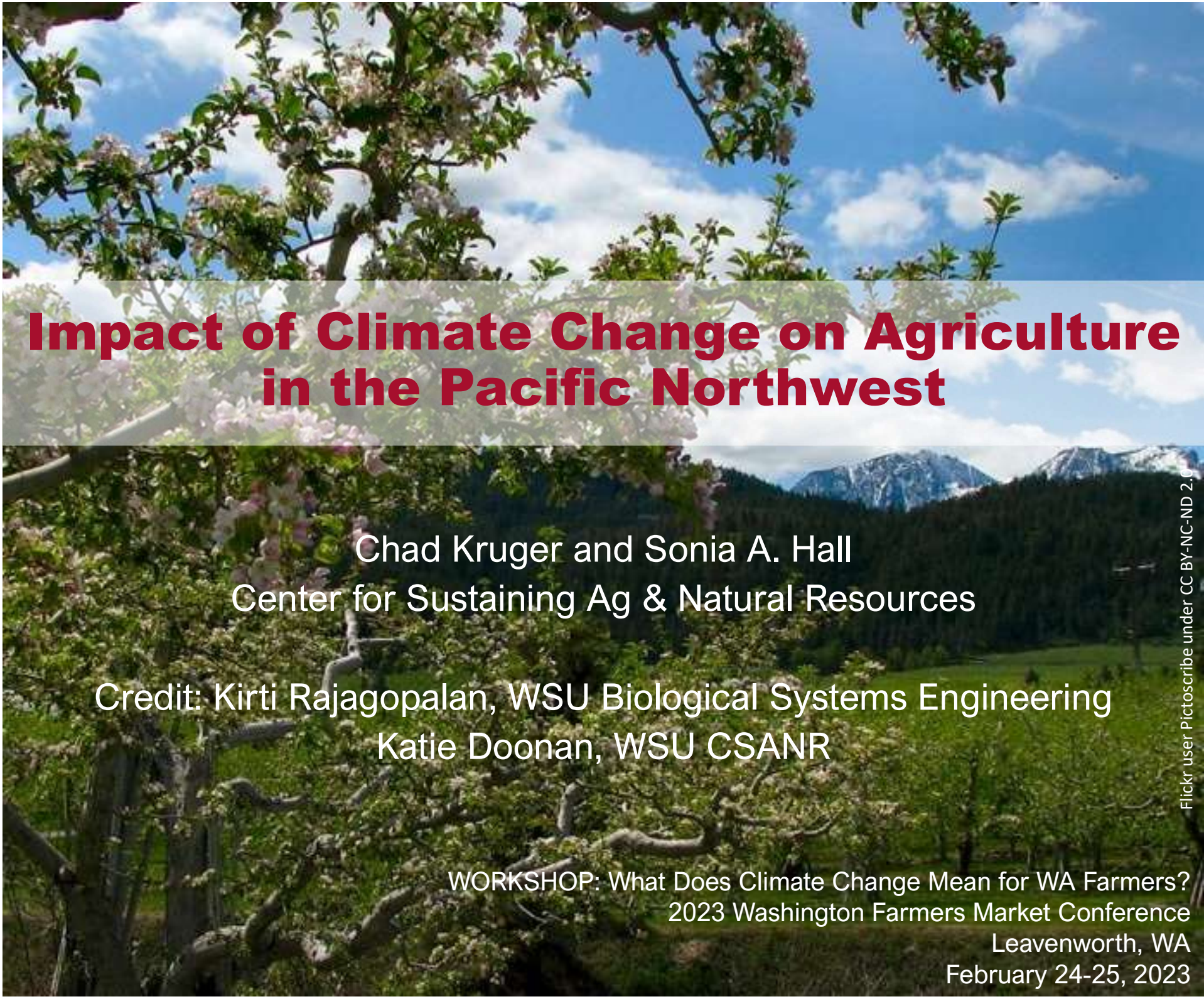

Impact of Climate Change on Agriculture in the Pacific Northwest

Chad Kruger and Sonia A. Hall
Center for Sustaining Ag & Natural Resources

Credit: Kirti Rajagopalan, WSU Biological Systems Engineering
Katie Doonan, WSU CSANR

WORKSHOP: What Does Climate Change Mean for WA Farmers?
2023 Washington Farmers Market Conference
Leavenworth, WA
February 24-25, 2023

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What We Will Cover Today

Overview

- Climate change impacts on plants
- Climate change impacts on water resources

Examples of Recent Research

- Abiotic stresses affected by climate
- Biotic stresses affected by climate

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Discussion

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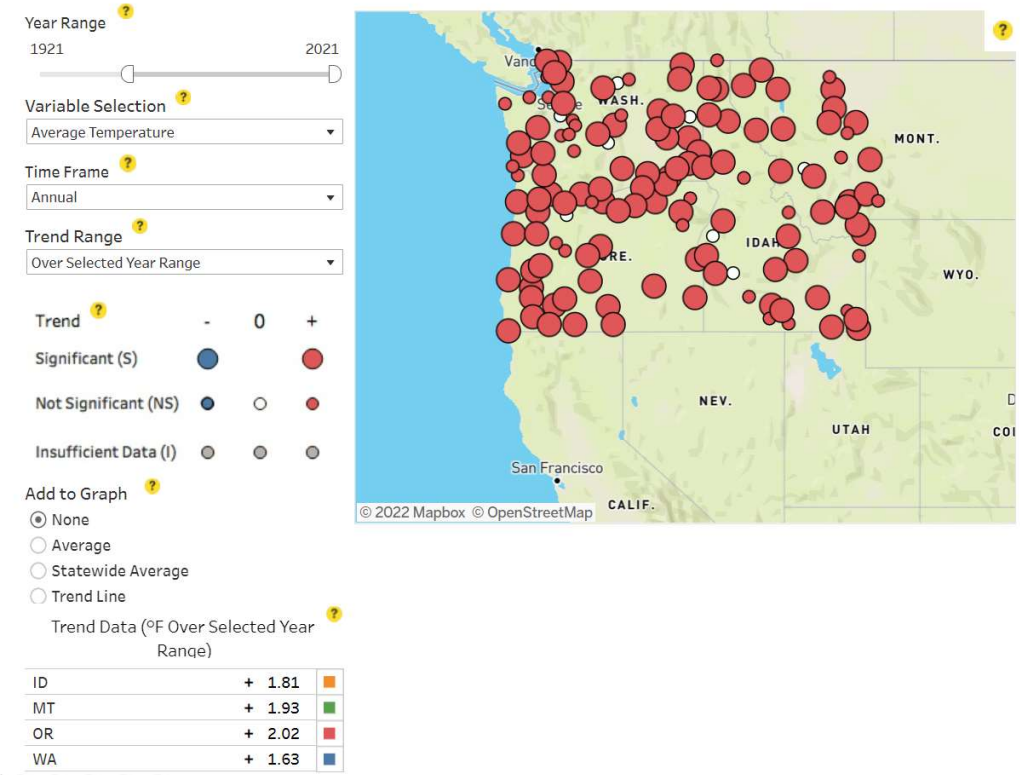
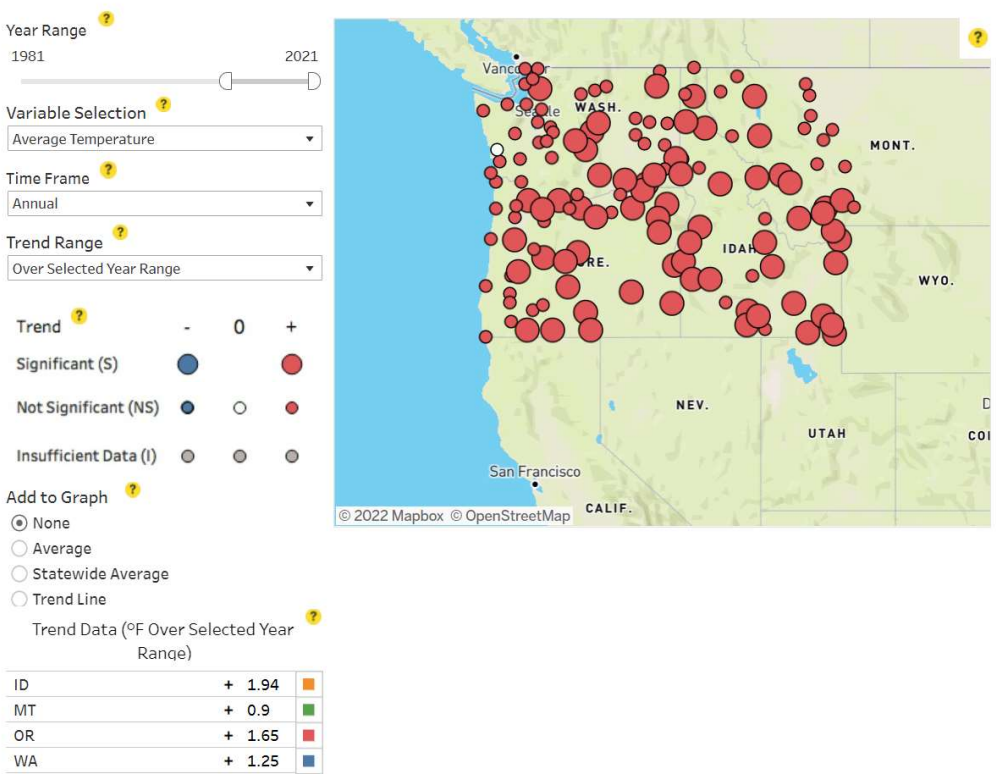
Regional Temperature Trends

1921-2021



1981-2021



https://climate.washington.edu/climate-data/trendanalysisapp/

Station Data Source: NOAA's U.S. Historical Climatolog Network version 2.5.5.20210712

Statewide Data Source: NOAA's US Climate Division Dataset (nClimDiv)

Regional Precipitation Trends

1921-2021

Year Range
1921 2021

Time Frame
Annual

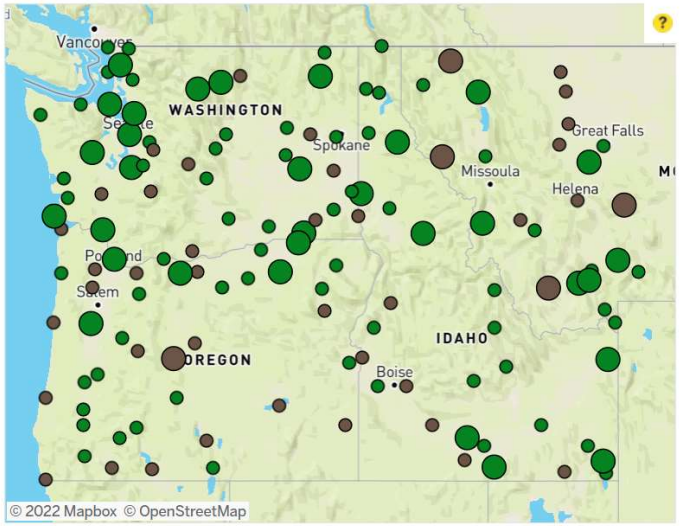
Trend Range
Over Selected Year Range

Trend	-	0	+
Significant (S)	●		●
Not Significant (NS)	●	○	●
Insufficient Data (I)	●	●	●

Add to Graph
- (•) None
- ( ) Average
- ( ) Statewide Average
- ( ) Trend Line

Trend Data (% Change Over Selected Year Range)

ID	+ 4.7	
MT	+ 5.4	
OR	+ 5.9	
WA	+ 10	



1981-2021

Year Range
1981 2021

Time Frame
Annual

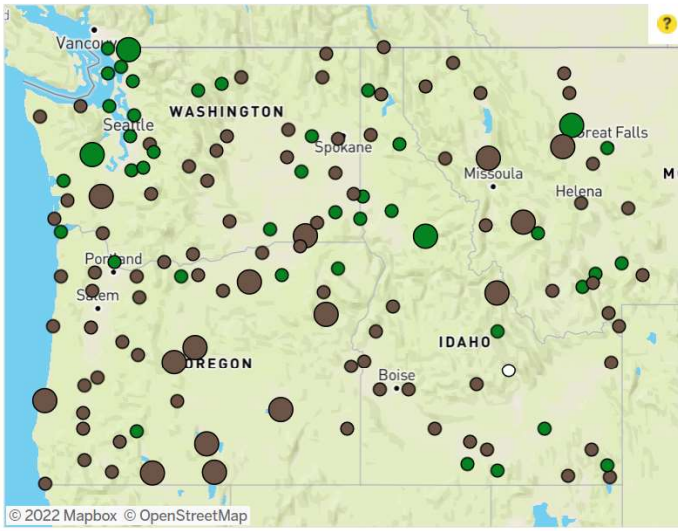
Trend Range
Over Selected Year Range

Trend	-	0	+
Significant (S)	●		●
Not Significant (NS)	●	○	●
Insufficient Data (I)	●	●	●

Add to Graph
- (•) None
- ( ) Average
- ( ) Statewide Average
- ( ) Trend Line

Trend Data (% Change Over Selected Year Range)

ID	+ 6.4	
MT	+ 5.5	
OR	+ 9.9	
WA	+ 2.2	



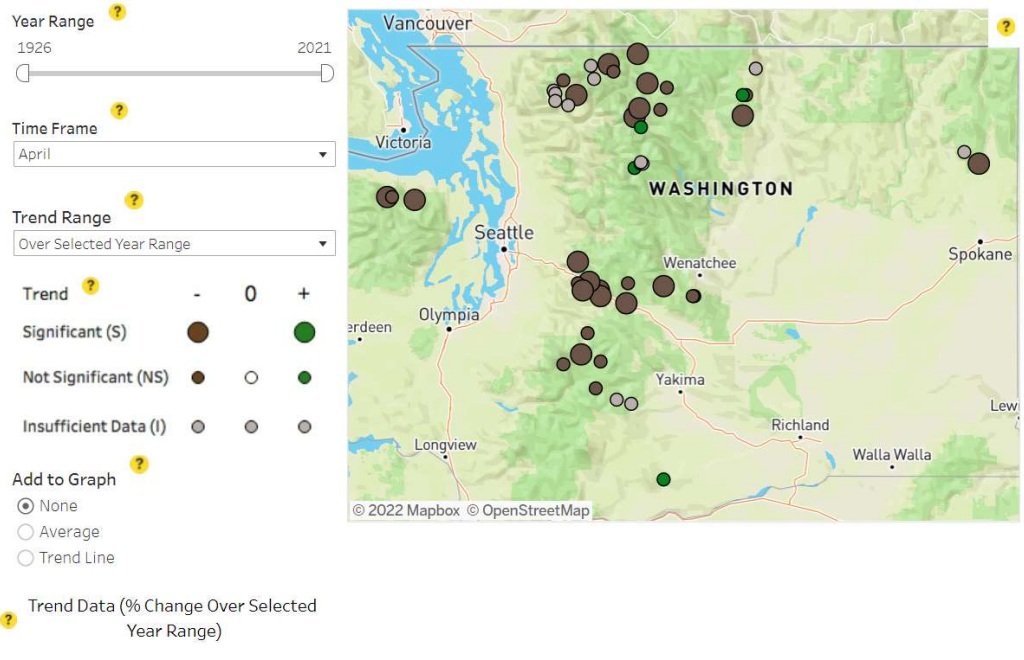
https://climate.washington.edu/climate-data/trendanalysisapp/

Station Data Source: NOAA's U.S. Historical Climatolog Network version 2.5.5.20210712

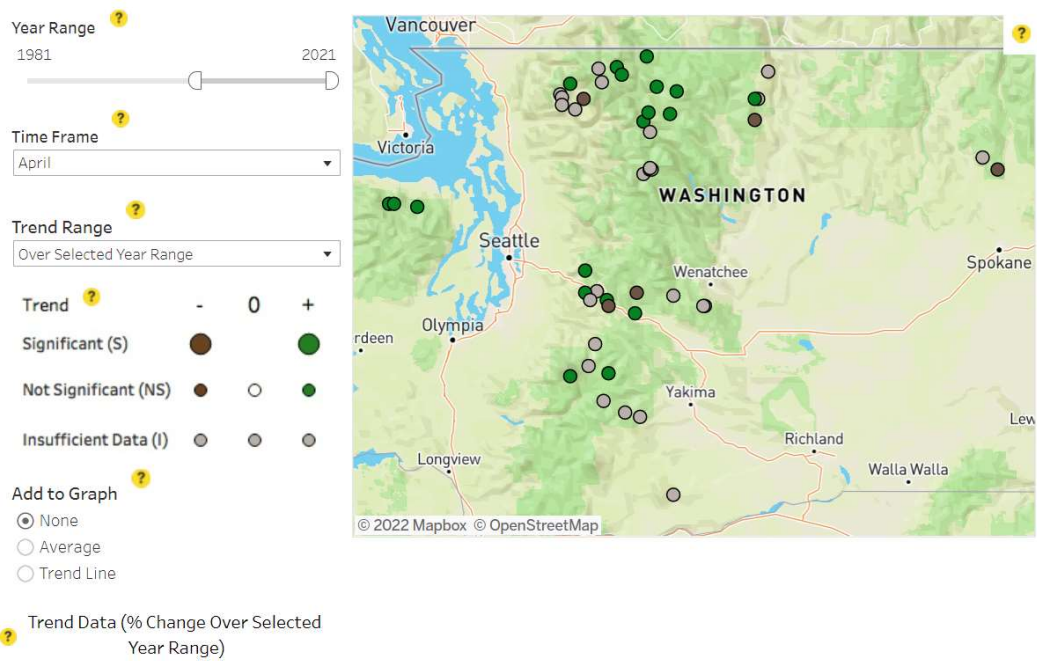
Statewide Data Source: NOAA's US Climate Division Dataset (nClimDiv)

Regional Snow Water Equivalent Trends

1926-2021



1981-2021



https://climate.washington.edu/climate-data/trendanalysisapp/

Station Data Source: NOAA's U.S. Historical Climatolog Network version 2.5.5.20210712

Statewide Data Source: NOAA's US Climate Division Dataset (nClimDiv)

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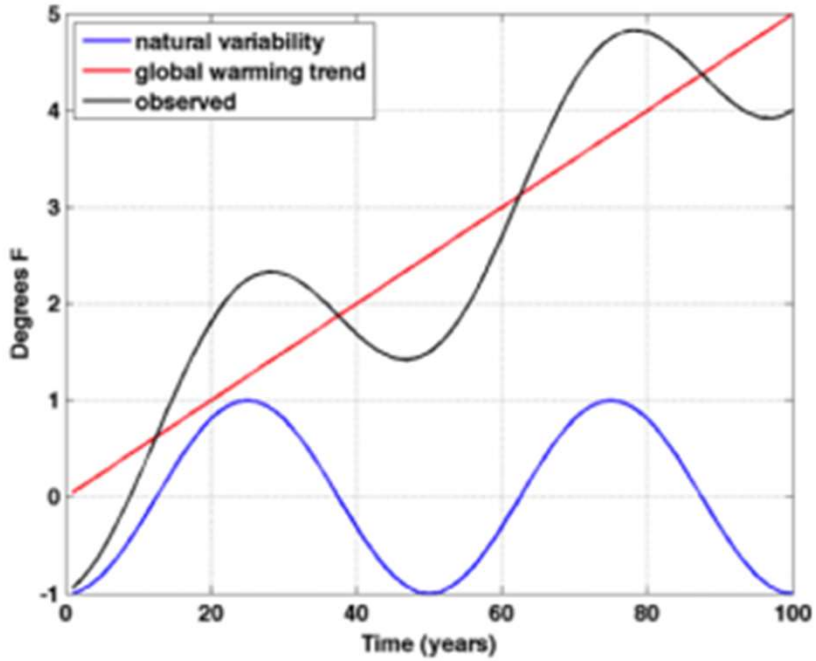
WSU

Natural Variability vs Climate Change

- El Niño: warmer & drier
- La Niña: cooler & wetter
- Pacific Decadal Oscillation (PDO): variable

Natural Variability: ***short-term*** influence

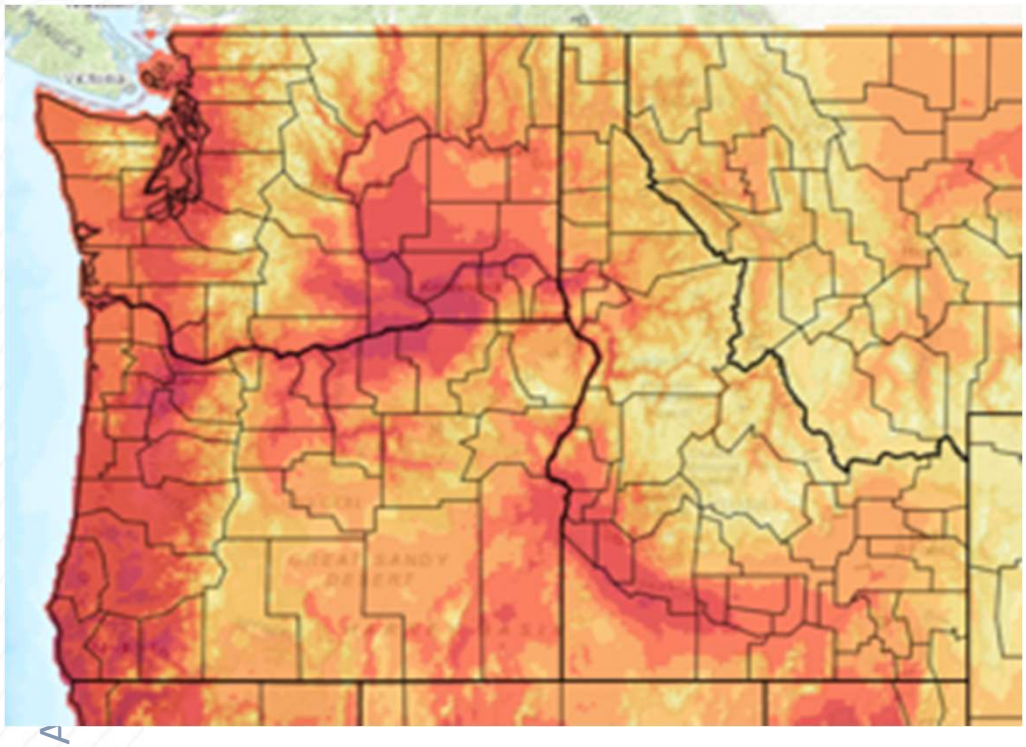
Climate Change: ***long-term*** influence



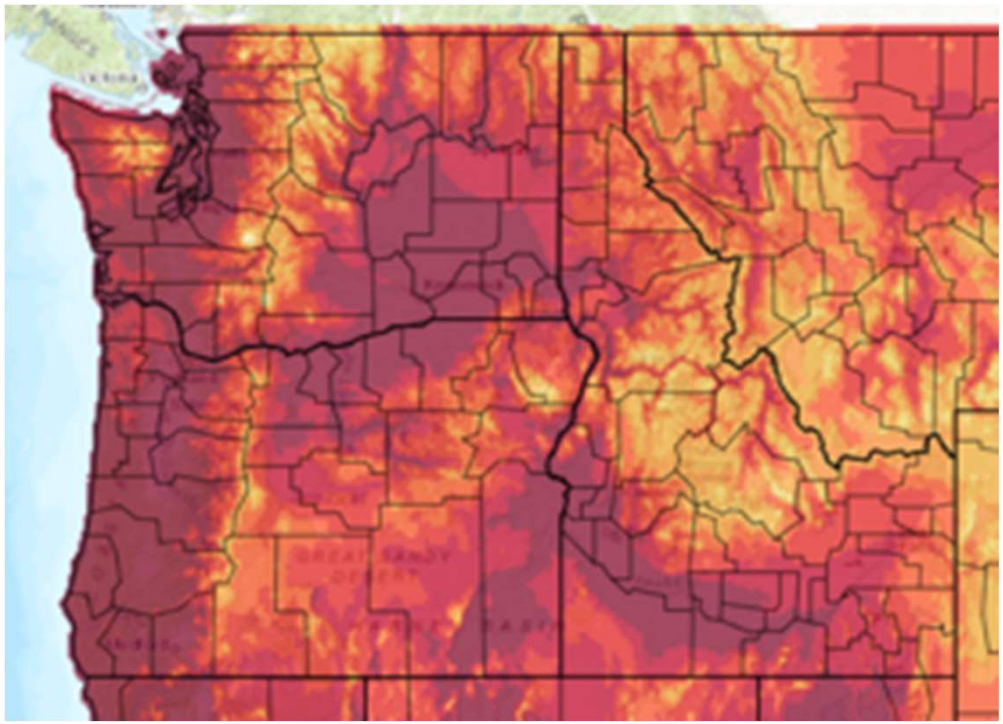
Source: UW Climate Impacts Group

Emerging climate challenges for farmers

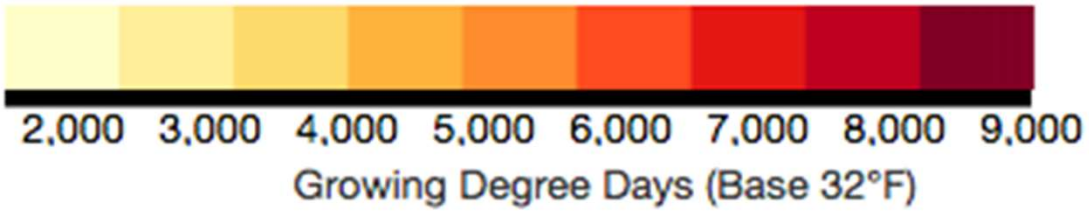
- Longer growing seasons and frost-free periods
- Increased heat and *snow* drought stress
- Changing biotic stressors



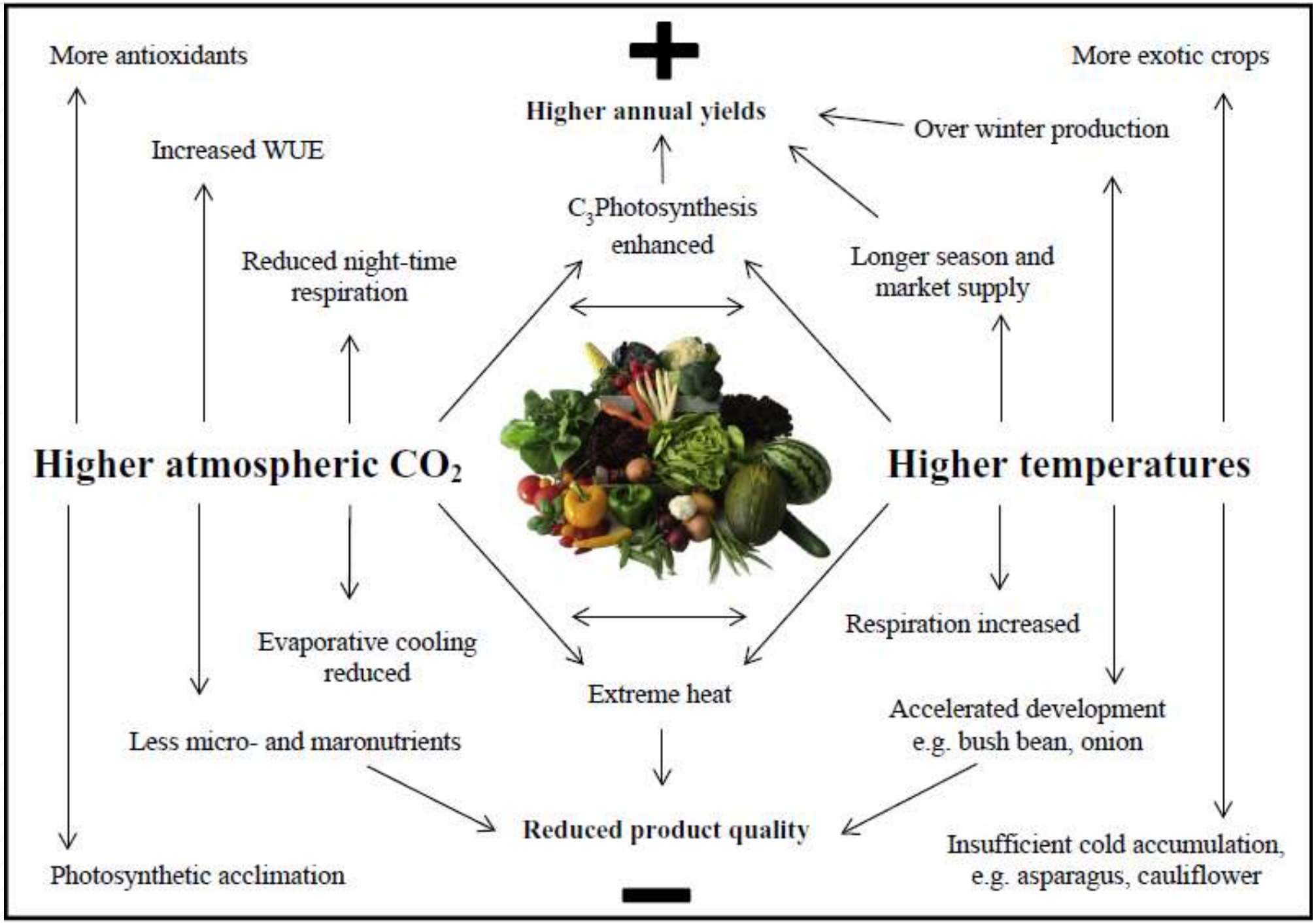
1971 - 2000



2040 - 2069 under RCP 8.5



Kruger et.al. 2017,
courtesy Abatzoglou



Bisbis et.al. 2018. Potential impact of climate change on vegetable production and product quality – a review. *Journal of Cleaner Production*

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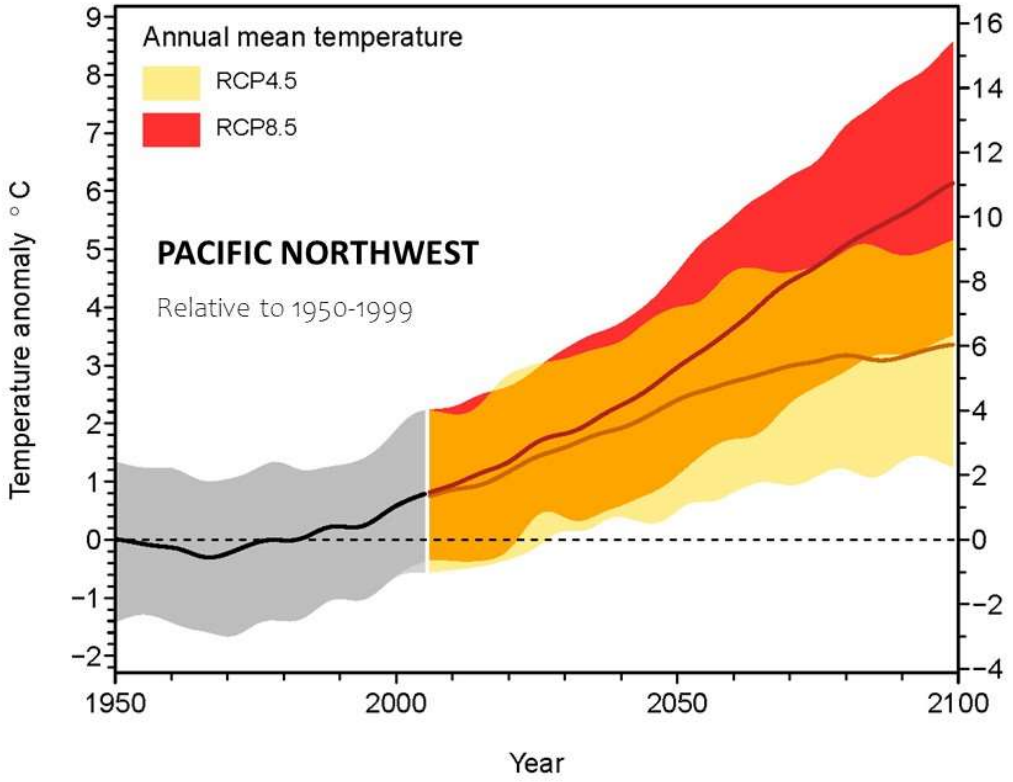
Climate Change Impacts on Water Resources

Change with 1.5°C		Risks
Reduced snowpack (April 1st snow water equivalent)	↓ 38%	Reduced water storage Irrigation shortages Winter and summer recreation losses
Higher winter streamflow (October-March)	↑ 16%	River flooding Costly stormwater management and flood protection Negative effects on salmon populations
Lower summer streamflow (April-September)	↓ 23%	Reduced summer hydropower Conflicts over water resources Negative effects on salmon populations

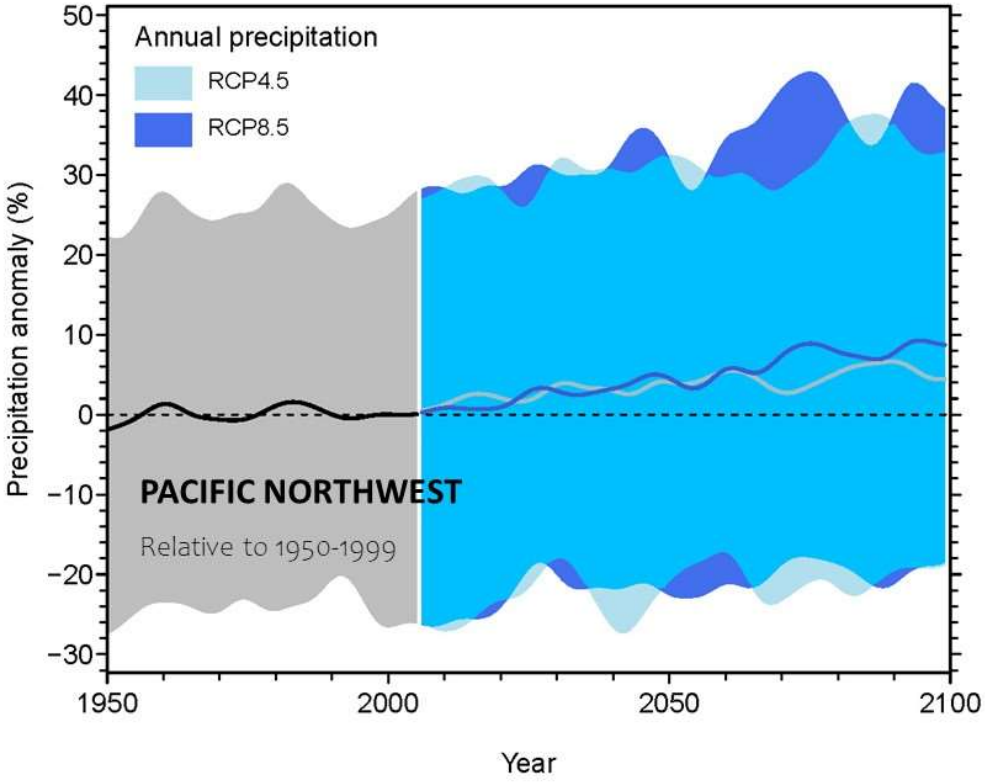
Snover et al. 2019
https://cig.uw.edu/projects/no-time-to-waste/

Regional Climate Projections

TEMPERATURE



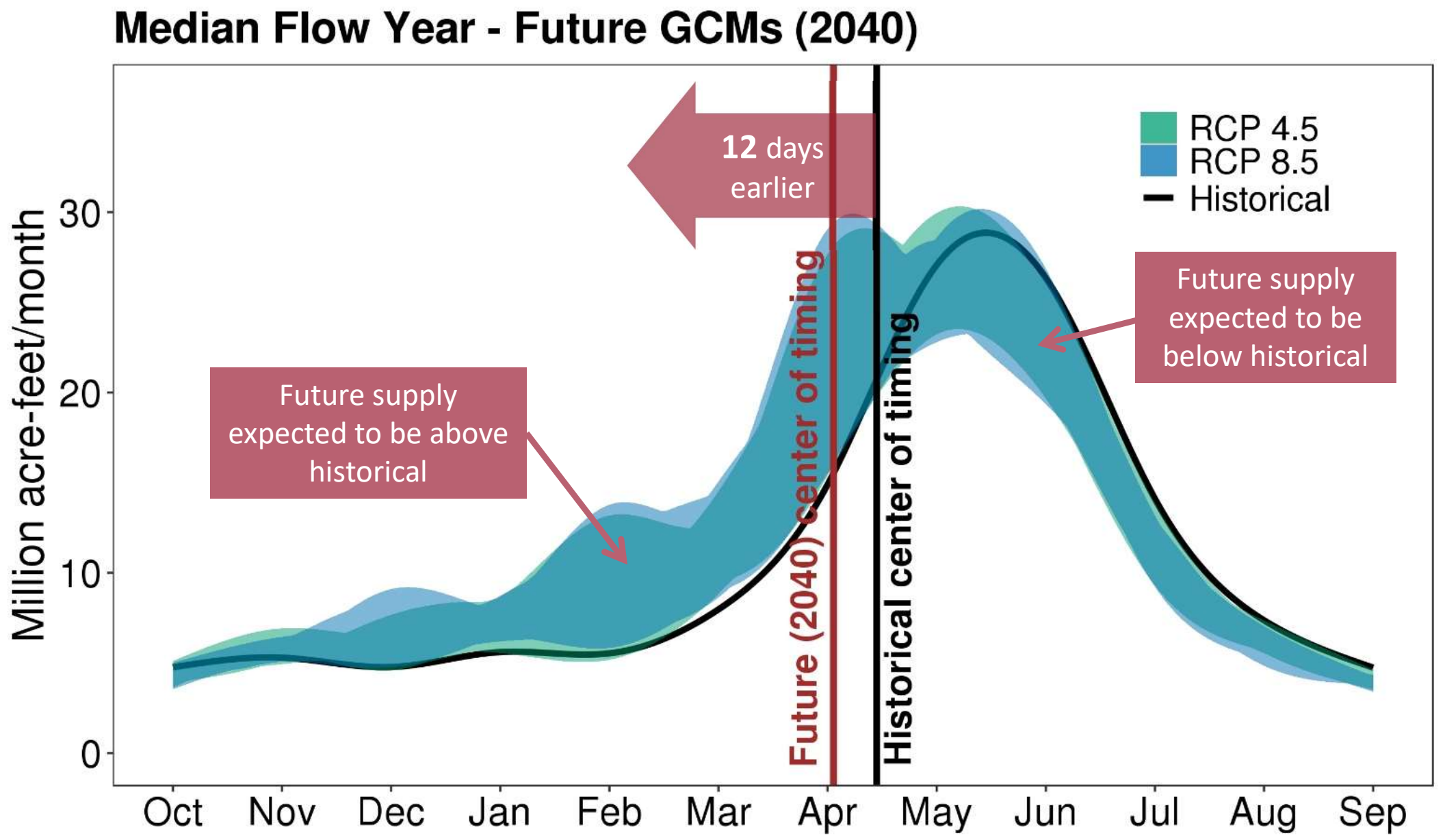
PRECIPITATION



Courtesy of David Rupp, Oregon State University (see also Rupp et al. 2017)

- More rain and less snow
- Smaller snowpack (storage)
- Earlier snowmelt

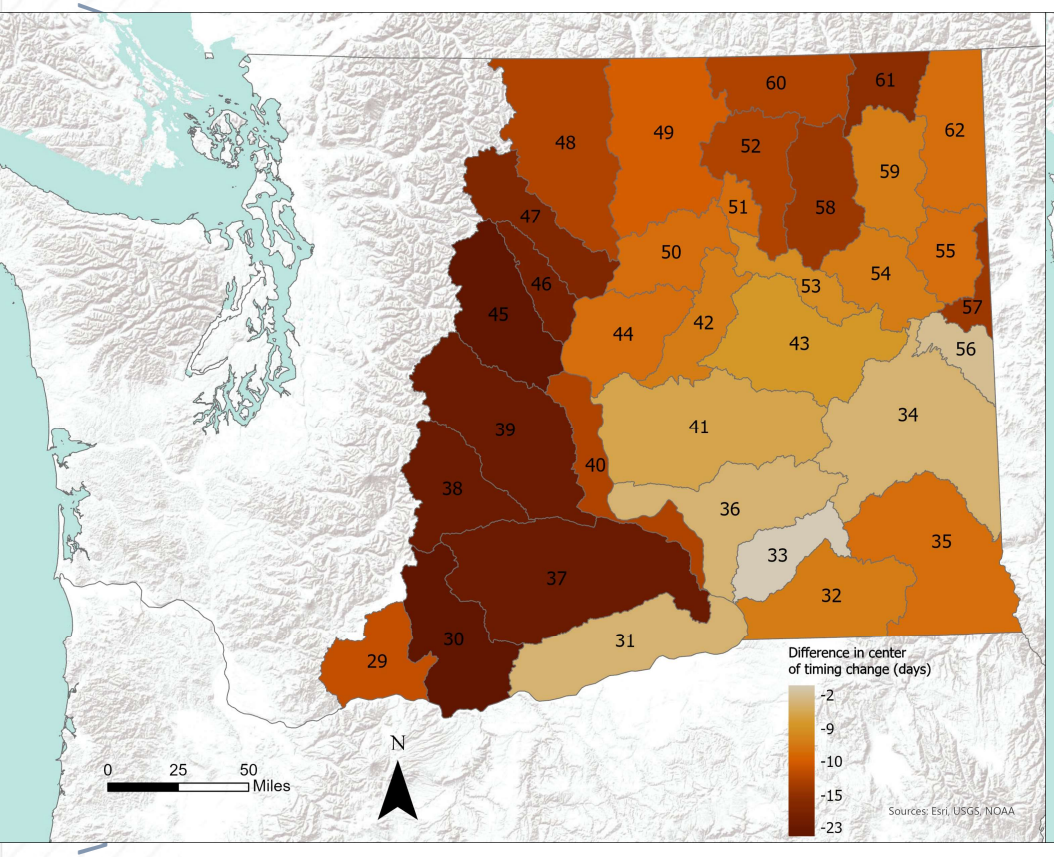
Changes in Water Supply



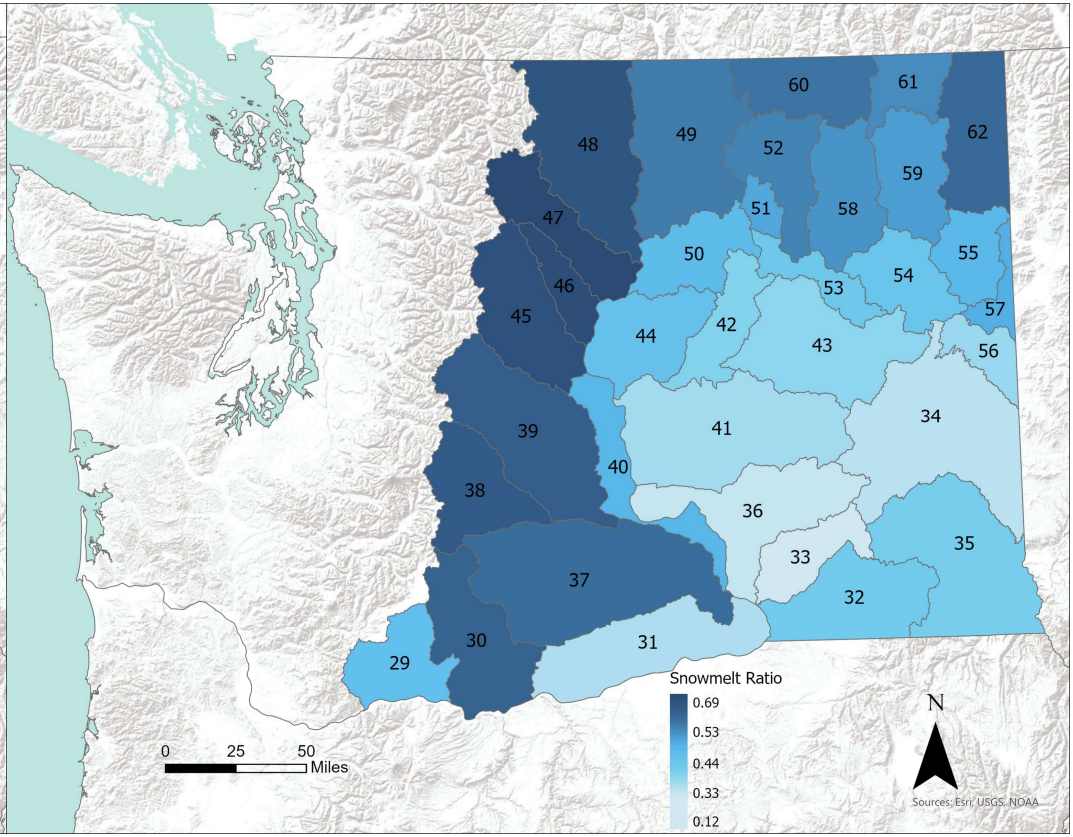
Hall et al. 2022

Changes in Water Supply

TIMING OF WATER SUPPLY



SNOWMELT RATIO



Hall et al. 2022

user lipecillo under CC BY-SA 2.0

Changes in Water Supply

+15% Nov to May

-29% Jun to Oct

Irrigation season	…cooler	…average	…warmer
	inches/day	inches/day	inches/day
early April	0.04	0.05	0.06
late April	0.08	0.09	0.1
early May	0.12	0.13	0.16
late May	0.17	0.2	0.25
early June	0.2	0.23	0.25
late June	0.25	0.29	0.32
July	0.27	0.32	0.38
early August	0.27	0.31	0.35
late August	0.21	0.24	0.3
early September	0.15	0.18	0.22
late September	0.08	0.1	0.15
October	0.05	0.07	0.09

http://treefruit.wsu.edu/orchard-management/irrigation-management/determining-your-irrigation-schedule/

Climate Change Impacts on Water Resources

Change with 1.5°C		Risks
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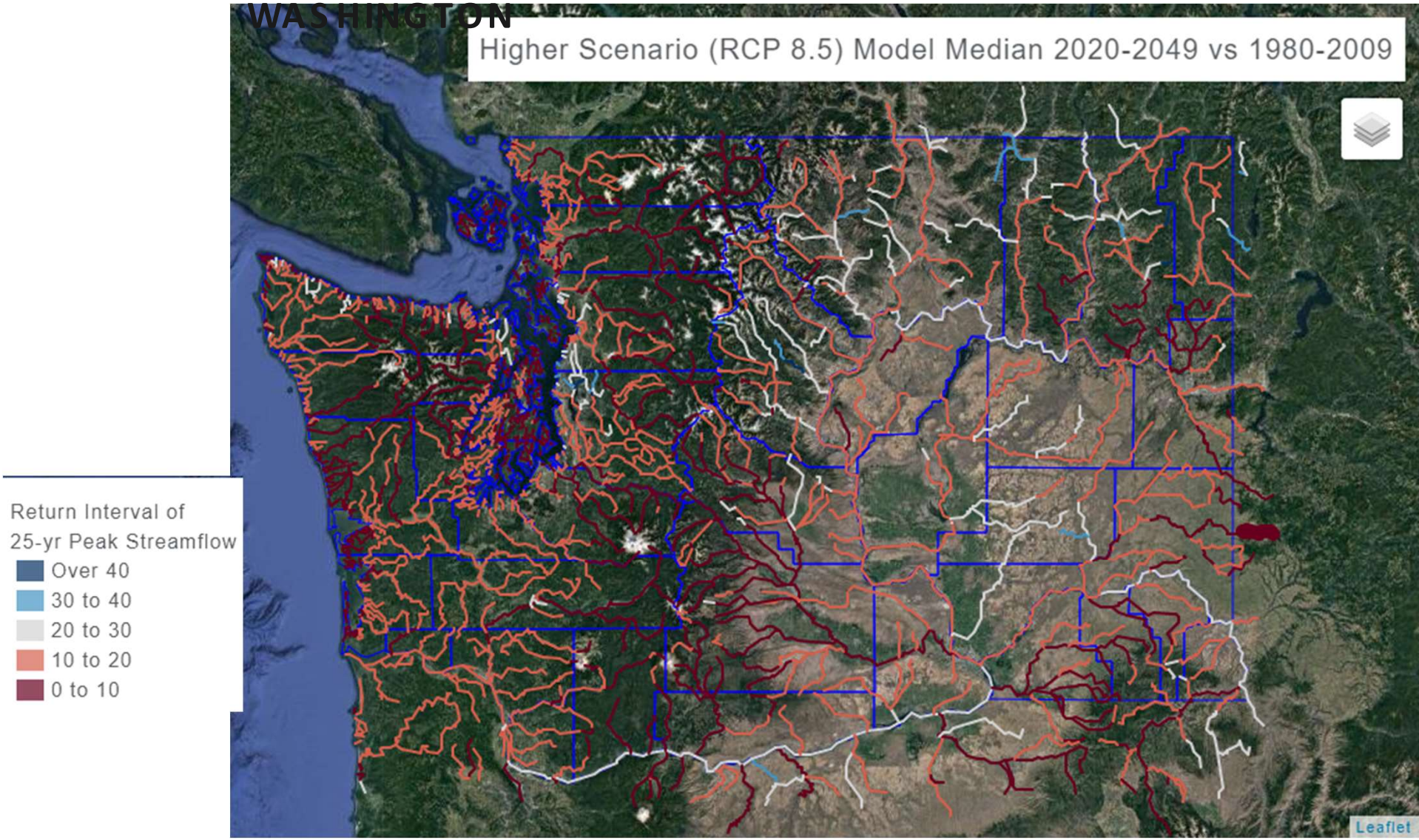
Snover et al. 2019
https://cig.uw.edu/projects/no-time-to-waste/

River Flooding

CLIMATE MAPPING FOR A RESILIENT WASHINGTON



https://cig-wa-climate.nkn.uidaho.edu/

CLIMATE IMPACTS GROUP | COLLEGE OF THE ENVIRONMENT UNIVERSITY of WASHINGTON

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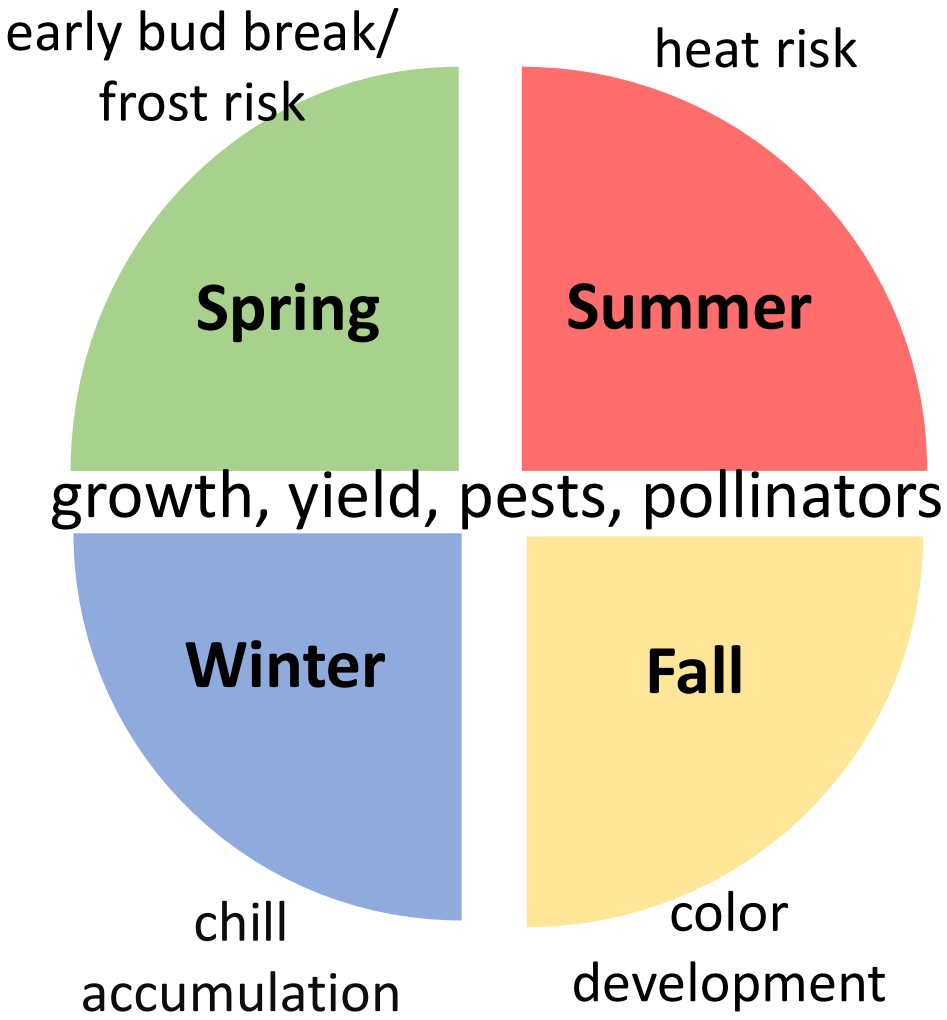
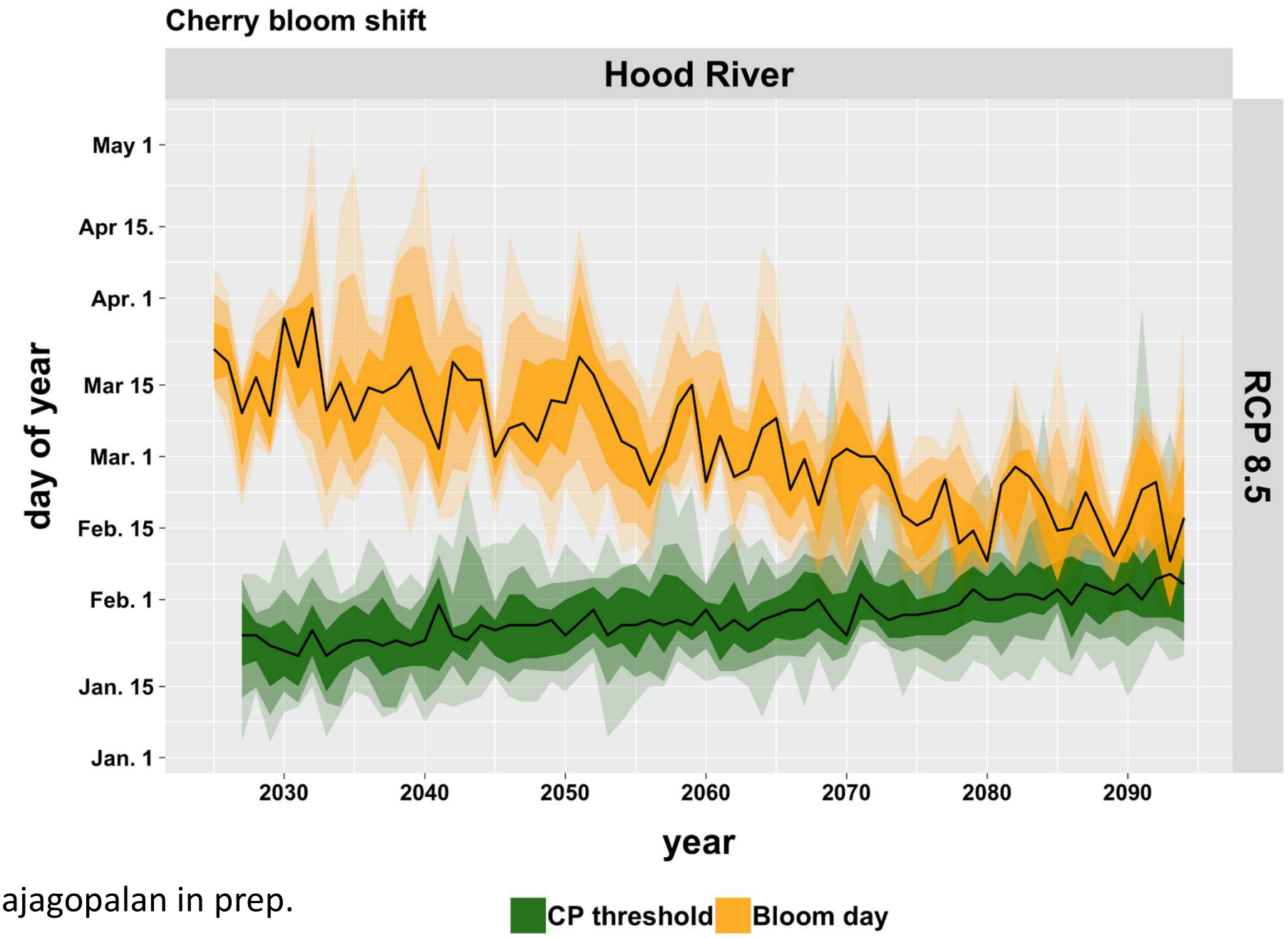
Climate change impacts on tree fruit production and management (temperature effects)



- Sunburn risk in apples
- Honeybee colony dynamics, fall temperature effects
- Codling moth pest pressures

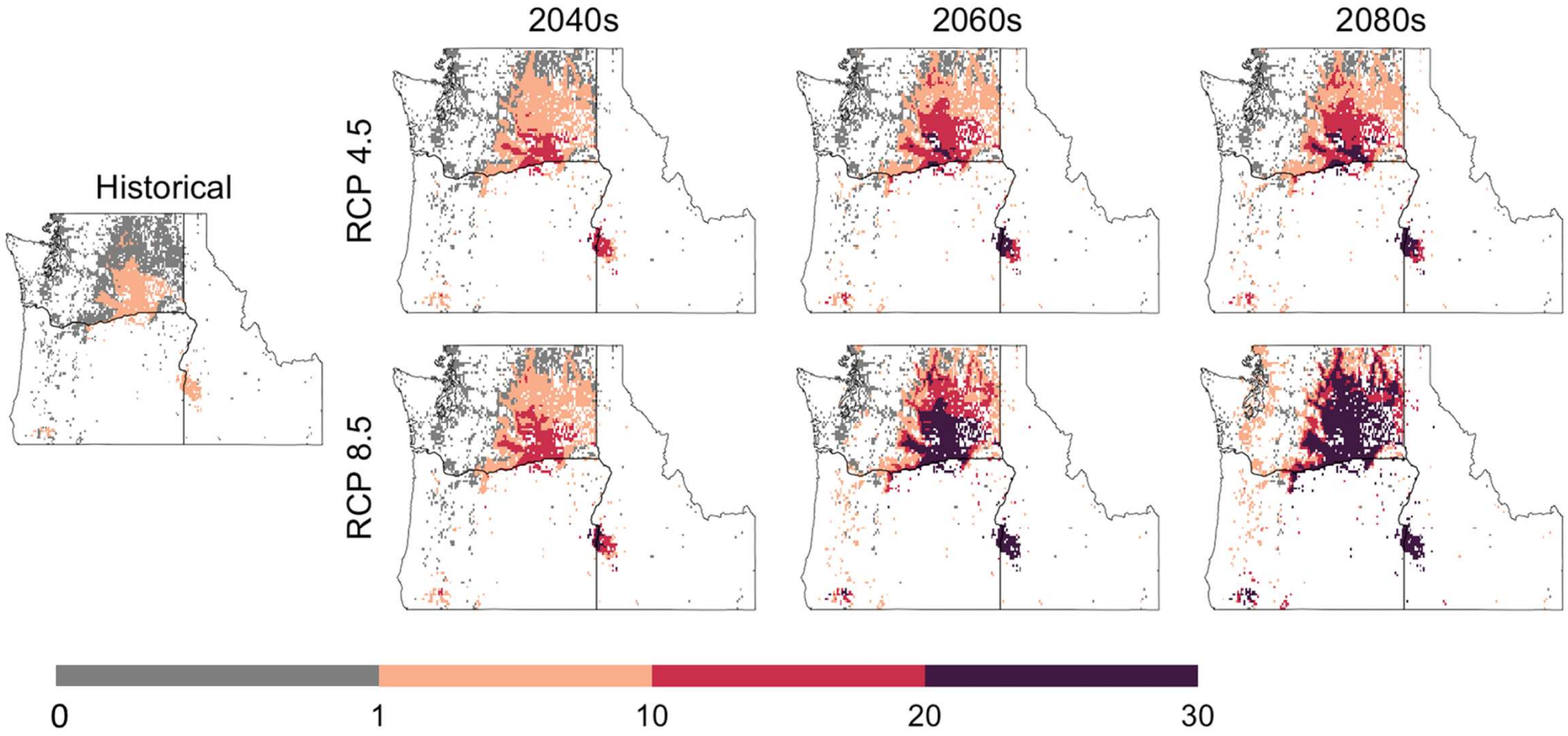
Credit: Rajagopalan

Converging factors may confound simple projections



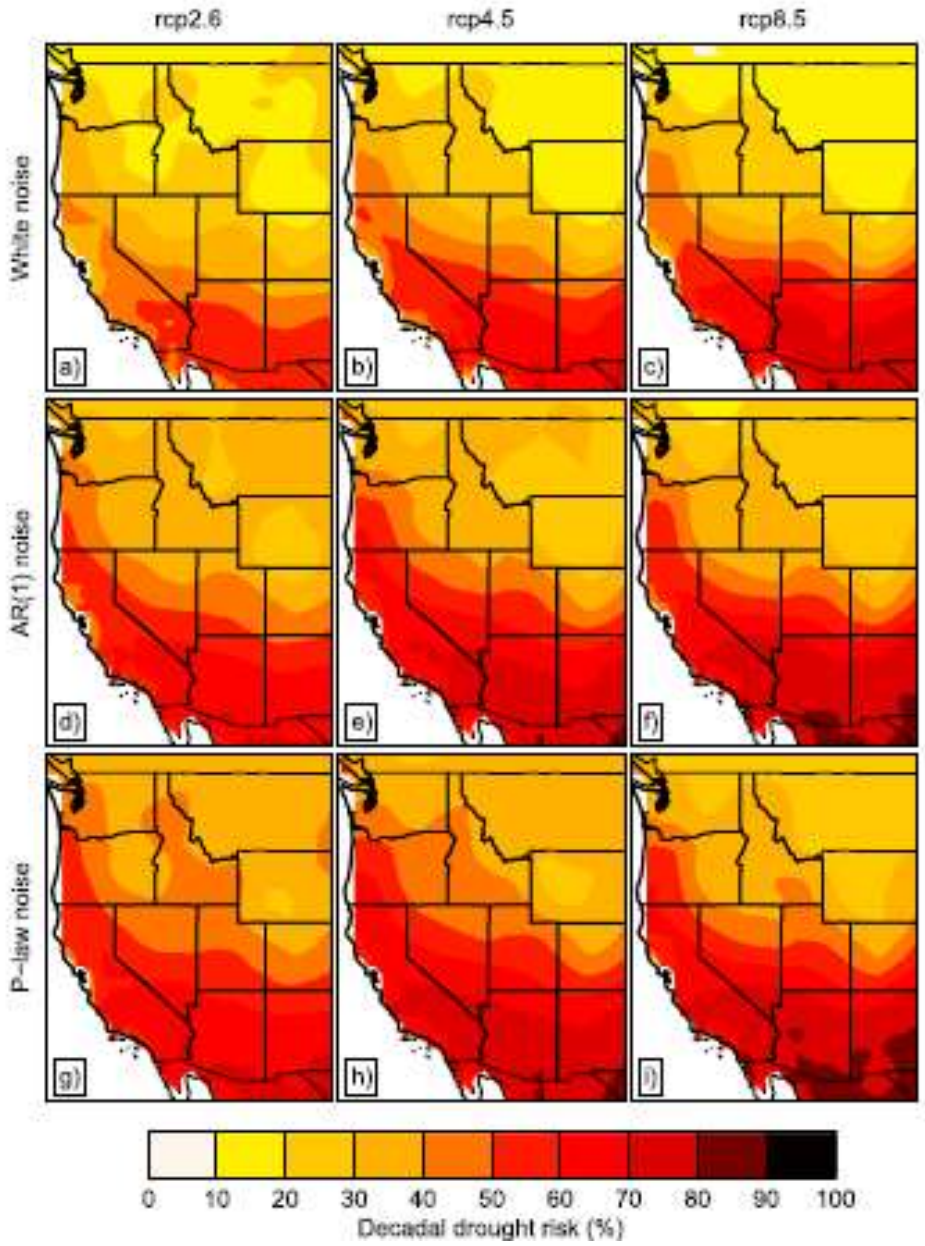
Rajagopalan in prep.

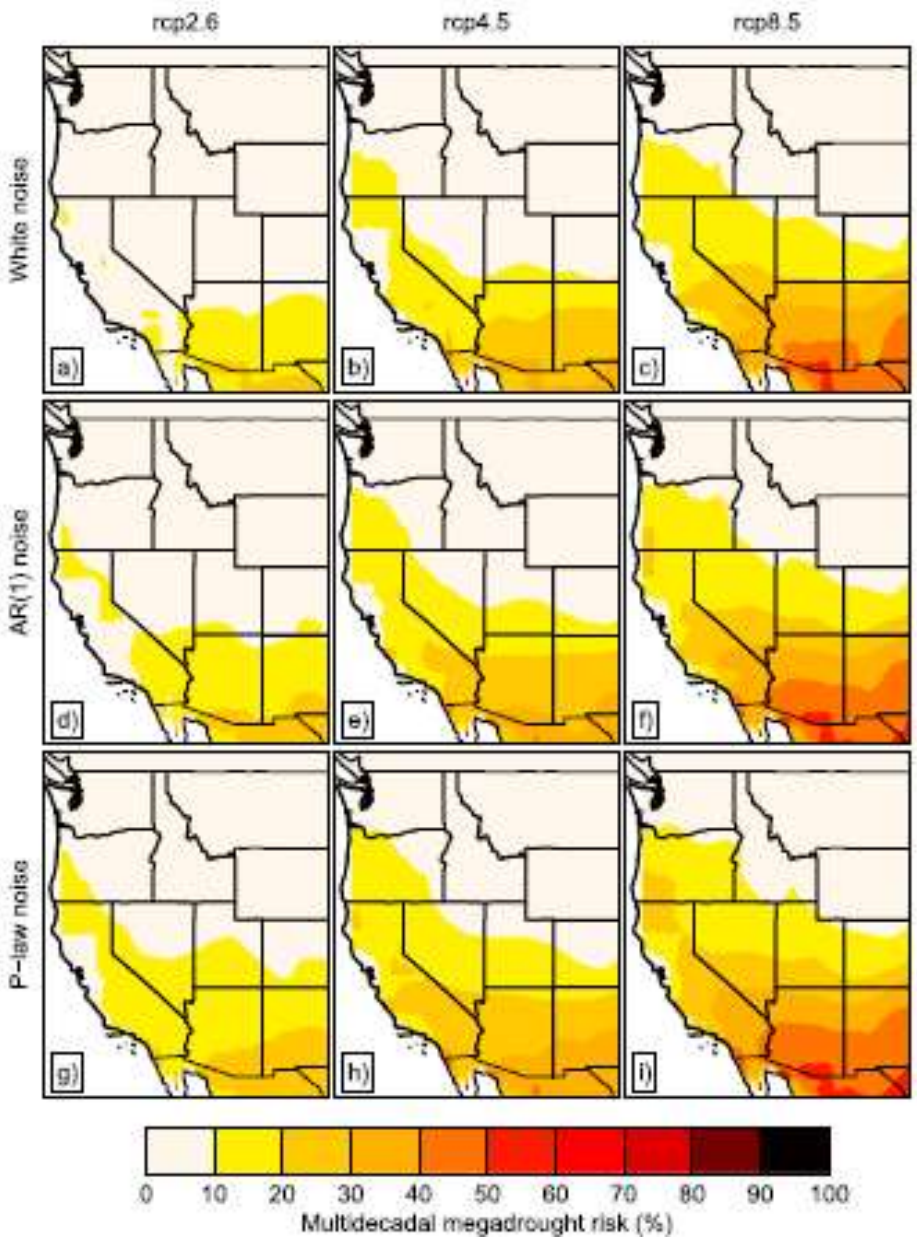
Projected changes (Honeycrisp; no netting)



Credit: Rajagopalan

Long-term Drought Risk?





Ault et.al. 2014

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Climate Change Impacts on Codling Moth

GOOD FRUIT GROWER

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Codling moth will have a third generation this year

Late flights might cause fruit damage.

DECISION AID SYSTEM
SCIENCE FOR CROP MANAGEMENT

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Predicting Third Generation of CM

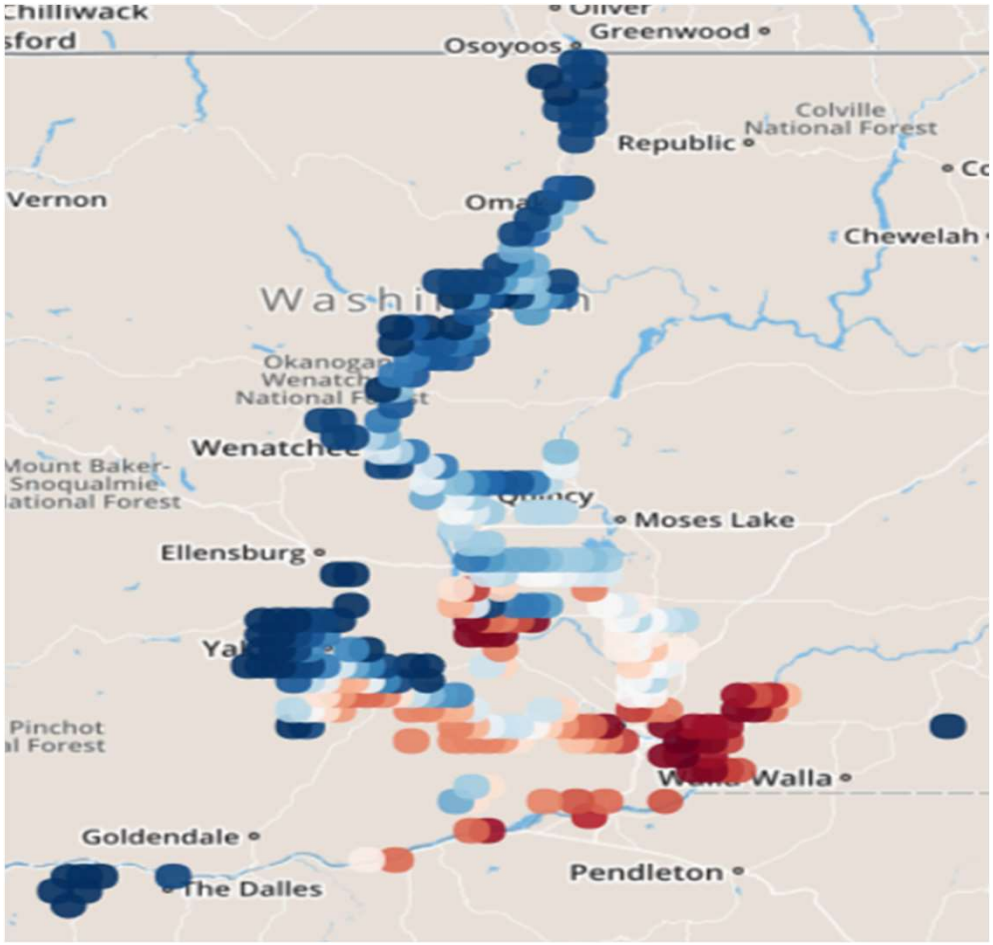
< Back

Sunday Aug 01, 2021

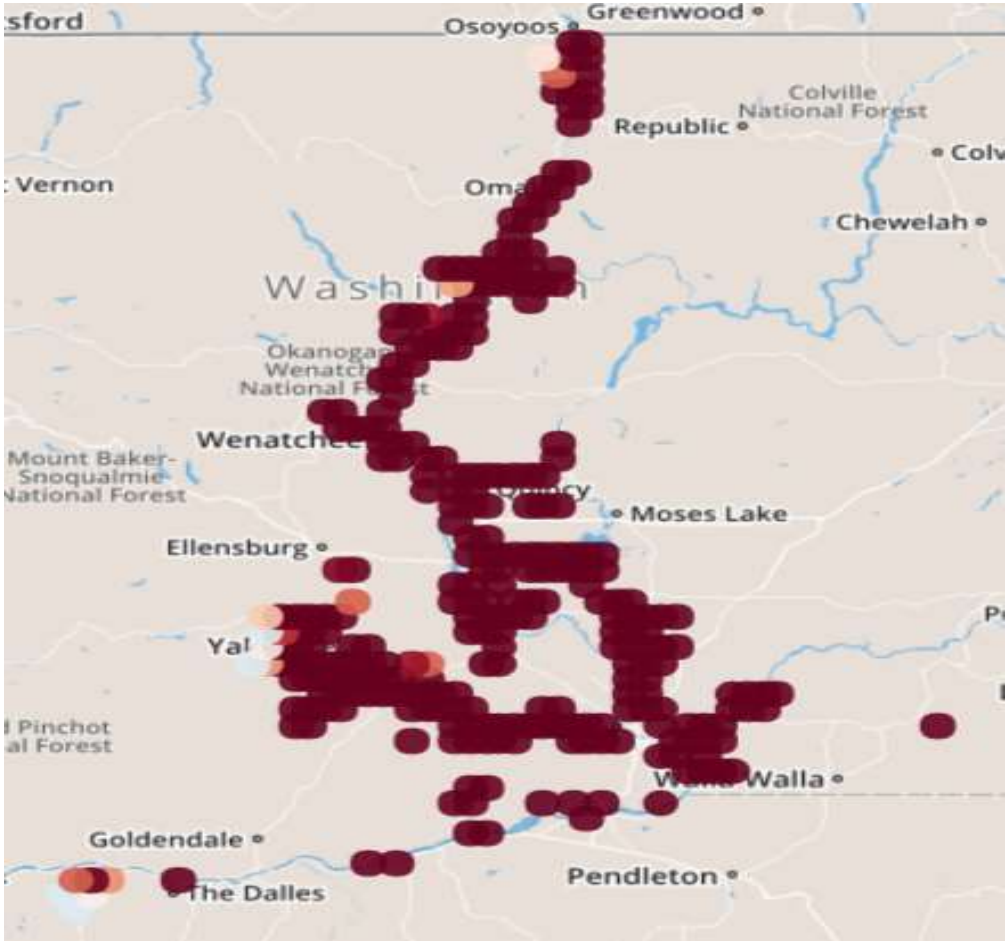
Most fruit growing regions in WA experience at least a partial third CM generation each year. Moths representing a third flight emerge in late August or early September and deposit eggs. Though a portion of these CM will not complete their lifecycle, the potential impact of this generation should not be underestimated. If left uncontrolled, third generation CM larvae will be feeding in the orchard just before harvest, which could result in unwanted fruit injury. Further, some third generation CM larvae may overwinter and contribute to the CM population that emerges the following spring.

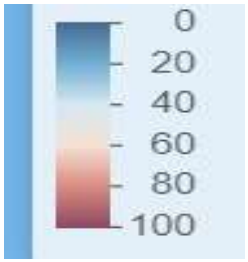
Codling Moth – Risk of a Third Generation

HISTORICAL



2040s



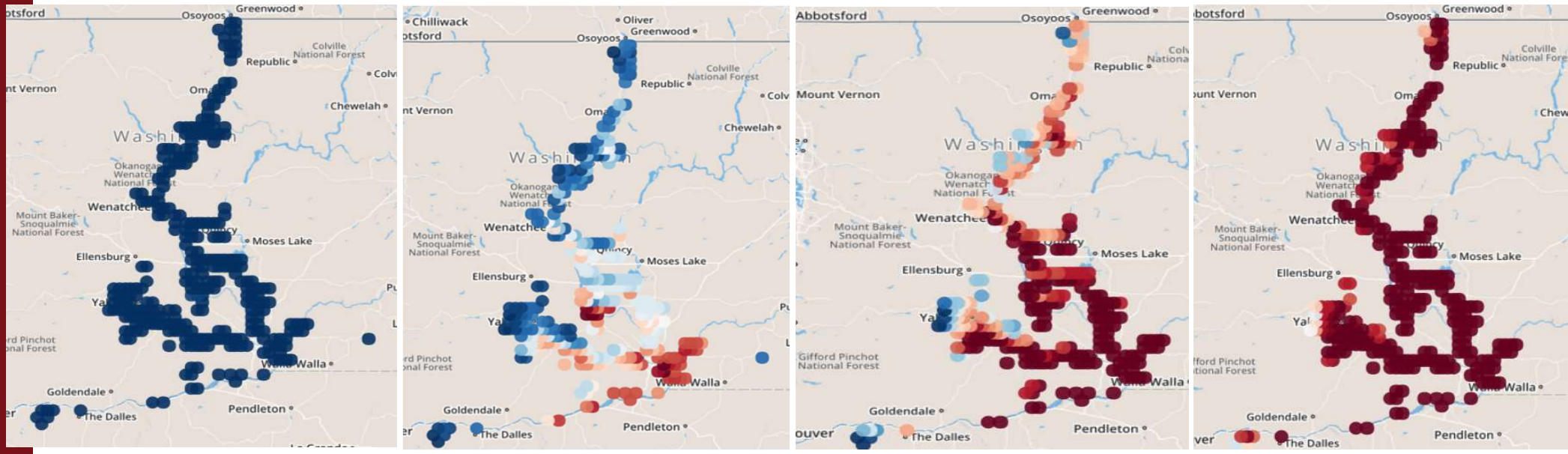


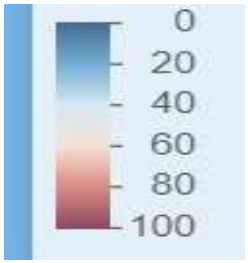
% years when more than 75% of 3rd generation eggs hatch into larvae

Credit: Rajagopalan

Codling Moth – Potential Fourth Generation

HISTORICAL 2040s 2060s 2080s

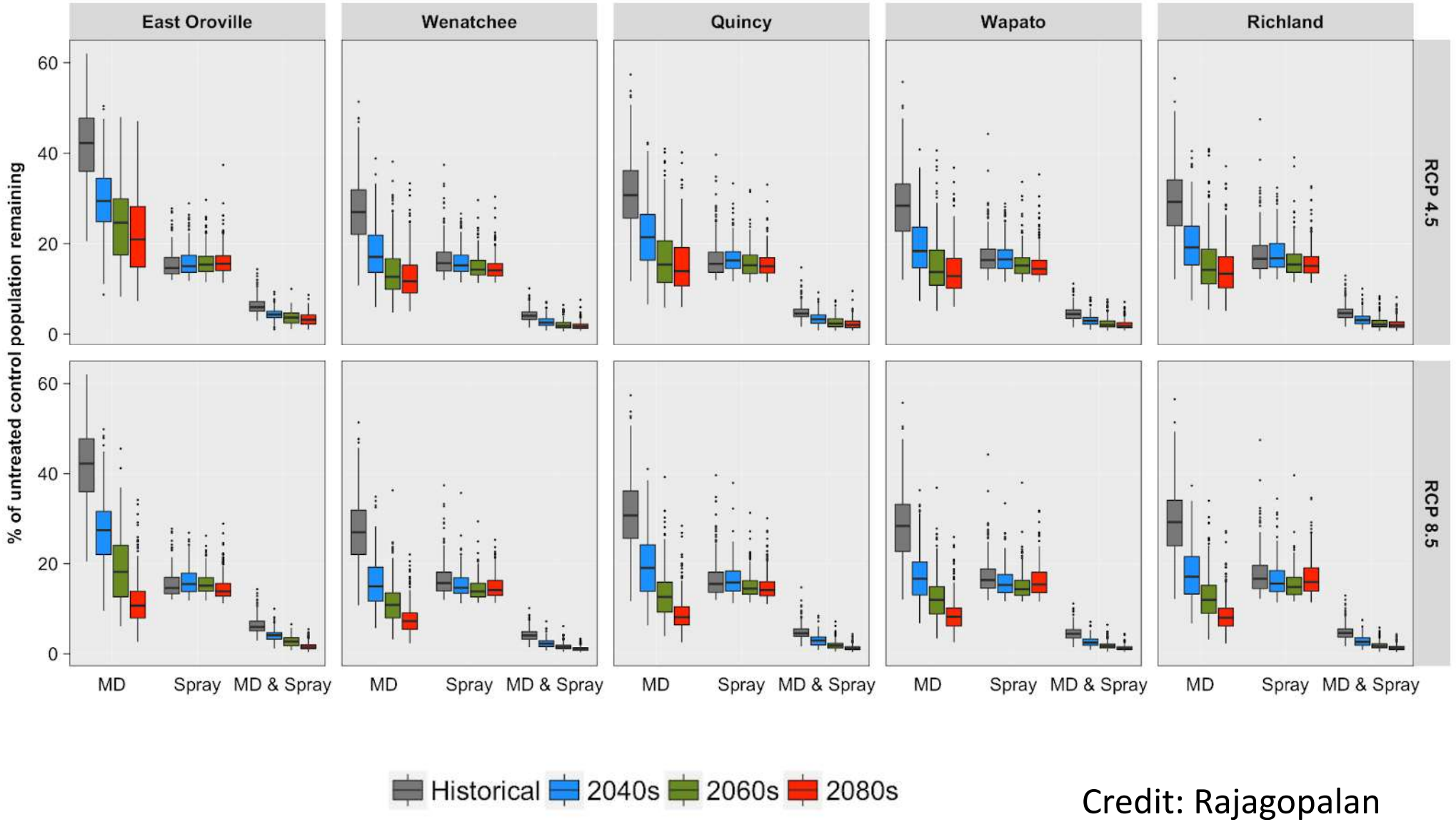




% years when more than 75% of 4rd generation eggs hatch into larvae

Credit: Rajagopalan

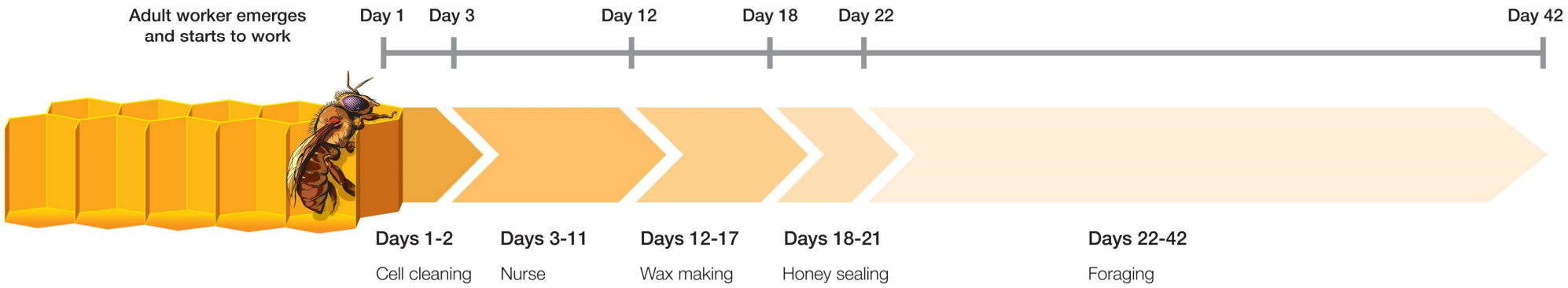
Codling Moth – Pest Control Effectiveness



Credit: Rajagopalan

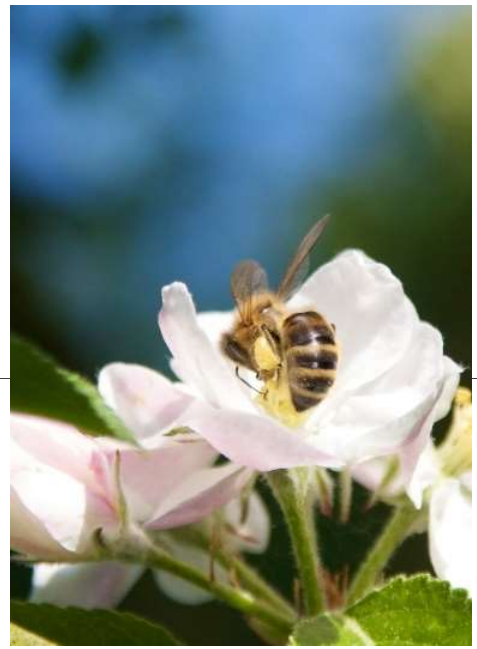
Honeybees – Effects of Foraging

Job progression of a worker bee



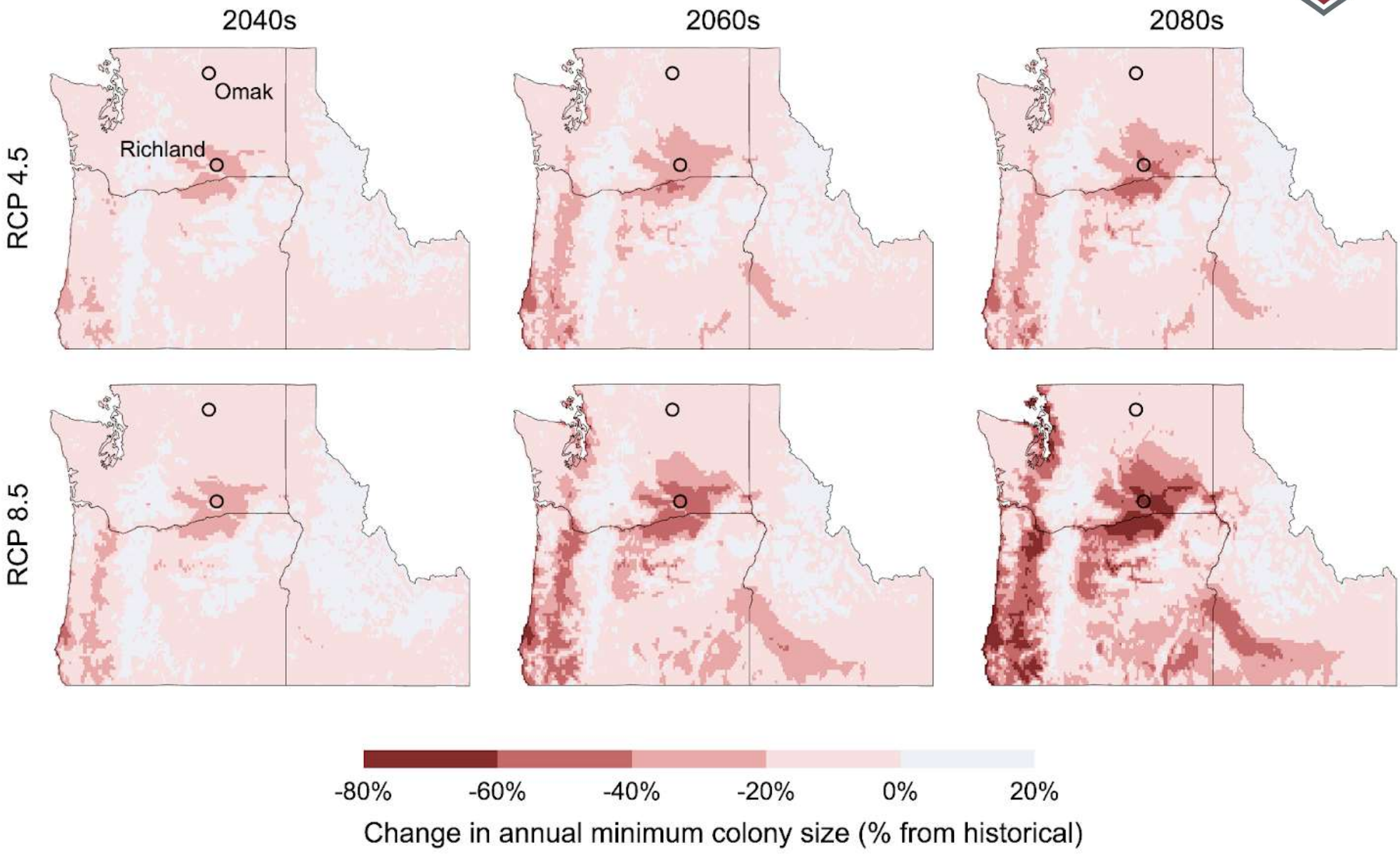
Worker bees do not keep the same job for life. As they age, they perform progressively more complex tasks.

Here is an overview of the types of jobs worker honey bees perform over the course of thier life.



https://www.serendipi-bee.ca/basics/intro/hive-jobs/

Honeybees – Impacts of Spring Colony Size



Increased risk of colony failure

Credit: Rajagopalan

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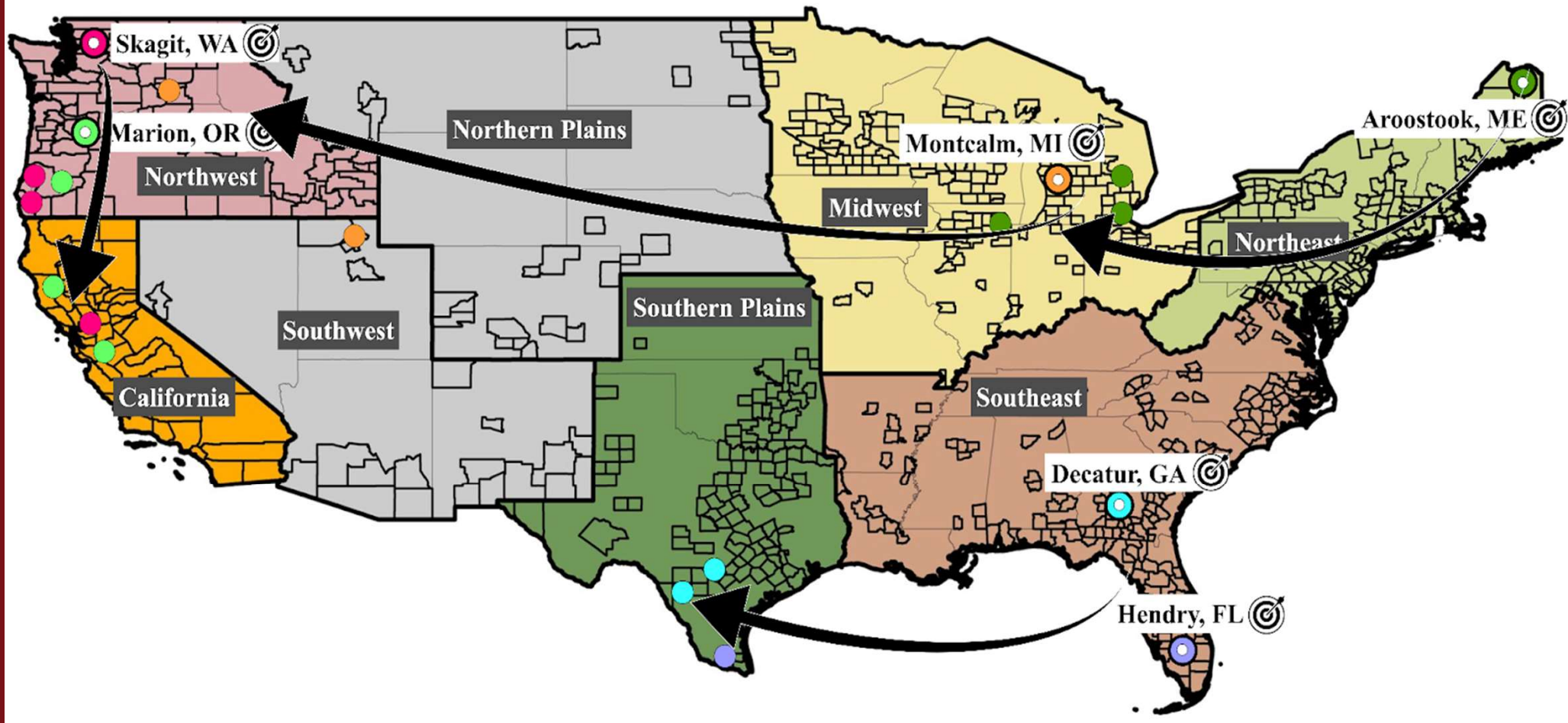
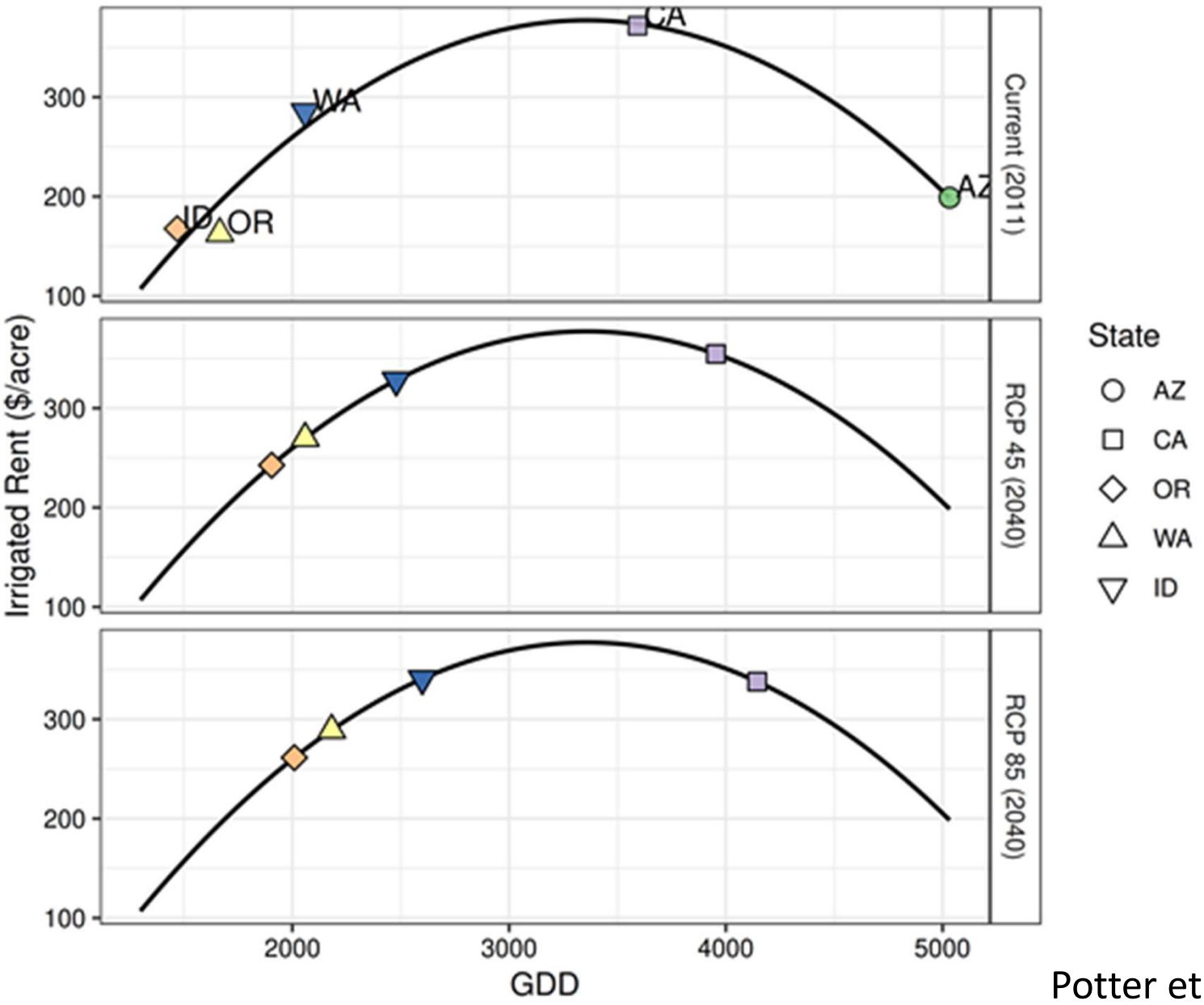
Where are the Growing Condition Analogs?



Climate Change Impact on Irrigated Rents



Potter et.al. in prep.

Agriculture Climate Network

Agriculture and Climate Change Research in the Pacific Northwest

February 18, 2022

A Cornucopia of Opportunities for Domestic Produce

By David I. Gustafson, Adjunct Research Faculty at Washington State University

This article is part of a series, Climate Friendly Fruit & Veggies, highlighting work from the Fruit & Vegetable Supply Chains: Climate Adaptation & Mitigation Opportunities (F&V CAMO) project, a collaborative research study co-led by investigators at the University of Florida and the Agriculture & Food Systems Institute. Other collaborators include researchers at the University of Arkansas, University of Illinois, the International Food Policy Research Institute, the World Agricultural Economic and Environmental Services, and Washington State University. This project seeks to identify and test climate adaptation and mitigation strategies in fruit and vegetable supply chains.

Most of our moms urged us to "eat our fruits and vegetables," and multiple studies confirm this motherly advice. For instance, the U.S. National Institutes of Health recently reported that consuming more fruits and vegetable results in reduced mortality. Unfortunately, the same report tells us what we already know: most Americans don't

July 18, 2022

Check it out: High Temperatures are Threatening Pollination of Crops in the Pacific Northwest

By Sarah Davis, Intern at Washington State University's Tree Fruit Research and Extension Center and the Center for Sustaining Agriculture and Natural Resources

Throughout the last year, I have spent hours researching and writing about molecular techniques to combat heat and drought stress in agricultural crops while completing my undergraduate capstone project. So, when I found an article describing how the integrity of pollen is threatened by increasing temperatures, it seemed extremely relevant to both my project as well as my new internship at Washington State University where I am researching sustainable ways to address climate change impacts on tree fruit.

Temperatures above 90° b[illegible]wn the [illegible]n of [illegible] pollen tube forma-[illegible] de-

September 16, 2022

Deficit Irrigation Conserves Water in Agriculture to Aid in Combating Water Stress

By Sarah Davis, Intern at Washington State University's Tree Fruit Research and Extension Center and the Center for Sustaining Agriculture and Natural Resources

Washington State has nearly 15 million acres of farmland with around 39,000 operating farms, each producing necessary agricultural commodities. A few of the most well-known crops that are produced and distributed from Washington State are apples, cherries, hops, raspberries, and pears. Even when traveling across the country, I can find Chelan apples, which shows just how productive the state is in their cultivation of high value foods. Many of the 39,000 operating farms require irrigation to produce much of the aforementioned fruit that get distributed far and wide, which consumes a large portion of water resources.

As temperatures rise, the impacts of climate change on

August 12, 2019

What You Need to Know About Fruit Acclimation to Heat Stress

By Antoinette Avorgbedor

Intern at Washington State University's Tree Fruit Research and Extension Center and the Center for Sustaining Agriculture and Natural Resources

Agriculture in arid conditions can be challenging for fruit development.

Did you know that people indigenous to the hotter equatorial regions have much lower sweat rates than people in cooler regions of the world? Similar to the ability of the human body to adjust to different climatic conditions, plants have evolved various mechanisms to survive extreme weather conditions. Besides long-term evolutionary modifications, plants have been found to develop quick short-term tolerance to extreme environmental conditions. Many different plant species have been reported to develop "memory" to stress, which then helps protect against future adverse conditions. I found this topic pretty in-

AGRICULTURE

A collection of tools for addressing questions relating to Agriculture.

Climate Mapper
Maps of historical and future climate information across multiple sectors

Launch Tool

Future Cold Hardiness Zones
Maps of future projections of cold hardiness zones

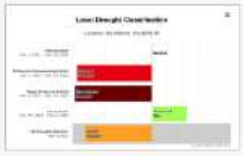
Launch Tool

Future Crop Suitability
Map of future crop suitability, phenology and irrigation projections for a location

Launch Tool

Future Tribal Climate
Maps/graphs of future climate projections for a tribal region

Launch Tool



Historical Water Watcher
Maps of real-time water monitoring over the contiguous US

Launch Tool

Future Boxplots
Compare projections for future time periods for a location

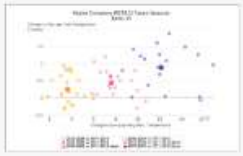
Launch Tool

Future Climate Analogs
Maps of future and historical climate analogs for locations in US National Parks

Launch Tool

Future Climate Dashboard
Dashboard of future climate and growing projections for a location

Launch Tool



Future Climate Scatter
Compare model projections for two variables for a location

Launch Tool

Applications

Click a category below to see a collections of tools for addressing questions relating to Agriculture, Climate, Fire Conditions, and Water.

https://climatetoolbox.org/agriculture

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Climate Toolbox | APPLICATIONS | TOOLS | DATA | VIDEOS | CASE STUDIES | TOOL SUMMARIES | GUIDANCE | NEWS | CONTACT

Documentation | Example | Cite Tool | Take Tour

Climate Mapper

Choose Drought Metrics

Select from the menus below

Time Scale: Future: Projections (through 2100)

Impact Area: Climate (Contiguous US)

Variable: Maximum Temperature

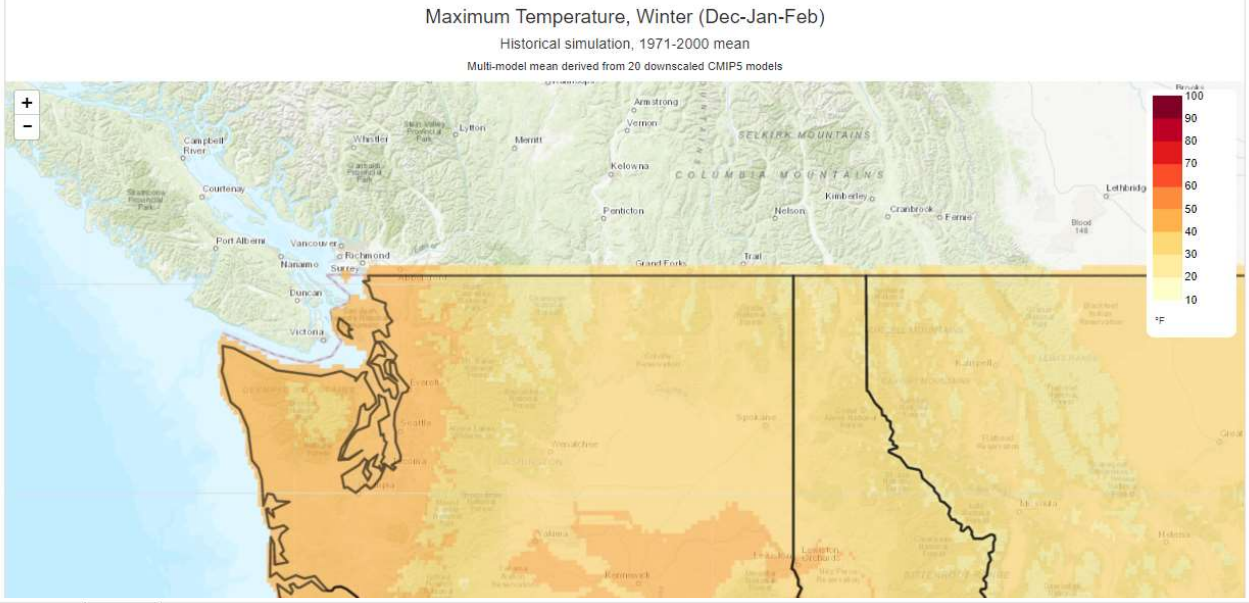
Calendar Time Period: Winter (Dec-Jan-Feb)

Future Scenario: Historical simulation, 1971-2000 mean

Model: Multi-model mean derived from 20 downscaled CMIP5 models

Choose a Location

Change Mapping



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Future Climate Dashboard

Generate a dashboard of climate projections for a location in the contiguous USA.

Location: Moscow, ID (46.7324° N, 117.0002° W)

Choose Location

Select a point location to view data averaged over a 2.5 square mile grid cell.

CHOOSE LOCATION

Choose Data

Dashboard: Growing Degree Days

Future Scenario: Higher Emissions (RCP 8.5)

Download Graph

To download the table, click the button

DOWNLOAD DASHBOARD

Local Projections: Growing Degree Days
Higher Emissions (RCP 8.5)

Moscow, ID (46.7324° N, 117.0002° W)

1990s	2025s	2055s	2085s
ANNUAL (Jan-Dec)	ANNUAL (Jan-Dec)	ANNUAL (Jan-Dec)	ANNUAL (Jan-Dec)
GDD 32F /GDD 37F	GDD 32F /GDD 37F	GDD 32F /GDD 37F	GDD 32F /GDD 37F
6060°F /4480°F	6960°F /5270°F	7990°F /6210°F	9230°F /7350°F
GDD 40F /GDD 50F	GDD 40F /GDD 50F	GDD 40F /GDD 50F	GDD 40F /GDD 50F
3570°F /1820°F	4270°F /2320°F	5130°F /2960°F	6190°F /3770°F

Climate Toolbox, Data Source: gridMET & MACAv2-METDATA (University of Idaho)

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USDA Climate Hubs
U.S. DEPARTMENT OF AGRICULTURE

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The tools presented below represent a portion of the tools available for the climate, agriculture and forestry sectors. The tools range from specialized calculators to maps, models and datasets estimating a variety of outputs (e.g., crop production, greenhouse gas flux, and species distribution). Certain tools may be more relevant to land managers to aid in year-to-year decision-making, while others are more useful for researchers studying agriculture and climate change. Keep in mind that all tools have limitations and make assumptions that may not be appropriate for an entity's climate/region/crop/soil type. USDA does not endorse the tools presented below. The tool list is provided for informational purposes only, and is not exhaustive.

Filter by topic

Animals

Apply

Future Crop Suitability Tool

The Specialty Crop Suitability Tool provides mapped and graphical summaries of the climatic suitability for cultivating…

Rangeland Analysis Platform

The Rangeland Analysis Platform (RAP) is an interactive web application designed to assist in managing and monitoring…

AgRisk Viewer

The AgRisk Viewer provides an accessible and discoverable web platform for crop insurance loss data from the U.S.…

USDA Urban Agriculture Toolkit

This toolkit lays out the common operational elements that most urban farmers must consider as they start up or grow…

CONUS Climate Console

These improvements better enable users to explore and interpret climate-related data, and incorporate that information…

Pacific Northwest Biochar Atlas

A growing body of evidence suggests that biochars can provide "win-win-win" solutions to sustain rural livelihoods,…

https://www.climatehubs.usda.gov/hubs/northwest/tools

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https://www.youtube.com/watch?v=rvL0hdn60Qo&t=5160s

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Some valuable climate and weather tools and data

WA State Climatologist Office – Climate Data
http://www.climate.washington.edu/climate.html

WA State Climatologist Office – Climate Outlook
http://www.climate.washington.edu/outlook.html

WSU Ag Weather Net
http://weather.wsu.edu/

WSU Decision Aid System
https://www.decisionaid.systems/

REACCH Project Climate Tools
https://www.reacchpna.org/tools

AgClimate Network – Tri-state collaborative clearinghouse
https://www.agclimate.net/

Climate Education Resources

For further education on climate topics presented through workshops, please look through the resources listed below. Resources will be updated as they come available, so please check back often.

Climate Change Basics Webinar

This webinar was recorded on 11/12/22 for Grant-Adams County Master Gardener training, hosted by Katie Doonan of WSU's Center for Sustaining Agriculture & Natural Resources. It outlines basic variables in climate change, potential changes in Washington climate conditions, and strategies for resilience and adaptation.

AgClimateNetwork

The AgClimate Network is a web-based hub for communication between regional scientists and stakeholders about climate change and agricultural and natural resources topics. A consortium of institutions including Oregon State University, University of Idaho, and Washington State University, and the United States Department of Agriculture Northwest Climate Hub support individuals who contribute content to this site and share articles and analyses.

Climate Analog Tool

Fruit and Vegetable Supply Chains- Climate Adaptation & Mitigation Opportunities. Interact with climate analogs and potential future conditions with this tool.

Climate Toolbox

A collection of web tools for visualizing past and projected climate and hydrology of the contiguous United States.

WSU AgWeatherNet

AgWeatherNet (AWN) provides Washington State farmers, gardeners, researchers and policy makers with weather data and weather-related decision-support tools to improve agricultural production (yield and quality), efficiency, and profitability while minimizing environmental impacts. AWN was established to serve irrigated

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CLIMATE EDUCATION RESOURCES

LATEST BLOG POSTS

- Announcement | AgAID Undergraduate Research Internships
- Potato Cropping Systems to

https://csanr.wsu.edu/educational-opportunities/climate-education-resources/

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What We Will Cover Today

Overview

- Climate change impacts on plants
- Climate change impacts on water resources

Examples of Recent Research

- Abiotic stresses affected by climate
- Biotic stresses affected by climate

Tools and Resources

Discussion

Acknowledgments

Center for Sustaining Agriculture & Natural Resources
Washington State University

USDA United States Department of Agriculture
National Institute of Food and Agriculture

NSF

Department of Ecology
State of Washington

State of Washington Water Research Center

Climate Friendly Farming™

USDA Climate Hubs
U.S. Department of Agriculture

BioEarth

CIRC
Climate Impacts Research Consortium

WA Ecology: Columbia River Forecast
BioEarth: NIFA award #: 2011-67003-30346
USDA Northwest Climate Hub
Columbia FEW: NSF EAR1639458
REACCH: NIFA Award #: 2011-68002-30191
Fruit & Veg Supply: NIFA Award #: 2017-68002-26789

Thank you!

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Opening (15 minutes):

- Reference to Katie Doonan's orientation Webinar - https://www.youtube.com/watch?v=rvL0hdn60Qo&t=5160s
- Overview of Climate Change and Plants in the PNW - Chad
- Overview of Climate Change and Water Resources in the PNW – Sonia

Examples from Recent Research (20 minutes):

- Abiotic stress – Chad
  - Sunburn
  - Chill Accumulation
- Biotic stress – Sonia
  - Codling Moth
  - Honeybees

Digging deeper with tools (10 minutes):

- Analogs for Dialogs – Chad
- Climate Tools (AgClimate, JA Climate Toolbox, USDA Climate Hubs) – Sonia
- Reminder – Katie's webinar for the basics - https://www.youtube.com/watch?v=rvL0hdn60Qo&t=5160s

Q&A and Discussion (30 minutes):