Direct and Indirect Impacts of Climate Change on Cropping Systems in Eastern Washington

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WSU Team of Collaborators

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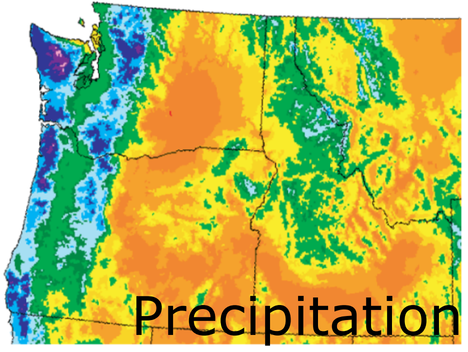
Outline

- Background
  - Water sustainability in the Columbia Basin
  - Potential impacts of climate change on crops
- Description of “The Columbia Basin Water Supply and Demand Forecast”
- Results from the study:
  - Impacts on water supply and demand
  - Impacts on crop yield:
    - Direct climate impacts
    - CO_2 impacts
    - Water rights curtailment impacts
- Proposed adaptation strategies



The Columbia River Basin (CRB) as a Water and Agricultural Resource

- Multiple competing water uses in the CRB:
  - In-Stream: hydropower, flood control, fish flows, navigation, recreation
  - Out-of-Stream: agricultural, municipal, industrial
- Washington's Agriculture
  - 300 commodities (first in US for 11 commodities)
  - Livestock and crops: $6.7B in 2006
  - 11% of the state's economy

(WSDA, 2008)

Potential Impacts of Climate Change on Agriculture

- Direct Impacts of Climate Change
  - Warming
    - lengthens the available growing season, but…
    - shortens the crop growth period
  - Growing season precipitation changes (non-irrigated crops)
  - Changes in frequency of extreme events
- Direct Impacts of Increasing CO_2
  - Increases radiation-use efficiency
  - Increases water-use efficiency
  - Largest effect for C3 crops (most crops; corn=C4 crop)
- Indirect Impacts of Climate Change through Water Rights Curtailment (irrigated crops)
- Indirect Impacts due to Changes to Pests, Weeds, Diseases, and Crop Quality

The Columbia Basin Water Supply & Demand Forecast

- Every 5 years, the Washington State Department of Ecology’s Office of the Columbia River (OCR) is required to submit a long-term water supply and demand forecast to the State Legislature

- Washington State University (WSU) was assigned to develop the 2030s forecast for water supply and out-of-stream demand

- The forecast helps improve understanding of where additional water supply is most critically needed, now and in the future

Office of Columbia River

OFFICE OF COLUMBIA RIVER (OCR)

- About OCR
- Water for the Odessa Subarea
- Water for Fish
- Water for Permitting New Water Rights
- Water for Drought Relief
- Water Supply Projects
- OCR Operations
- Legislative Reports
- Web Tools

- Publications
- Policy Advisory Group (PAG)
- Columbia River Basin Water Management Grant Application
- Water Resources Laws, Rules, and Cases
- Contacts
- Water Resources Program

Office of Columbia River > Long Term Water Supply and Demand Forecast

Columbia River Basin 2011
Long Term Water Supply and Demand Forecast

Home | Introduction | Significant Findings | Overview | Contact

2011 Water Supply and Demand Forecast

The Office of Columbia River (OCR) continues to aggressively pursue development of conservation and water supply projects to meet eastern Washington's economic and environmental needs. To support this mission, every five years OCR prepares and submits to the Washington State Legislature a long-term water supply and demand forecast (Forecast). The Forecast provides a generalized, system-wide assessment of how future environmental and economic conditions are likely to change water supply and demand by 2030. Understanding where additional water supply is most critically needed will assist OCR in making smarter investments that help improve water supply for eastern Washington's instream and out-of-stream users.

To view specific sections of the report, click on the tabs above and the buttons below.

Director's Letter

View / Download Complete Reports (pdf)

Definitions of terms used in this Forecast

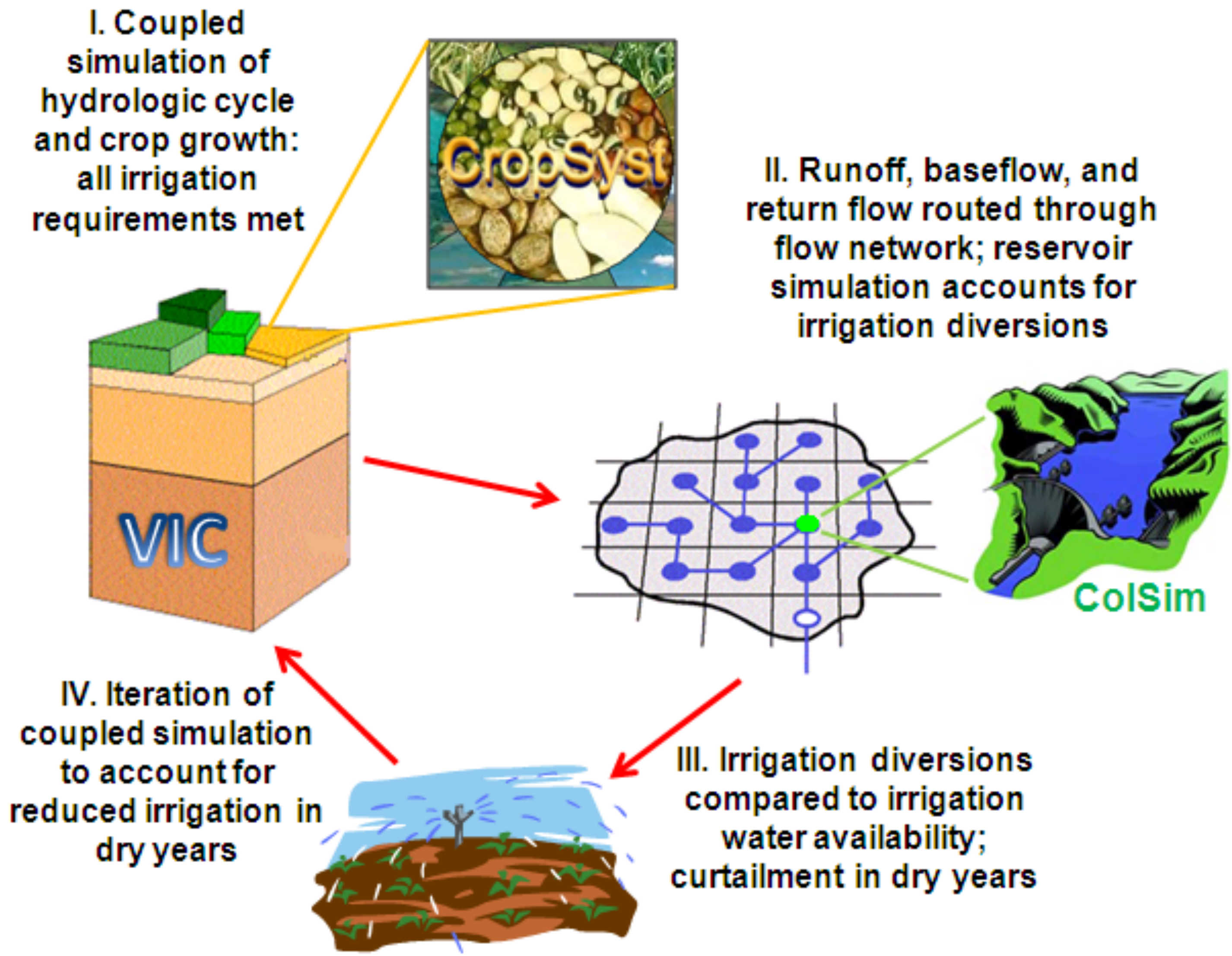
http://www.ecy.wa.gov/programs/wr/cwp/forecast/forecast.html

Modeling Capabilities Developed

- Started with tools developed at the University of Washington Climate Impacts Group (UW CIG) through the State-Wide Assessment (Elsner et al. 2010), and added:

1. Integrated surface hydrology and crop systems modeling
2. Inclusion of water management
    1. Reservoirs
    2. Curtailment
3. Interaction between biophysical and economic decision making models

Integrated Hydrology, Cropping Systems, and Water Management



Crops Modeled:
irrigated and non-irrigated (dryland)

Major Crops

- Winter Wheat
- Spring Wheat
- Alfalfa
- Barley
- Potato
- Corn
- Corn, Sweet
- Pasture
- Apple
- Cherry
- Lentil
- Mint
- Hops

- Grape, Juice
- Grape, Wine
- Pea, Green
- Pea, Dry
- Sugarbeet
- Canola

Vegetables

- Onions
- Asparagus
- Carrots
- Squash
- Garlic
- Spinach

Other Pastures

- Grass hay
- Bluegrass
- Hay
- Rye grass

Lentil/Wheat Type

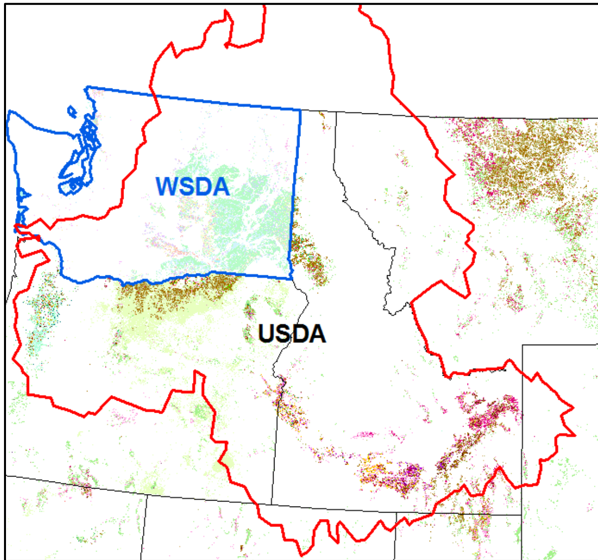
- Oats
- Bean, green
- Rye
- Barley
- Bean, dry
- Bean, green

Berries

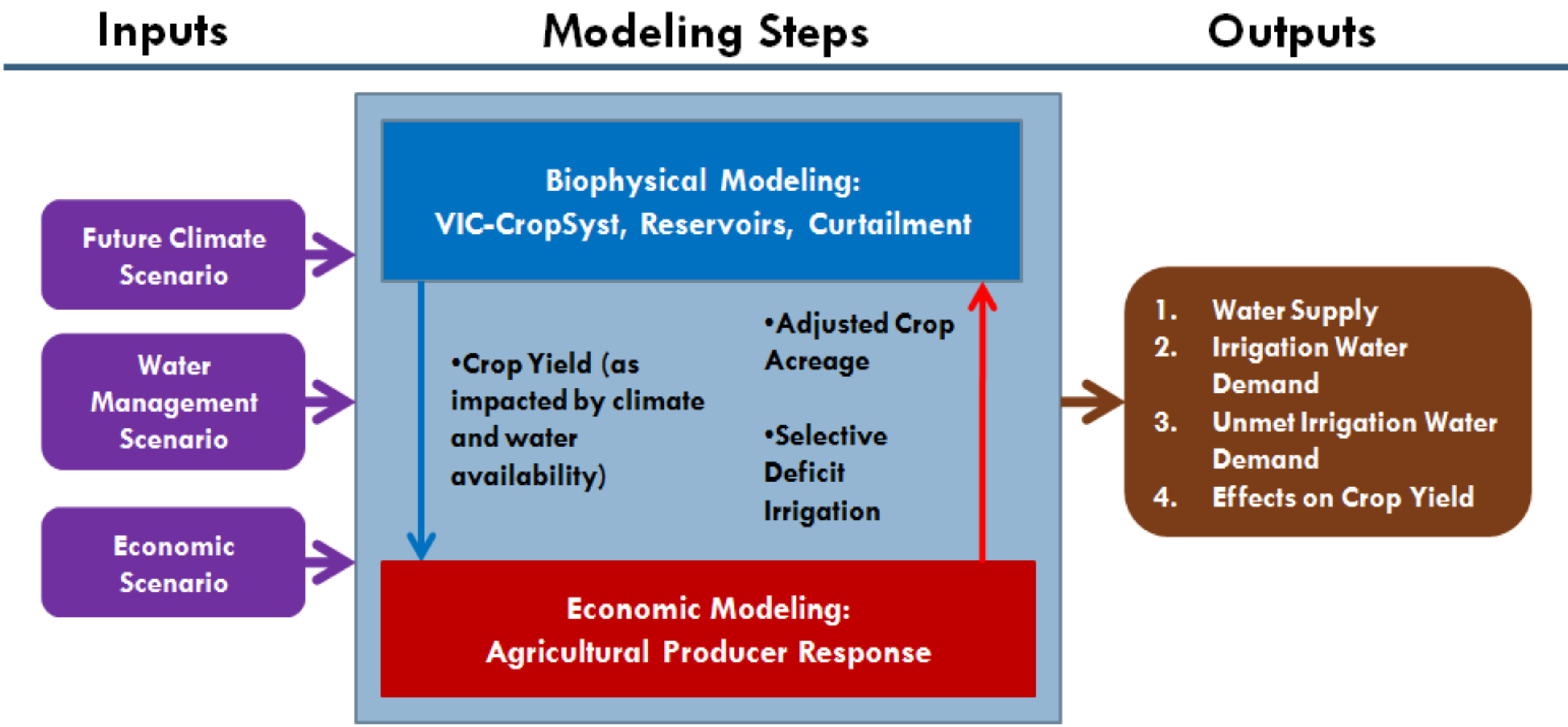
- Caneberry
- Blueberry
- Cranberry

Other Tree Fruits

- Pear
- Peaches



Interactions with Economic Modeling



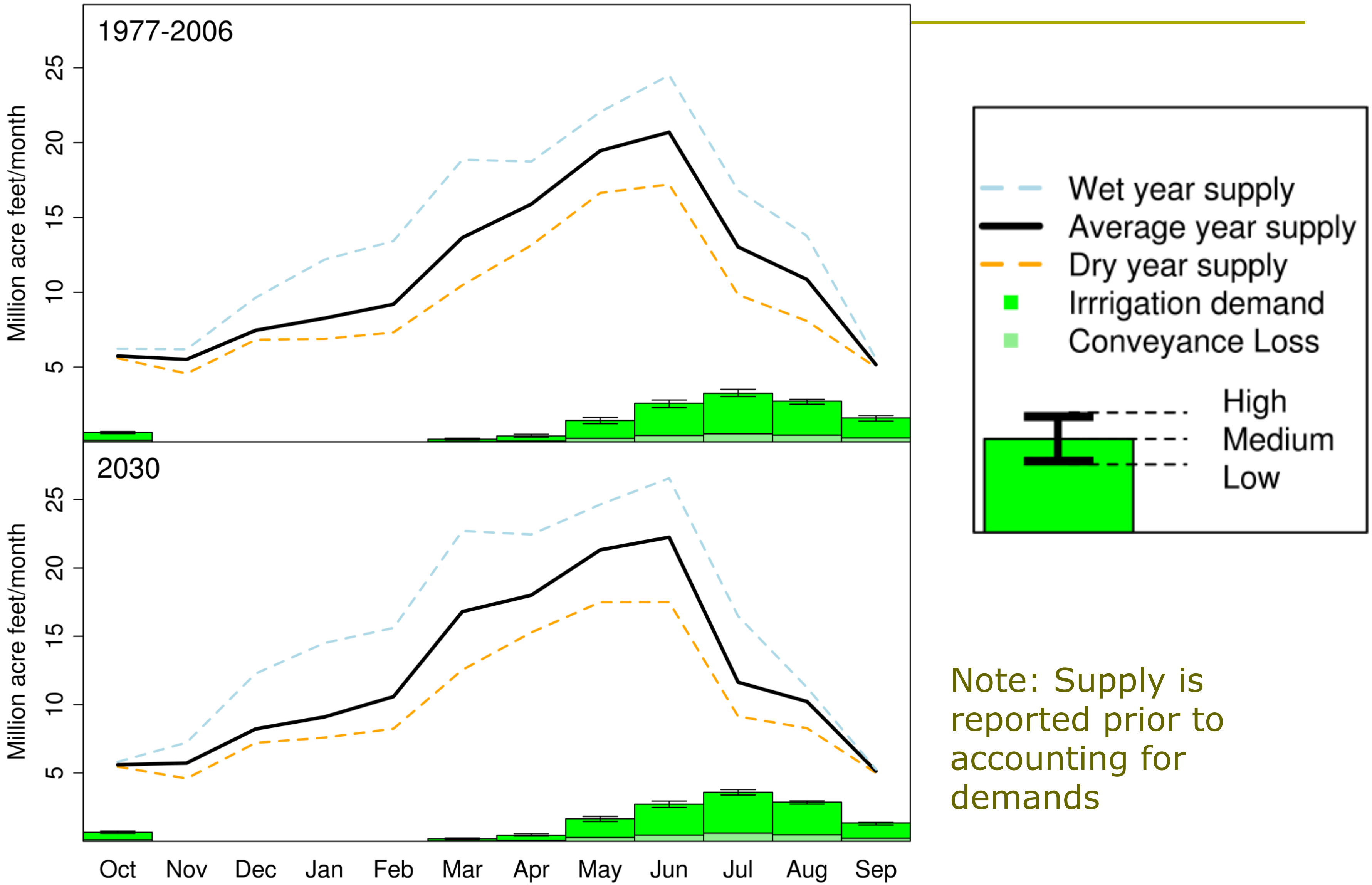
Results

- Impacts on water supply and demand
- Impacts on crop yield:
  - Direct climate impacts
  - CO_2 impacts
  - Water rights curtailment impacts

Projected Climate Change Impacts on Water Supply and Demand

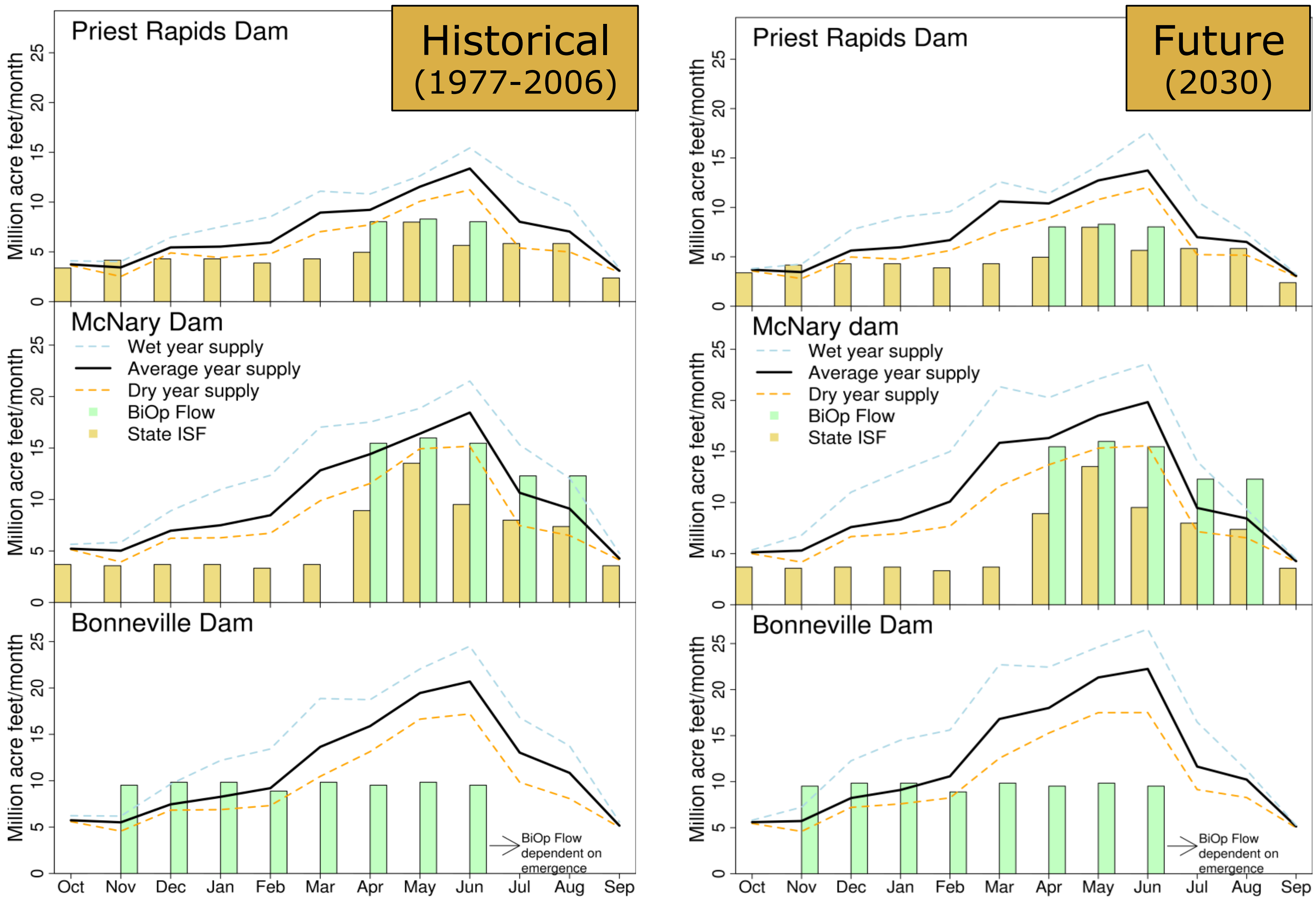
- A small increase of around **3.0 (±1.2)%** in average annual supplies by 2030 compared to historical (1977-2006)
- Unregulated surface water supply at Bonneville will
  - ↓ **14.3 (±1.2)%** between June and October
  - ↑ **17.5 (±1.9)%** between November and May
- The irrigation demand under 2030s climate was roughly 2% above modeled historic levels under average flow conditions
- Most severe impacts at smaller scales, i.e., for specific watersheds

Regulated Supply and Demand at Bonneville



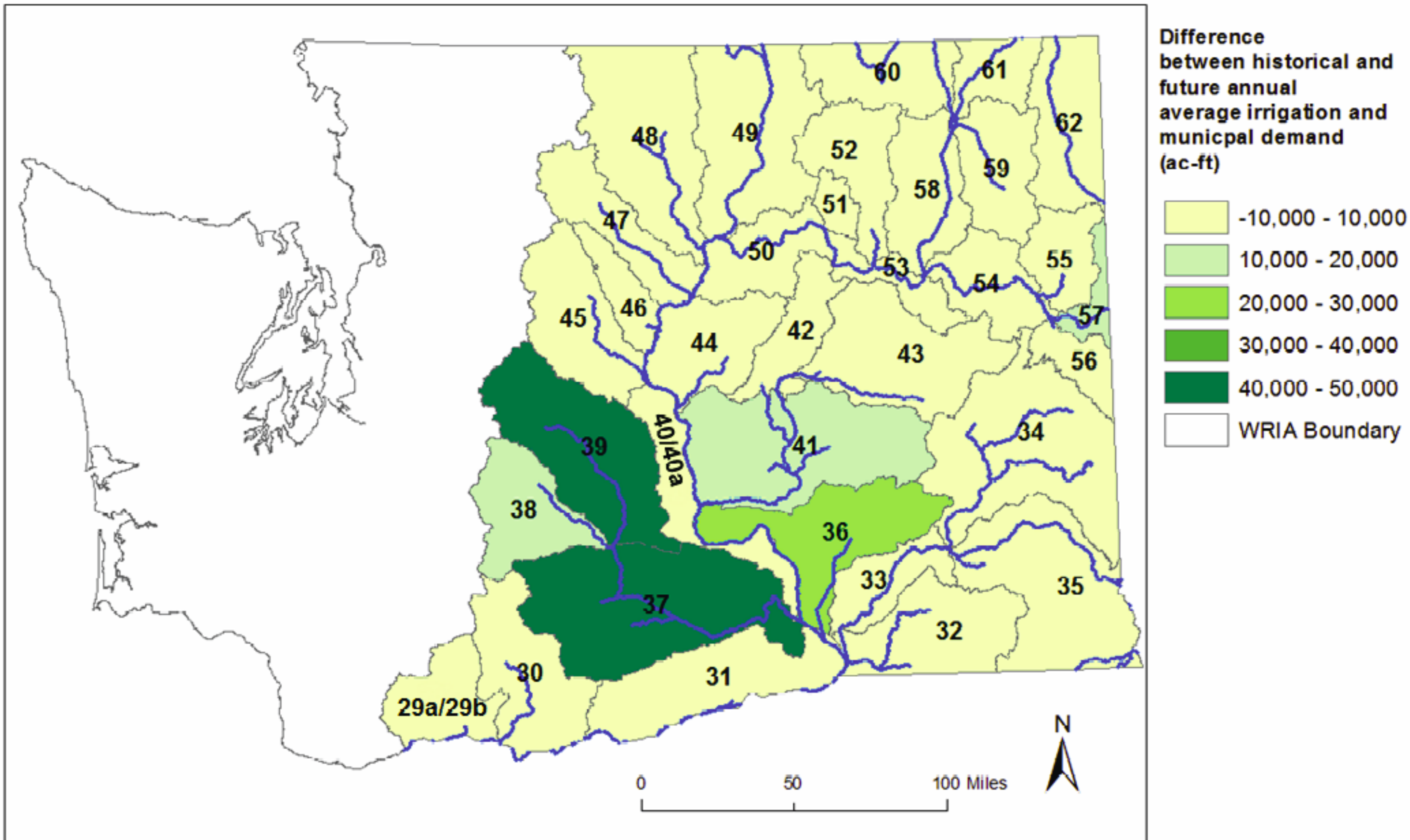
Note: Supply is reported prior to accounting for demands

Regulated Supply and In-Stream Flow Requirements at Key Locations



Note: Supply is reported prior to accounting for demands

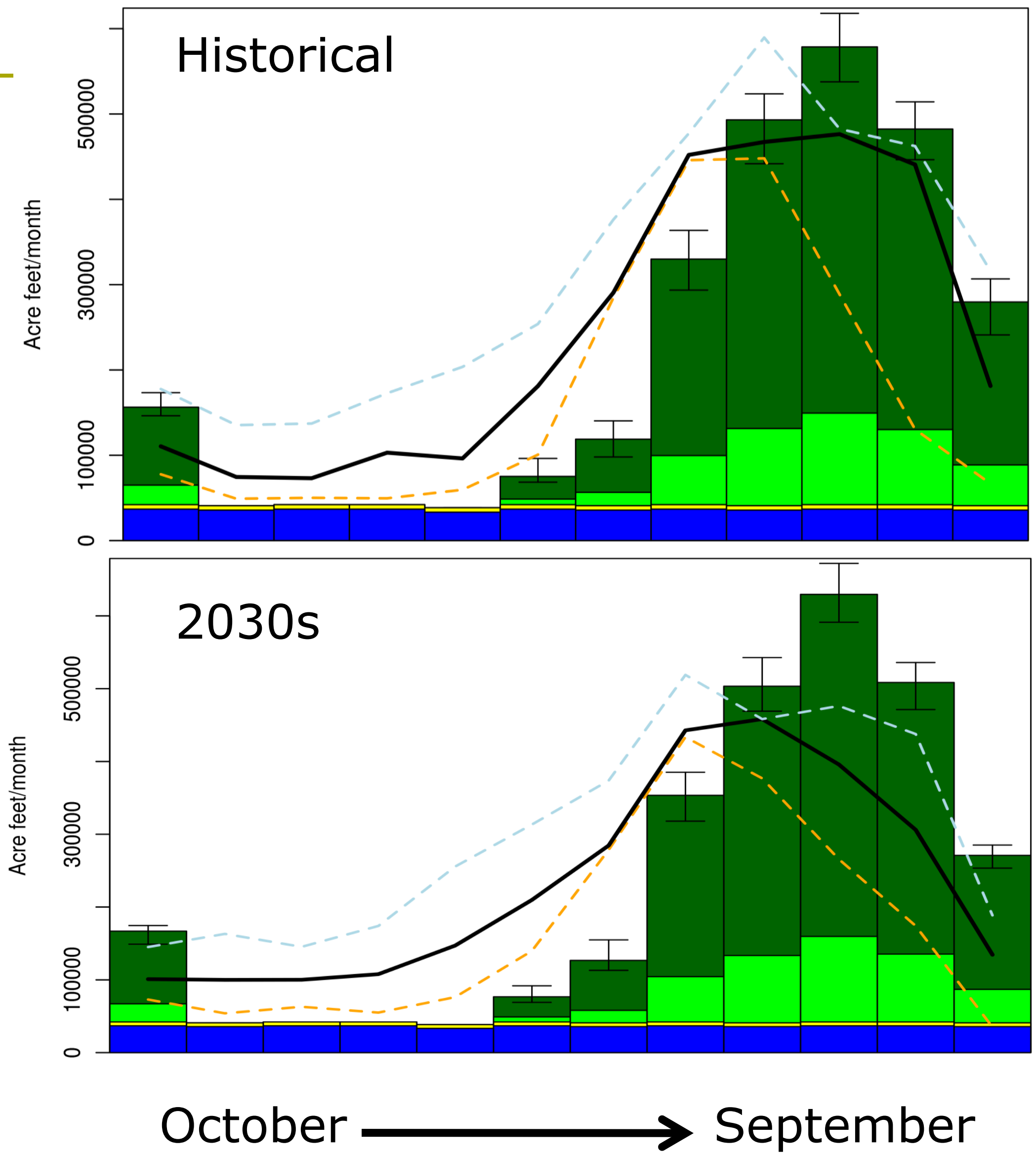
Change in Total Water Demand (2030s – Historical)

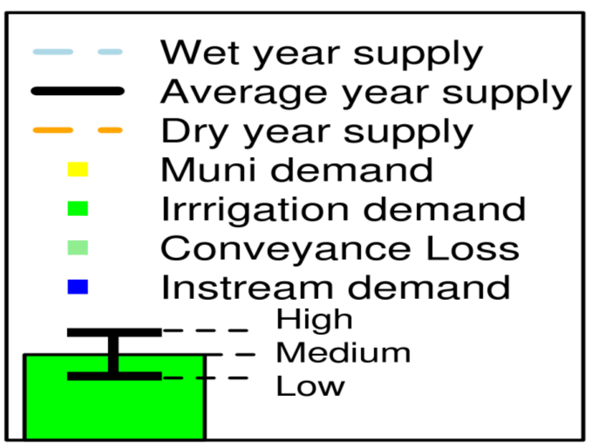


Yakima River Basin

- WA's largest agricultural economy, 5th in nation
- Tree fruit, vineyards, field crops, forage, pasture, vegetables, specialty crops
- 5 reservoirs hold ~30% of mean annual runoff

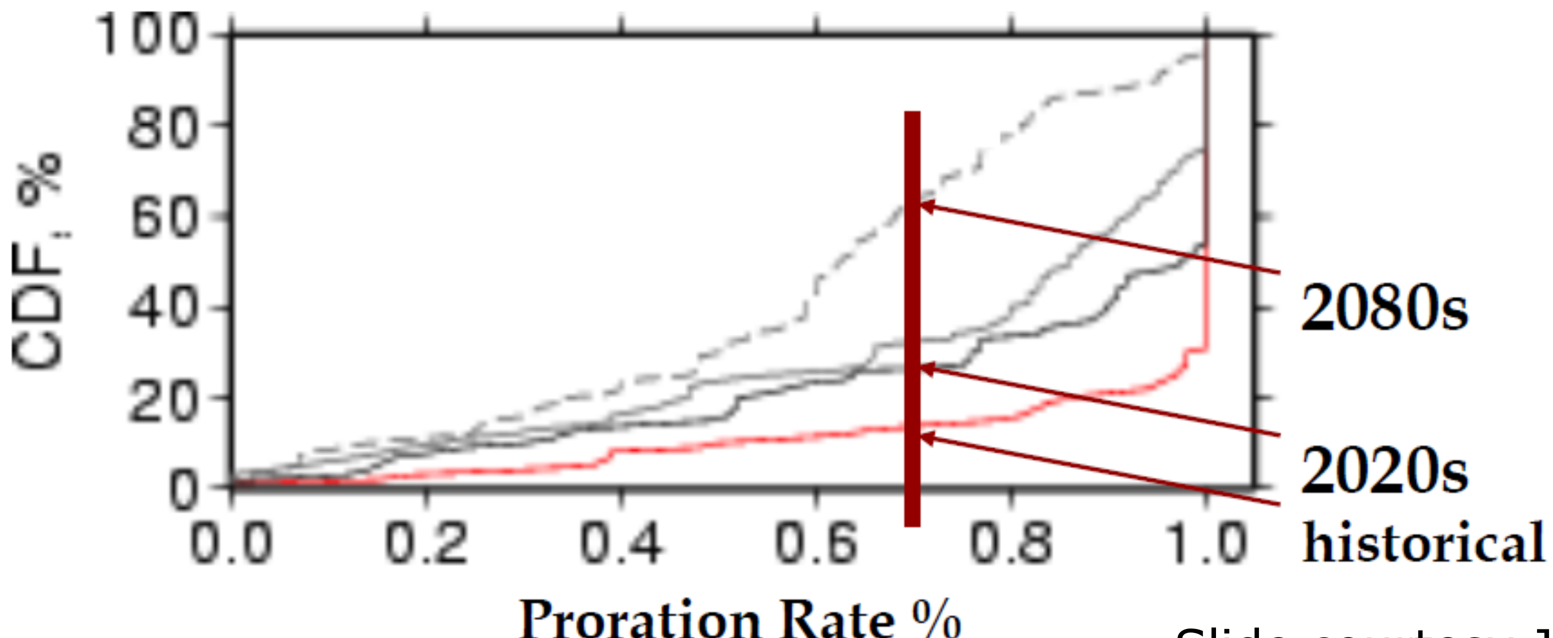
Changes in regulated supply and demand





Vano et al (2010) Study of Irrigated Agriculture in the Yakima Basin

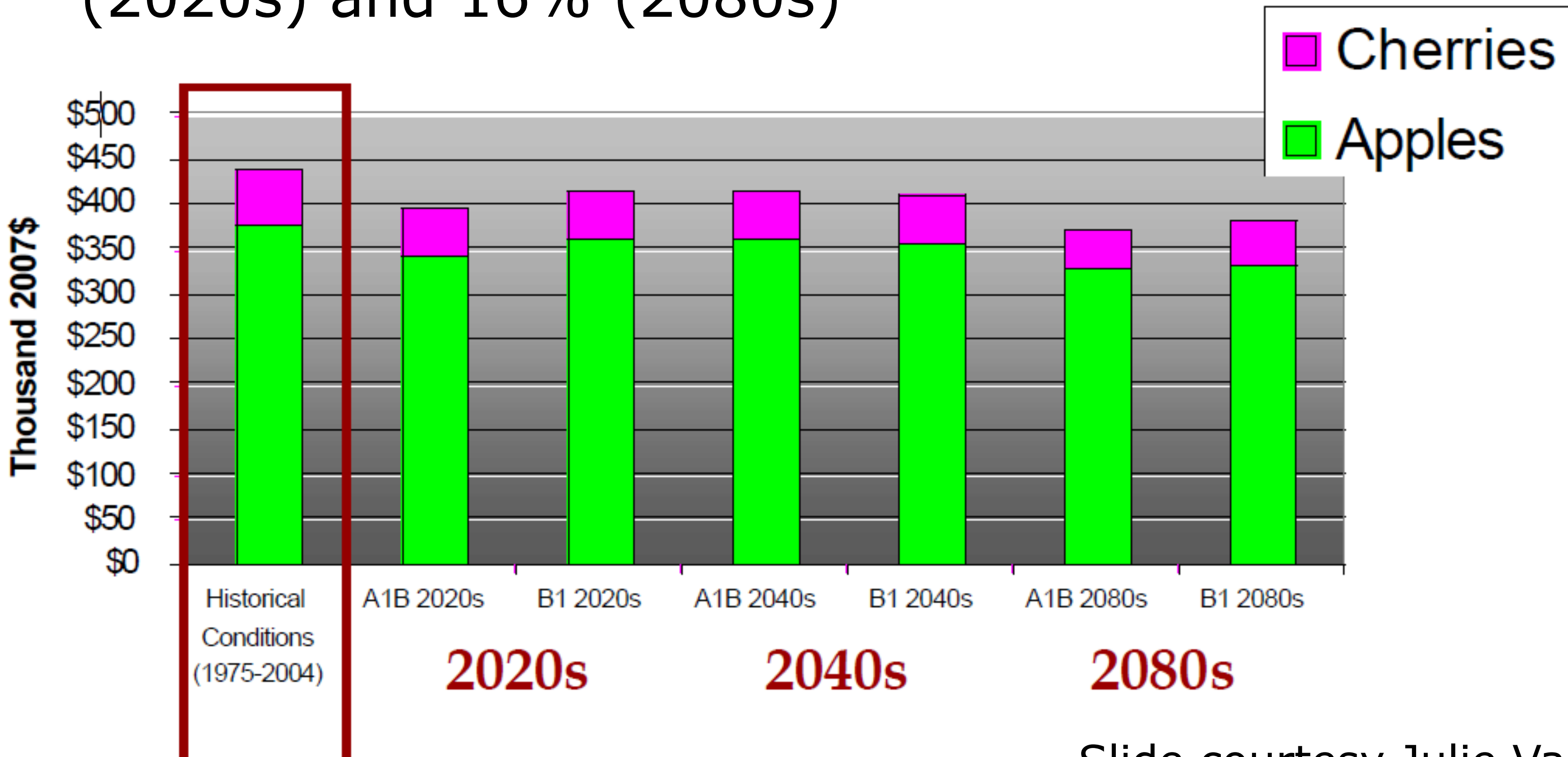
- For junior irrigators receive less than 70% of water (level of prorating):
  - 14% historically
  - 27% in 2020s (A1B)
  - 33% in 2040s (A1B)
  - 68% in 2080s (A1B)



Slide courtesy Julie Vano

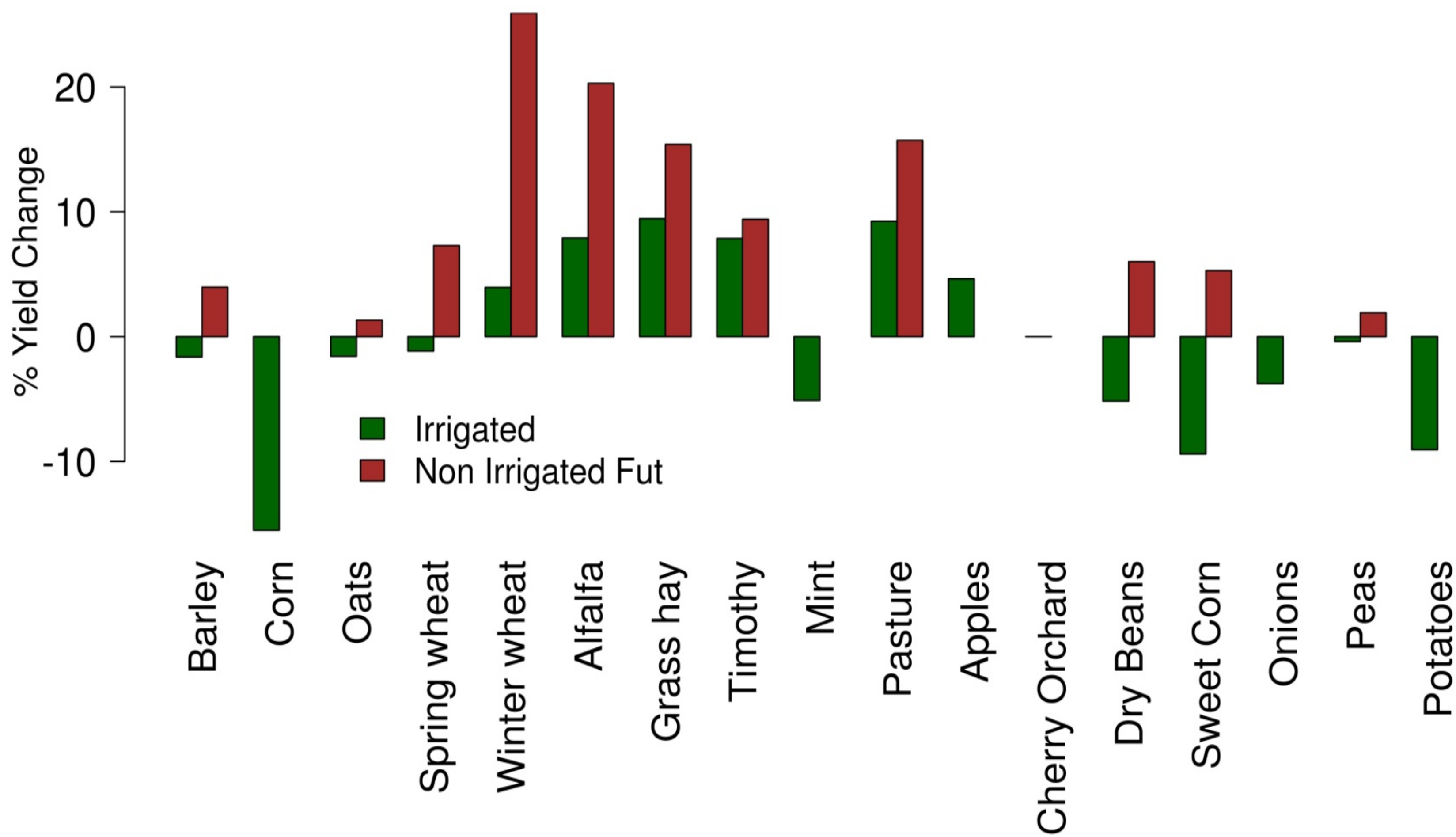
Vano et al (2010) Study of Irrigated Agriculture in the Yakima Basin

- Applies, sweet cherries: 48% of region's crop value
- Total production declines from historic by 5% (2020s) and 16% (2080s)



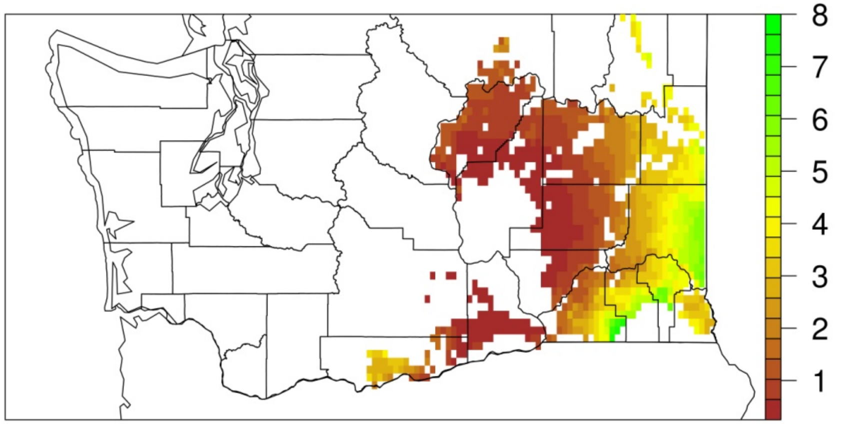
Slide courtesy Julie Vano

Projected Climate Change Impacts on Crop Yield: Climate and CO_2

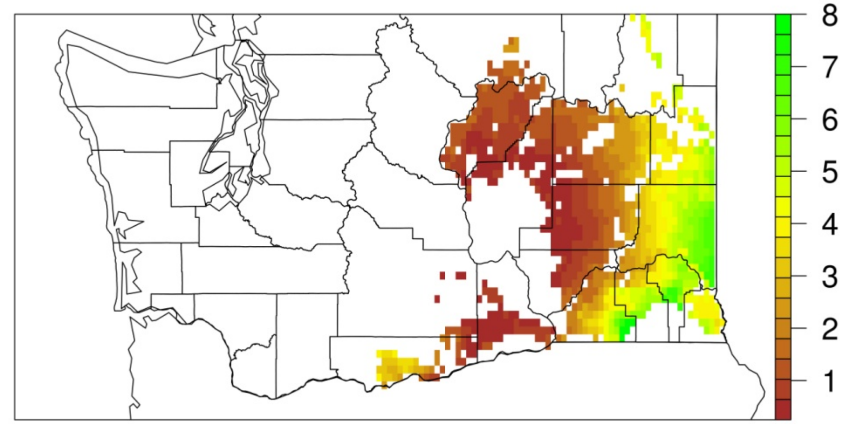


Projected Climate Change and CO_2 Impacts on Non-Irrigated Winter Wheat

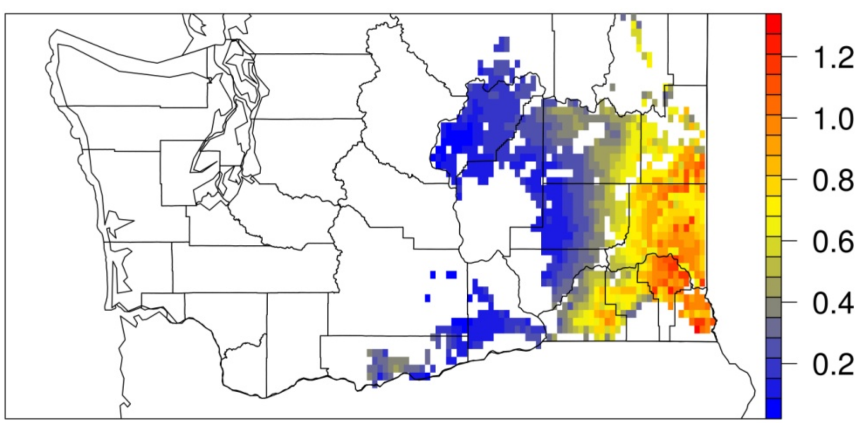
Historical Yield [Non Irrigated] (tonnes/hectare)



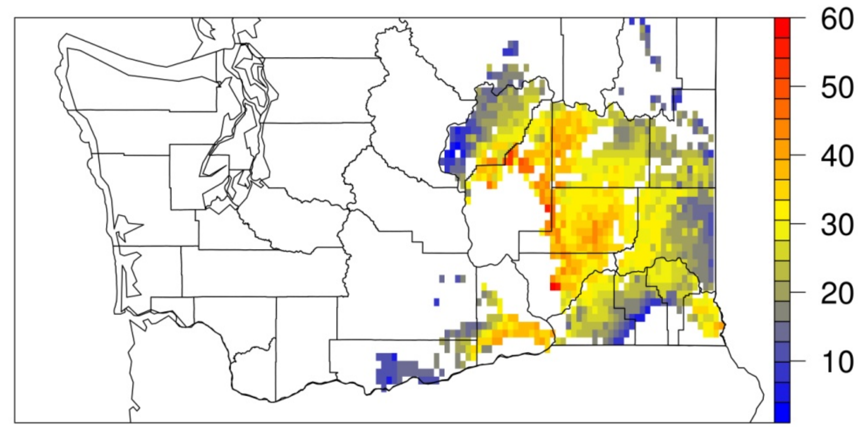
Future Yield [Non Irrigated] (tonnes/hectare)



Future Change in Yield [Non Irrigated] (tonnes/hectare)

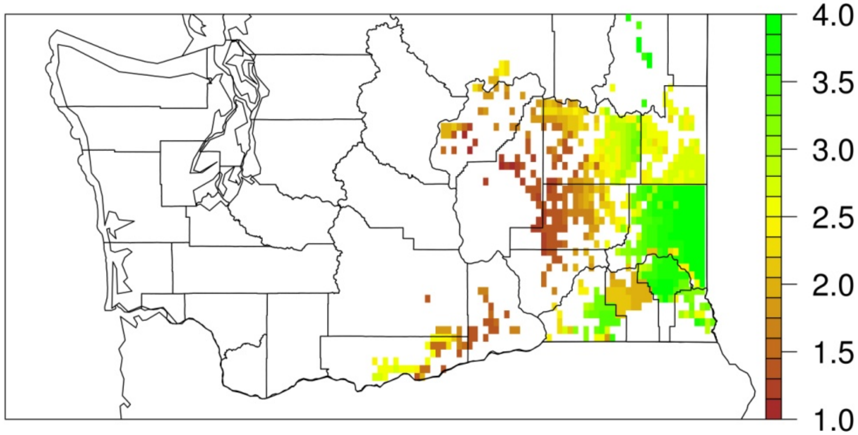


% Change in Yield [Non Irrigated]

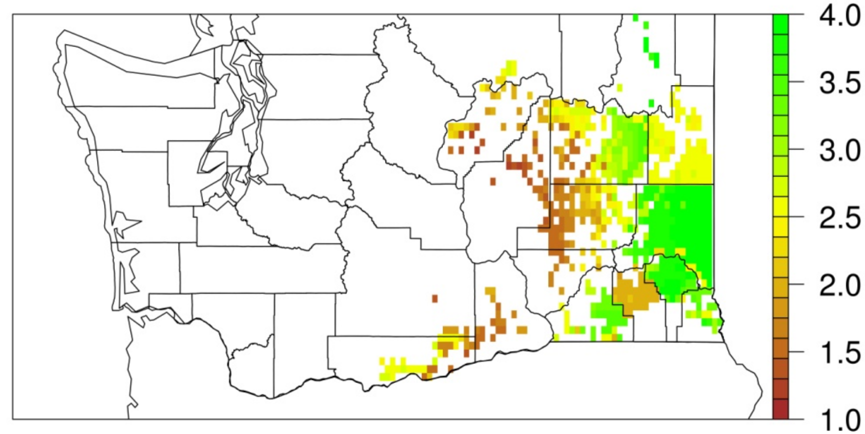


Projected Climate Change and CO_2 Impacts on Non-Irrigated Spring Wheat

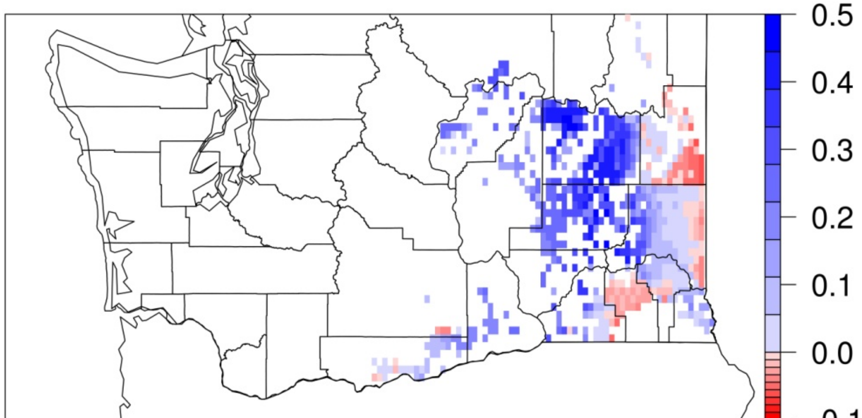
Historical Yield [Non Irrigated] (tonnes/hectare)



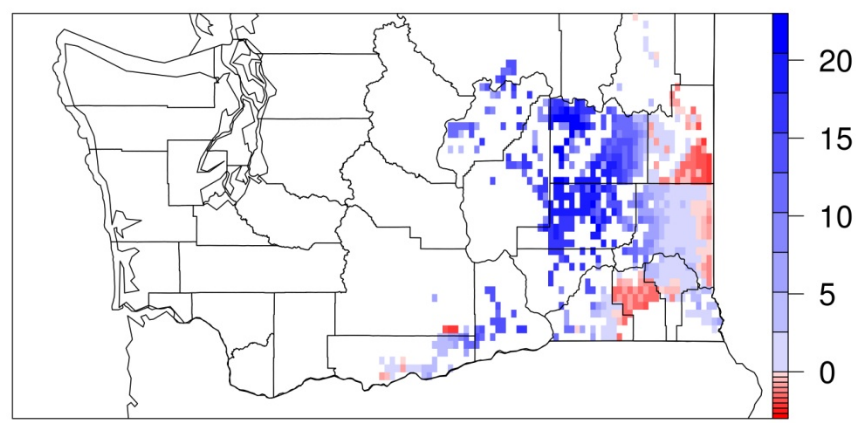
Future Yield [Non Irrigated] (tonnes/hectare)



Future Change in Yield [Non Irrigated] (tonnes/hectare)

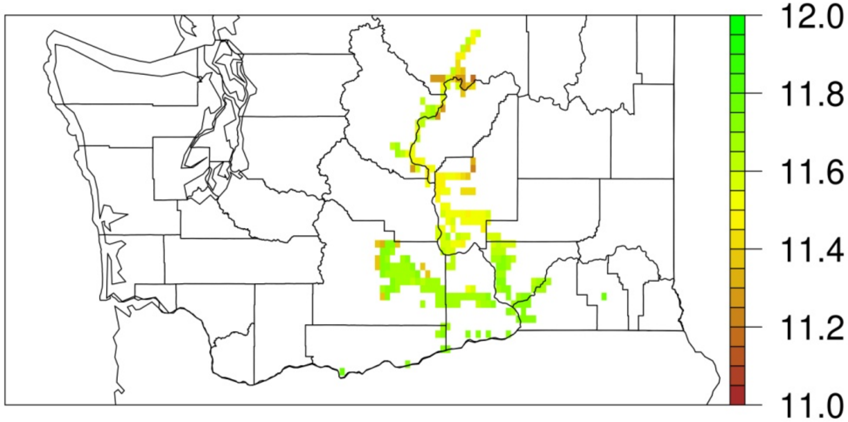


% Change in Yield [Non Irrigated]

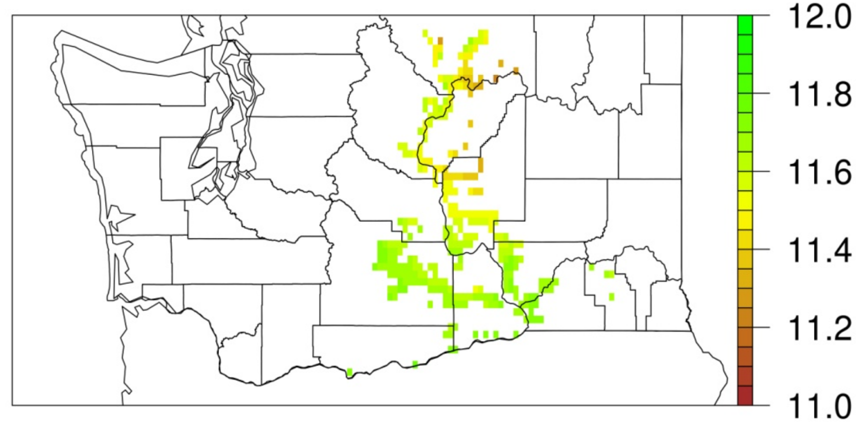


Projected Climate Change and CO_2 Impacts on Apples

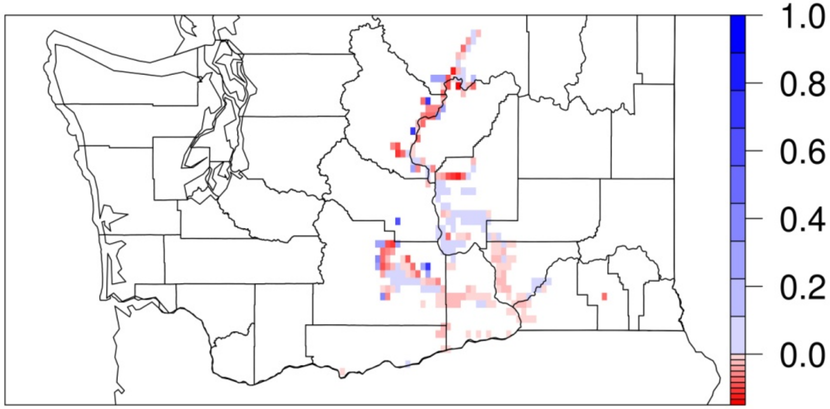
Historical Yield [Irrigated] (tonnes/hectare)



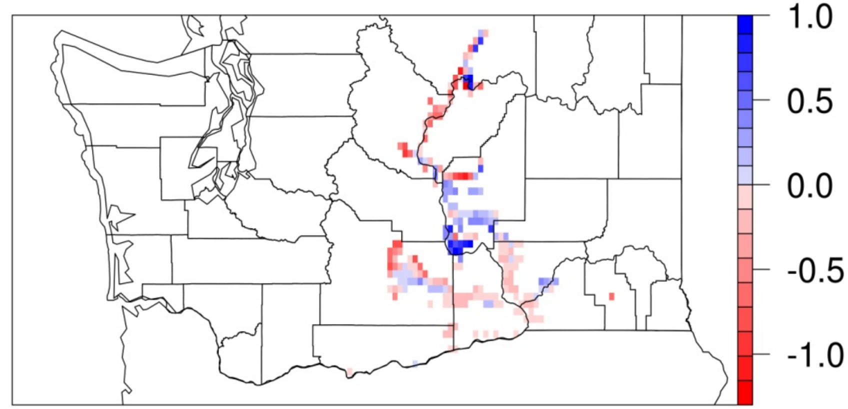
Future Yield [Irrigated] (tonnes/hectare)



Future Change in Yield [Irrigated] (tonnes/hectare)

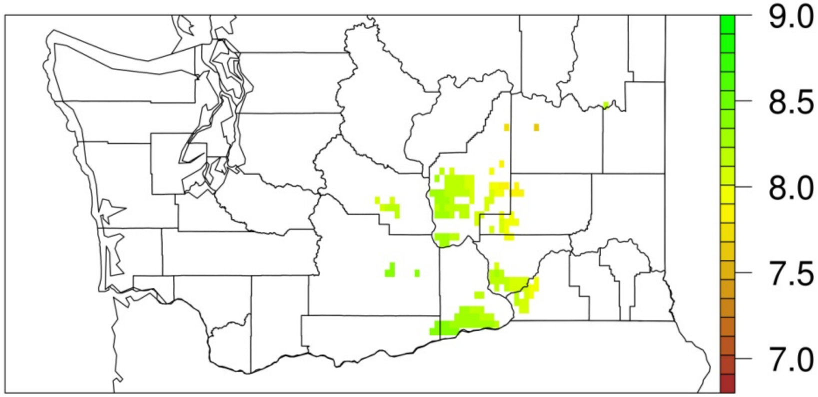


% Change in Yield [Irrigated]

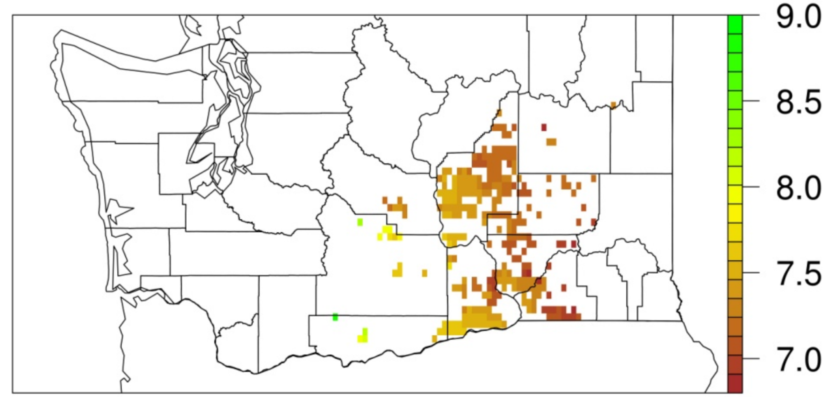


Projected Climate Change and CO_2 Impacts on Sweet Corn

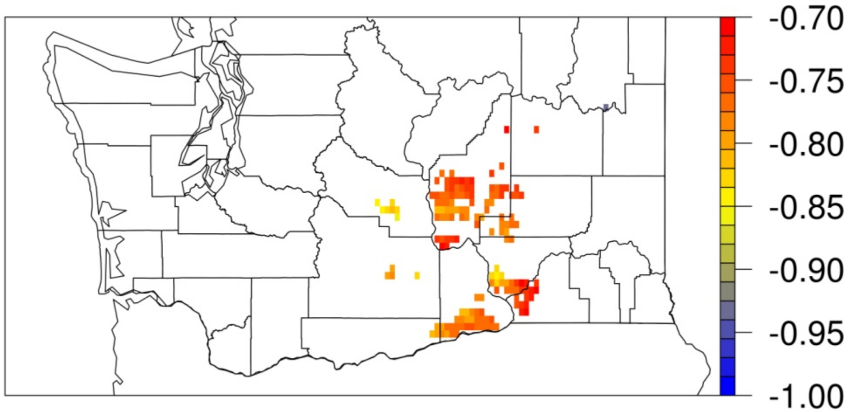
Historical Yield [Irrigated] (tonnes/hectare)



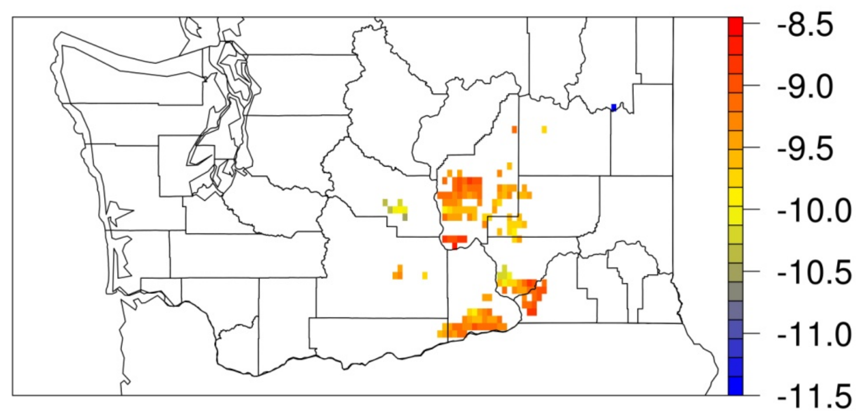
Future Yield [Irrigated] (tonnes/hectare)



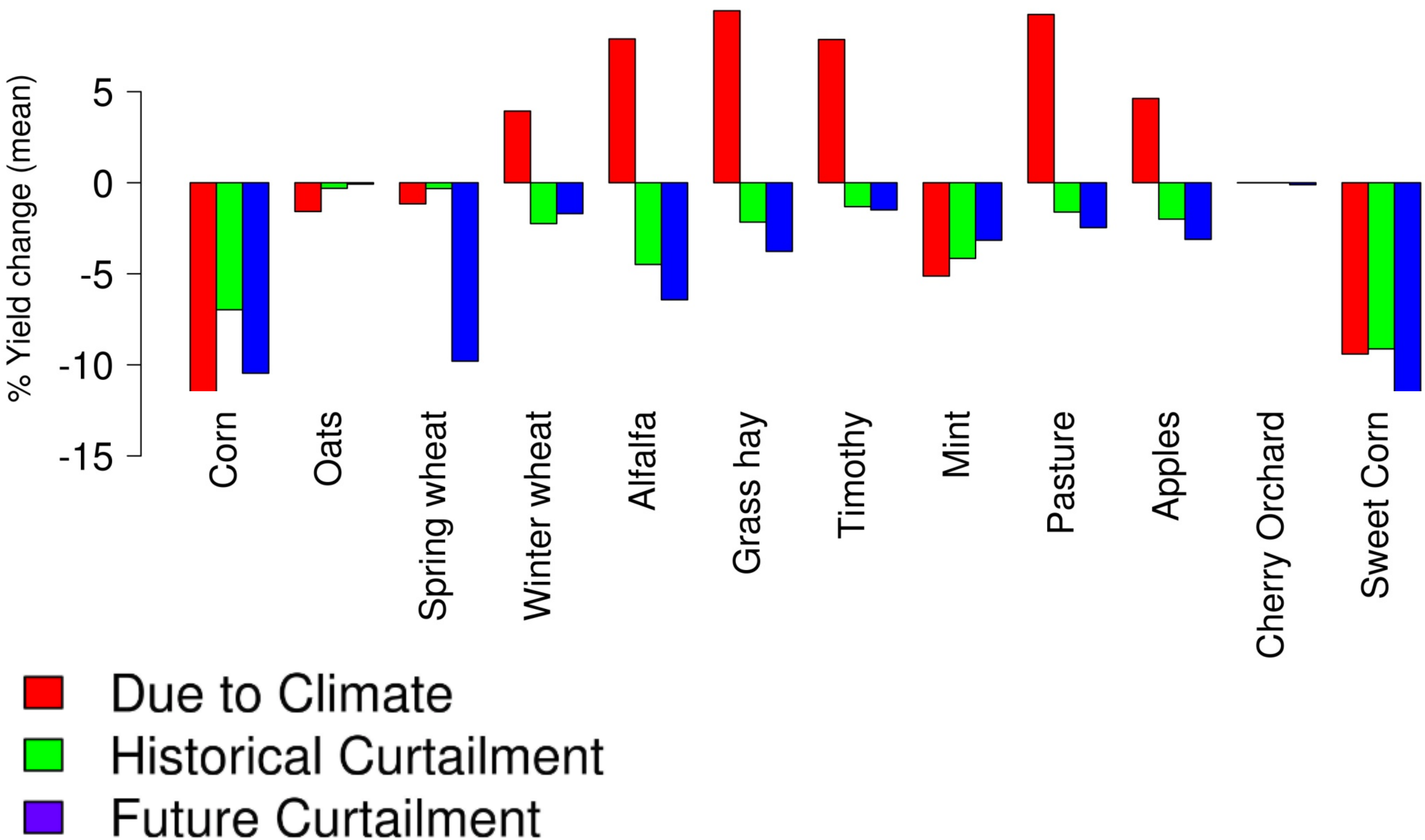
Future Change in Yield [Irrigated] (tonnes/hectare)



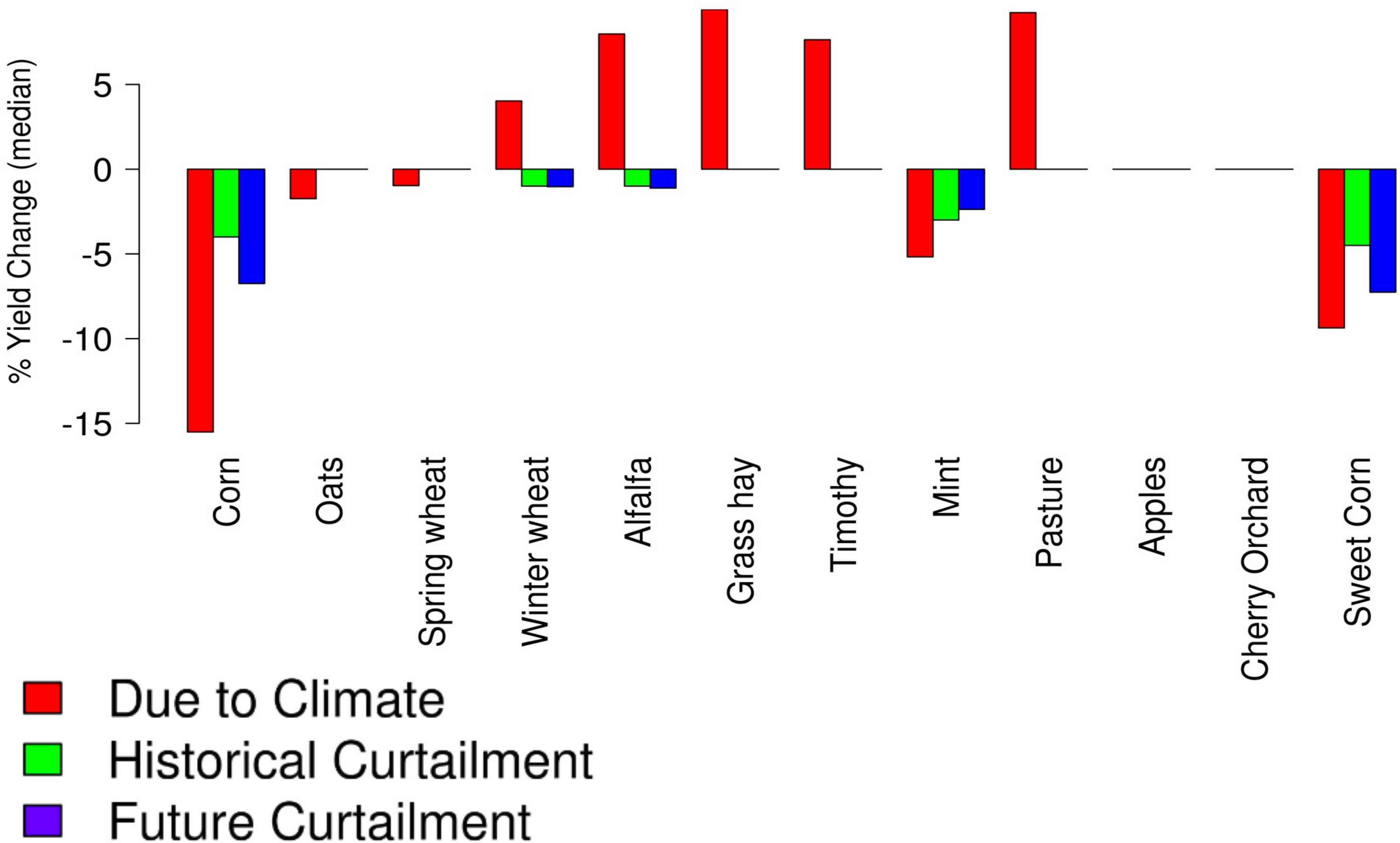
% Change in Yield [Irrigated]



Projected Climate Change Impacts on Crop Yield: Curtailment



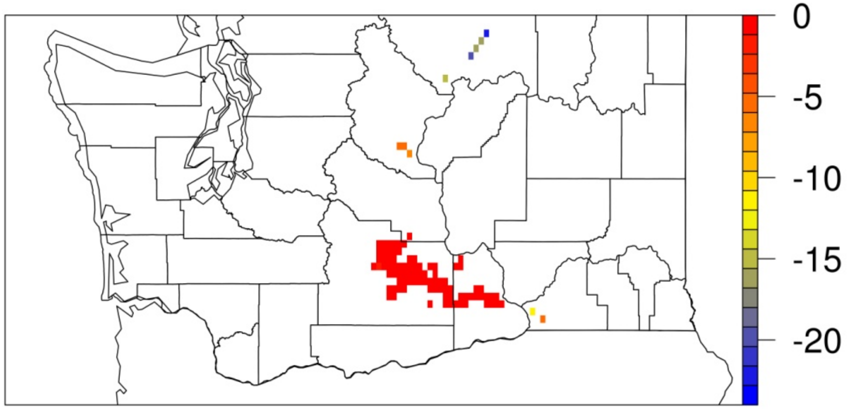
Projected Climate Change Impacts on Crop Yield: Curtailment



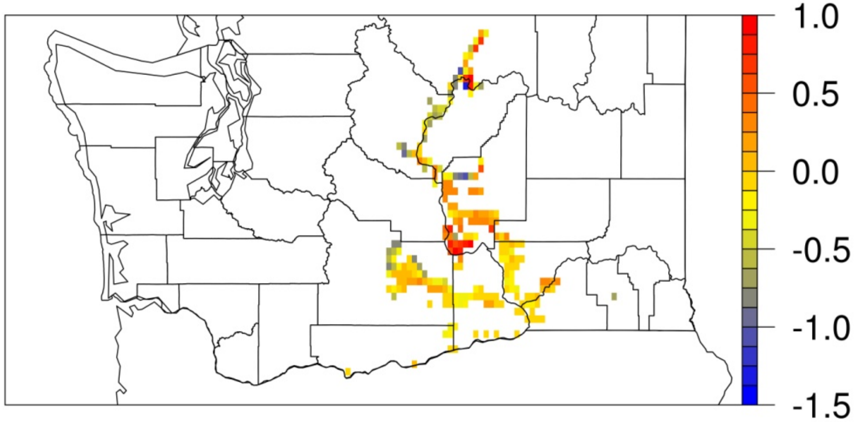
Projected Curtailment Impacts on

Apples

Future Yield Change Due to Curtailment (%)

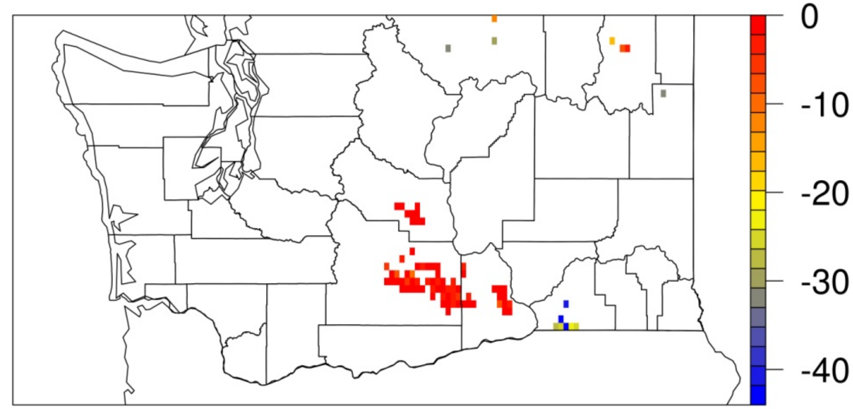


Future Yield Change Due to Climate (%)

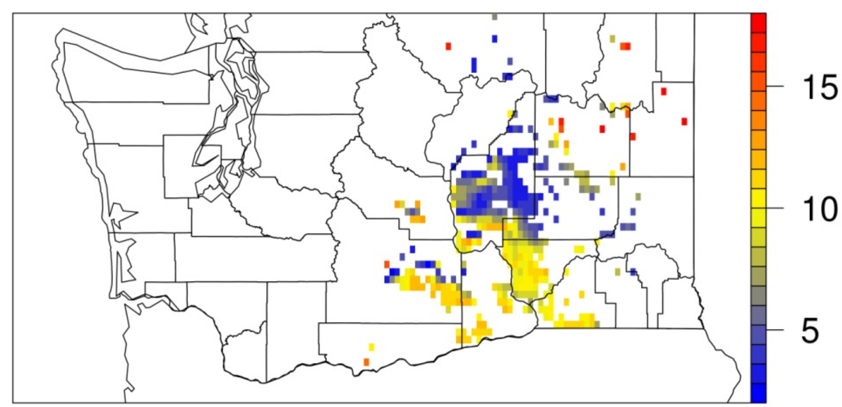


Alfalfa

Future Yield Change Due to Curtailment (%)



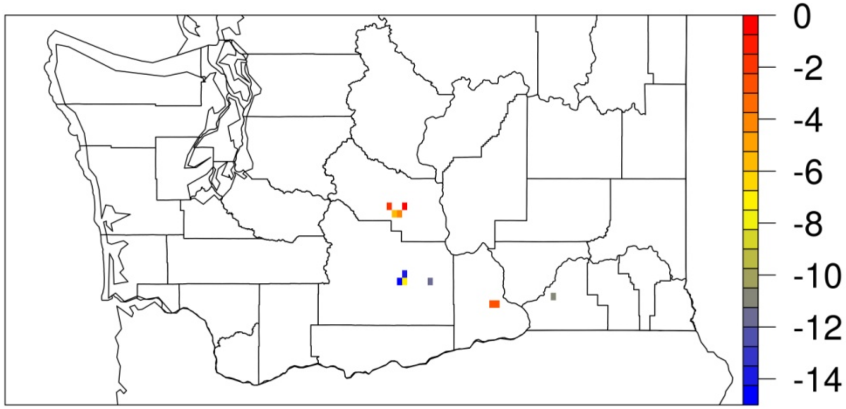
Future Yield Change Due to Climate (%)



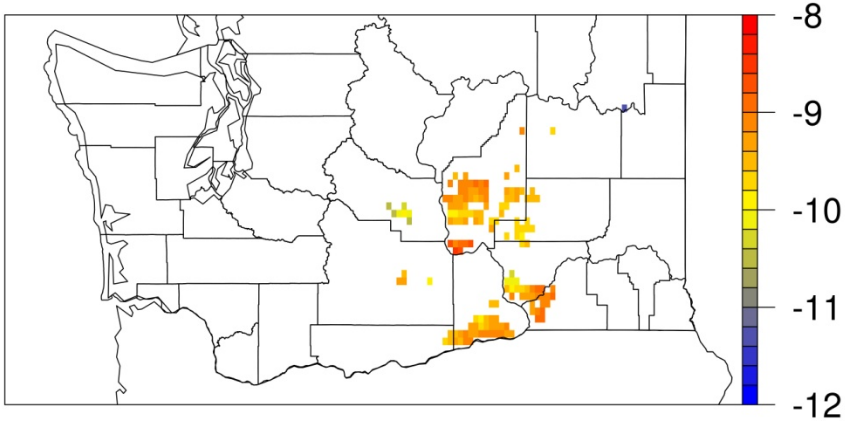
Projected Curtailment Impacts on

Sweet Corn

Future Yield Change Due to Curtailment (%)

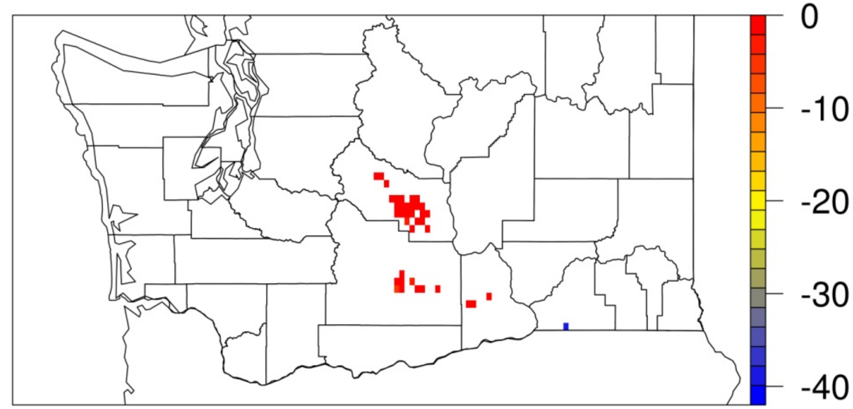


Future Yield Change Due to Climate (%)

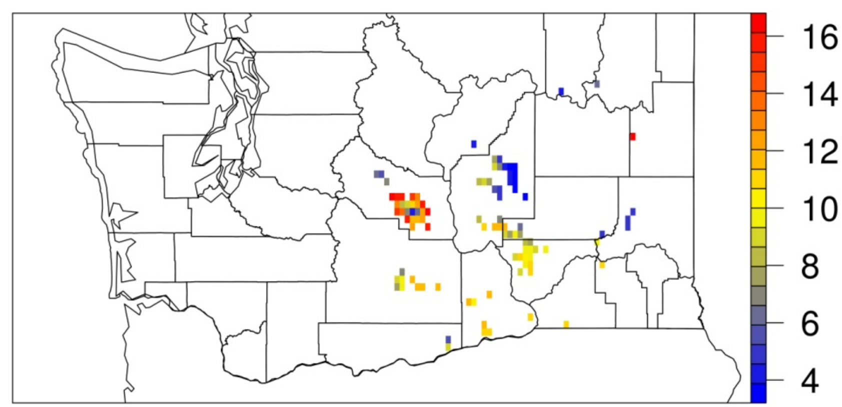


Pasture

Future Yield Change Due to Curtailment (%)



Future Yield Change Due to Climate (%)



Caveats

- Impacts related to pests, weeds, diseases, and crop quality were not considered
- We assumed that crops are not nitrogen-limited
- Water supply and demand considered 5 climate scenarios; crop yield results are for the middle climate scenario
- The large scales of our models are likely not capturing more extreme impacts at finer temporal and spatial scales
- We did not complete a full analysis of the Odessa Subarea of the Columbia Basin Project, where groundwater is expected to be fully depleted by 2030
- Limitations with water rights information
- A scenario of no adaptation was assumed

Proposed Adaptation Strategies

- Crop Management
  - Change planting dates for annual crops
  - Plant/develop crop varieties better adapted to future climate conditions
- Water Management
  - Structural Alternatives: e.g., new seasonal storage, groundwater extraction, divergences
  - Non-Structural Alternatives: e.g., modify reservoir operations, increase capabilities for water transfers between users, water conservation measures
- Building/Implementing Adaptive Capacity
  - Access to information about climate and climate impacts
  - Increase technical capacity to incorporate information on climate impacts
  - Increase legal and administrative capacity to adapt to climate change
- Need for "horizontal integration" among sectors impacted by climate change, e.g., integrated management of our water resources for hydropower, agriculture, ecosystems, flood control, etc…

Hamlet 2011, Miles et al 2010, Stöckle et al 2010, Vano et al 2010, Whitely Binder et al 2010

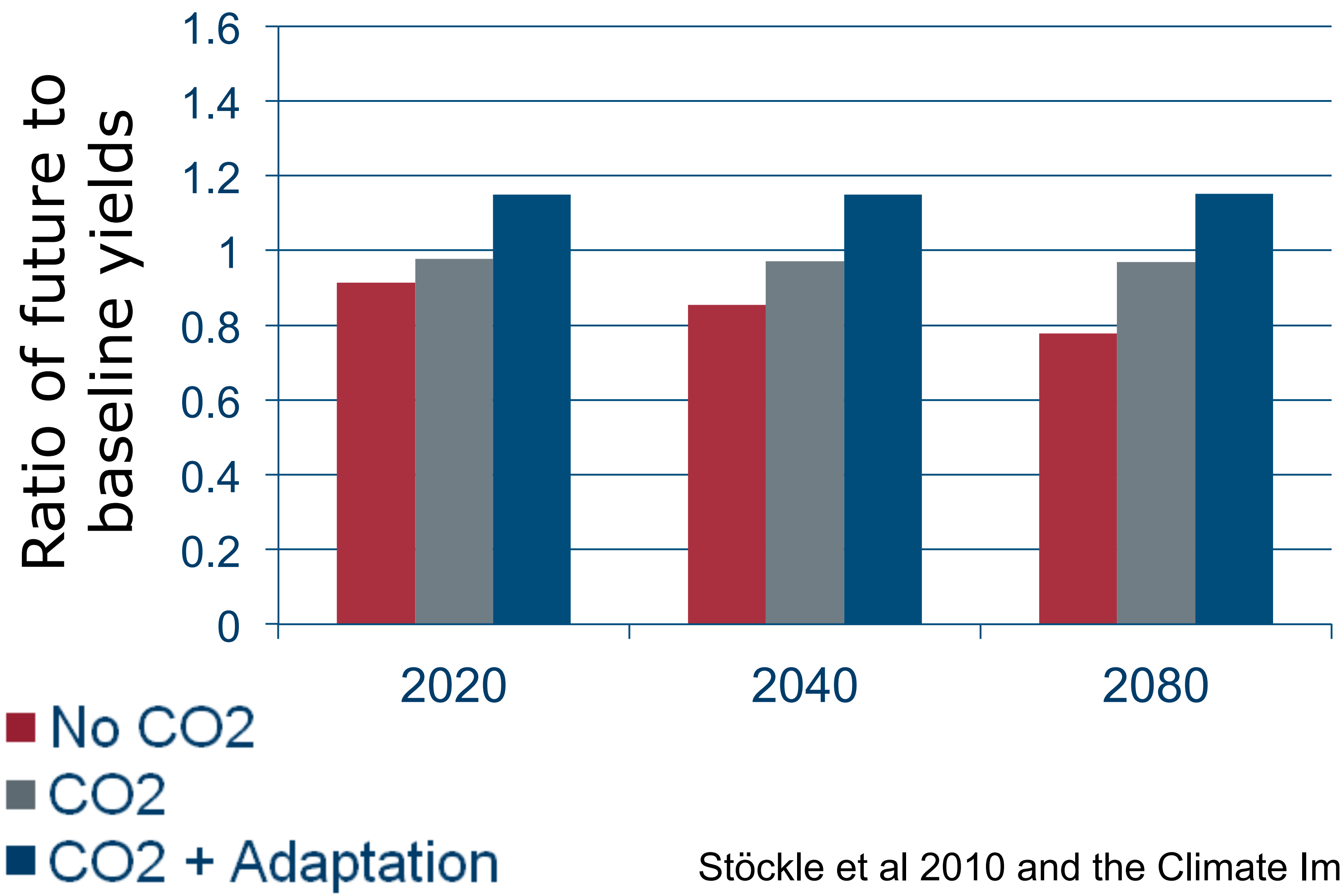
Summary

- Climate change is associated with warming, changes in precipitation seasonality, changes in the frequency of extreme events, and increases in CO_2
- While annual freshwater supply may slightly increase, freshwater availability will decrease during the growing season without adequate reservoir storage
- Irrigation water demand is also increasing
- Crop yields are impacted by these changes
  - Decreases due to warming
  - Increases due to CO_2 enhancement
  - Decreases due to more frequent curtailment
- Adaptation will involve both crop and water management strategies, and increasing the state's adaptive capacity


Thank you!

Extra Slides

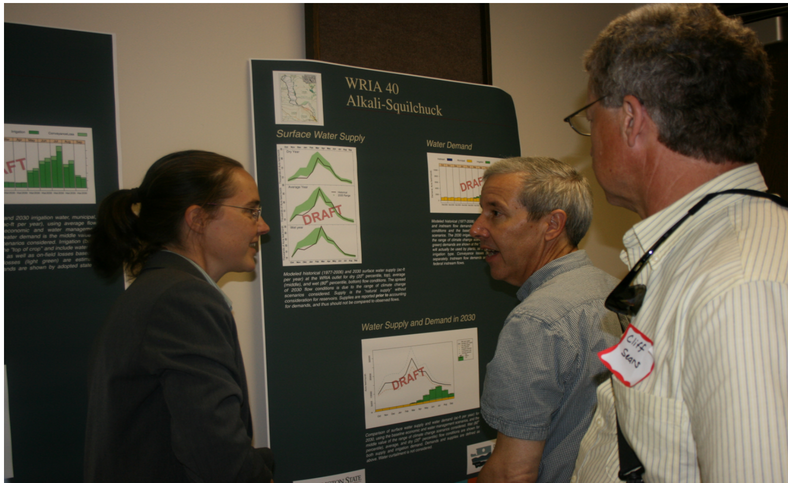
Projected Climate Change and CO_2 Impacts on Potatoes at Othello, WA



Stöckle et al 2010 and the Climate Impacts Group

Review and Stakeholder Interaction Process

- National Review Panel
- Regional Review Panel
- OCR Policy Advisory Group
- 30-Day Public Comment Period
- Public stakeholder workshops (Tri-Cities, Wenatchee, and Spokane) in Sep 2011
  - Inform stakeholders
  - Seek feedback



CropSyst

Cropping Systems

Stöckle and Nelson 1994

VIC

Macro-Scale Hydrology

Liang et al, 1994

W_d: **water demand**

I_c: **interception**

T_p: **transpiration**

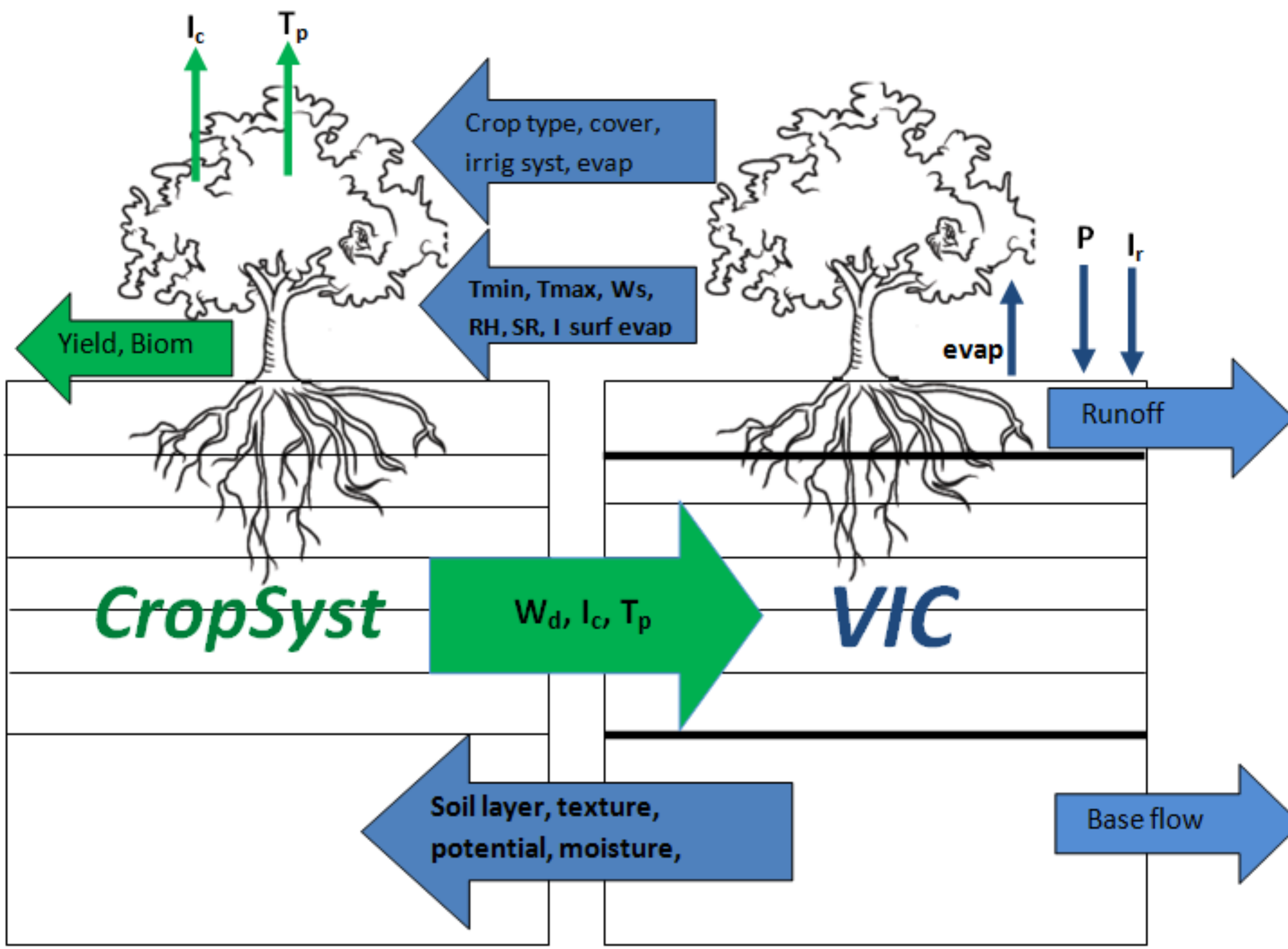
RH: **relative humidity**

SR: **solar radiation**

Ws: **wind speed**

I_r: **irrigation**

P: **precipitation**



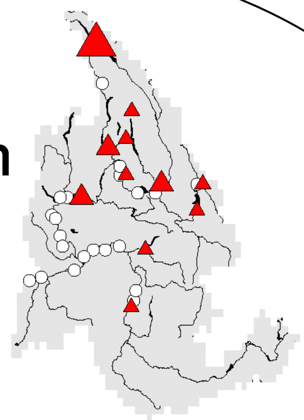
Modeling Scenarios (Low/Middle/High)

- Climate Change Scenarios
  - HADCM_B1, CCSM_B1, CGCM_B1, PCM_A1B, IPSL_A1B
  - Hybrid Delta Downscaling Approach (2030s climate) (UW CIG)
  - GCMs and Emission Scenarios chosen for low/middle/high precipitation and temperature change combinations
- Water Management Scenarios
  - Additional Storage Capacity
  - Cost Recovery for Newly Developed Water Supply
- Economic Scenarios
  - International Trade
  - Economic Growth

The Reservoir Model (ColSim)

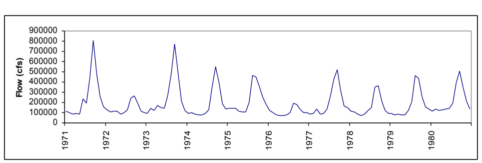
(Hamlet et al., 1999)

Physical System
of Dams
and Reservoirs



Reservoir Operating Policies

VIC Streamflow Time Series



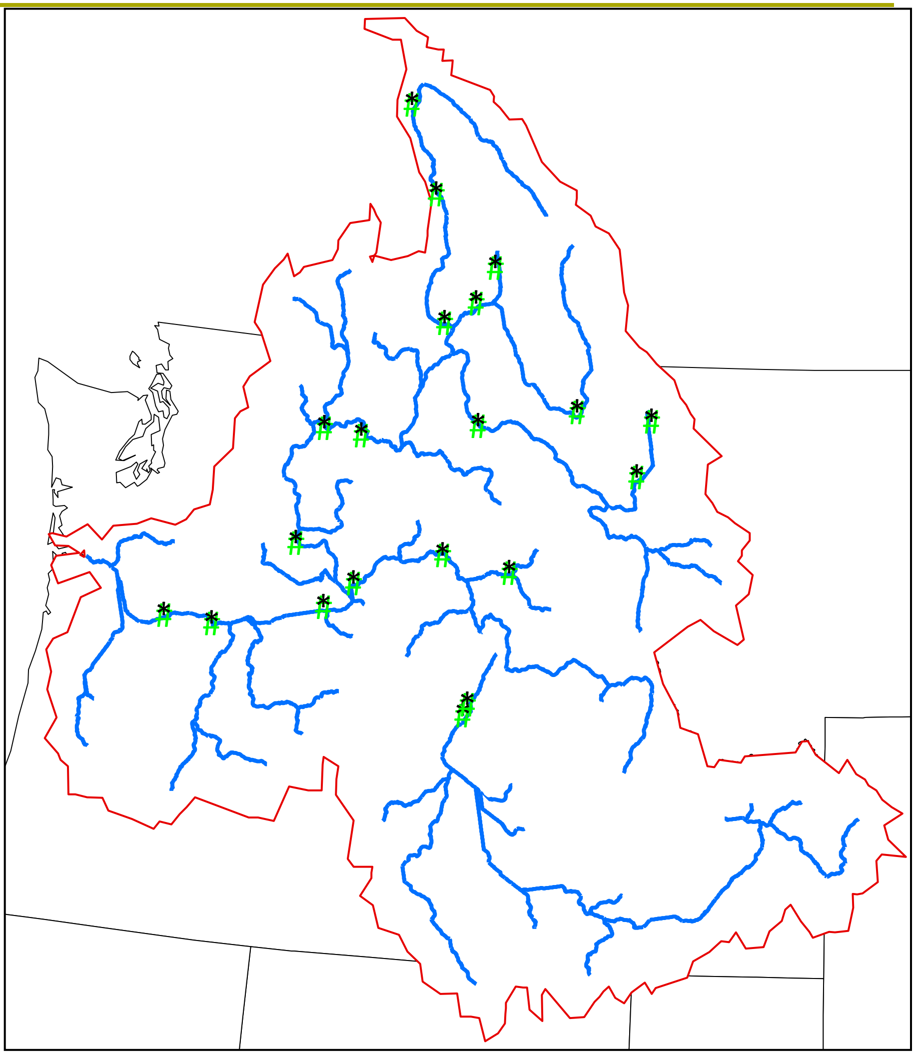
Reservoir Storage
Regulated Streamflow
Flood Control
Energy Production
Irrigation Consumption
Streamflow Augmentation

Slide courtesy of Alan Hamlet

ColSim Reservoir Model (Hamlet et al., 1999) for Columbia Mainstem

Model used as is, except for

- Withdrawals being based on VIC-CropSyst results
- Curtailment decision is made part of the reservoir model



Green triangles show the dam locations

Curtailment Rules (Washington State)

Curtailment based on instream flow targets

- Columbia Mainstem
- Lower Snake
- Central Region (Methow, Okanogan, Wenatchee)
- Eastern Region (Walla Walla, Little Spokane, Colville)

Prorated based on a calculation of Total Water Supply Available

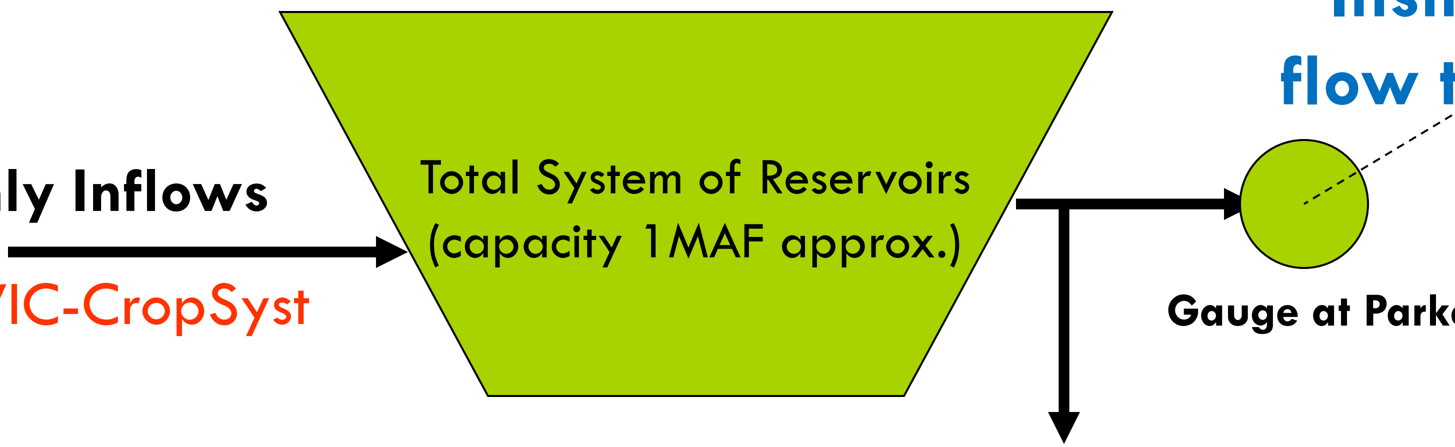
- Yakima

Yakima Reservoir Model

Instream flow targets

Monthly Inflows

from VIC-CropSyst



Gauge at Parker

Irrigation demand from VIC/ CropSyst

Curtailment rules

Proratable water rights prorated according to Total Water Supply Available (TWSA) calculated each month

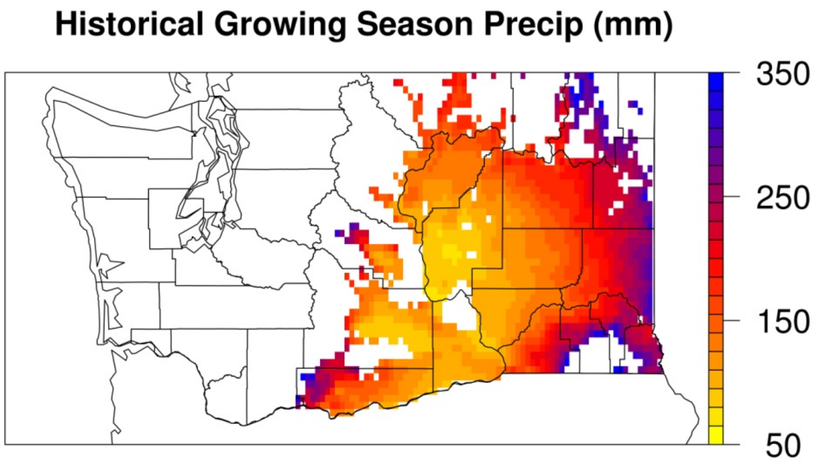
Objectives:

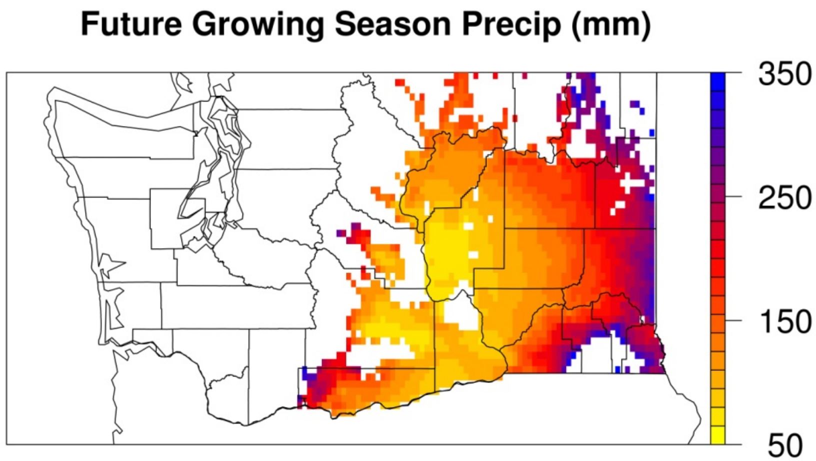
- Reservoir refill by June 1st
- Flood space availability

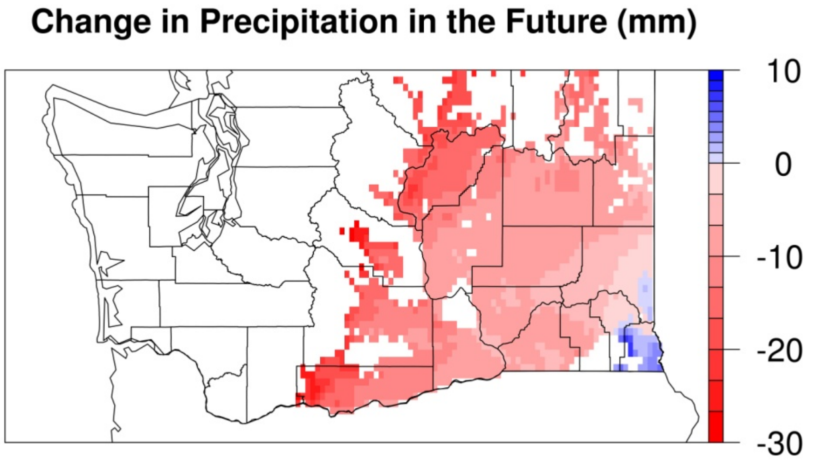
Model Calibration/Evaluation

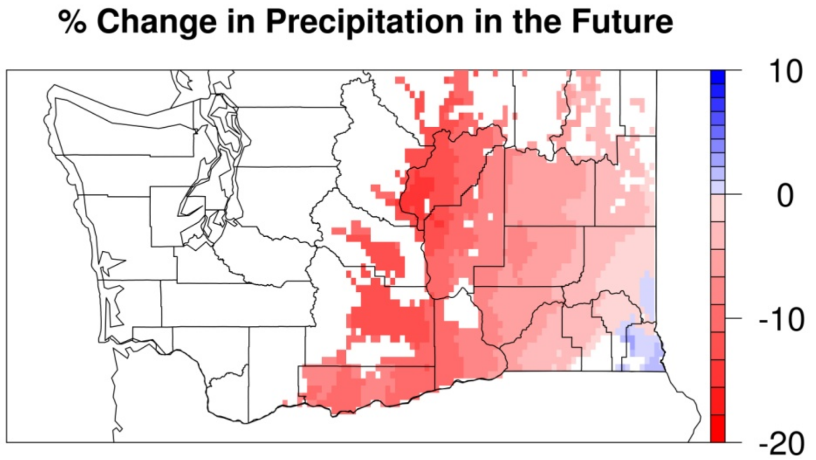
- Calibration:
  - Streamflows (we used calibration from Elsner et al. 2010 and Maurer et al. 2002)
  - Crop Yields (using USDA NASS values)
  - Irrigation Rules (using reported irrigated extent by watershed)
- Evaluation:
  - Streamflows (Elsner et al. 2010 and Maurer et al. 2002)
  - USBR Diversions from Bank’s Lake (for Columbia Basin Project)

Precipitation



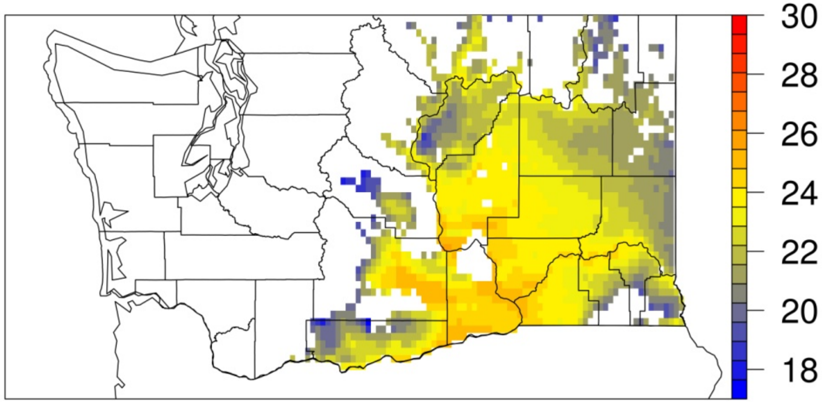




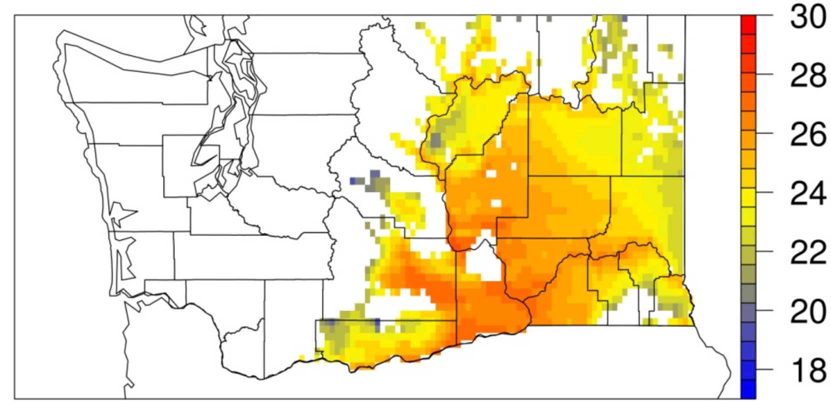


Maximum Daily Temperature

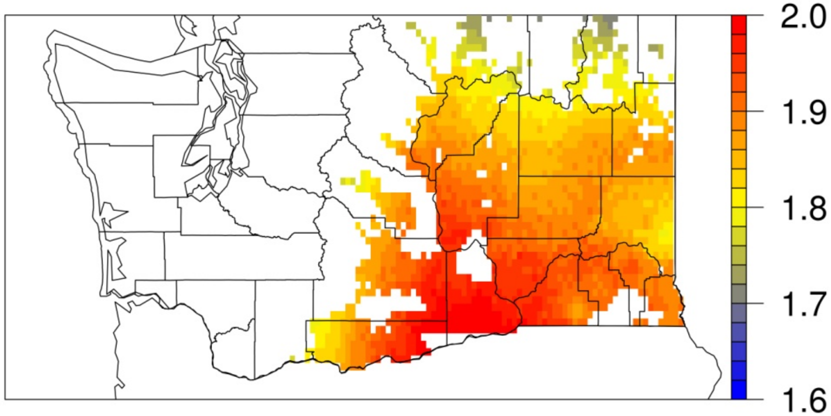
Historical Growing Season Avg Tmax (degree C)



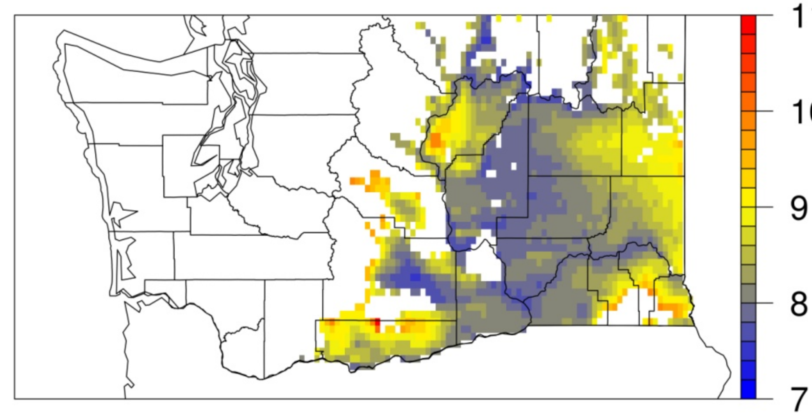
Future Growing Season Avg Tmax (degreeC)



Future Change in Avg Tmax (degree C)



% Change in Avg Tmax



Minimum Daily Temperature