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WASHINGTON STATE
Academy of Sciences

TH ANNUAL MEETING & SYMPOSIUM
CLIMATE CHANGE IN WASHINGTON STATE
Research Questions Critical to Preparing for the Future

Hydrology, Water Resources and Agriculture

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UW

Climate Change Impacts: Water Resources and Agriculture in the Columbia River Basin



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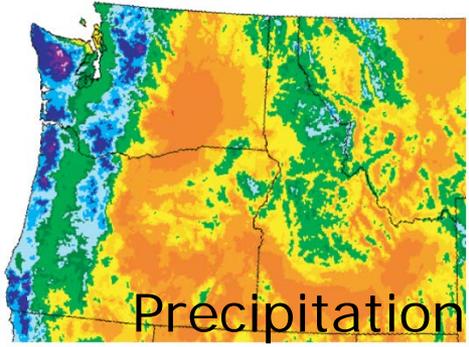
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The Columbia River Basin (CRB) as a Water and Agricultural Resource

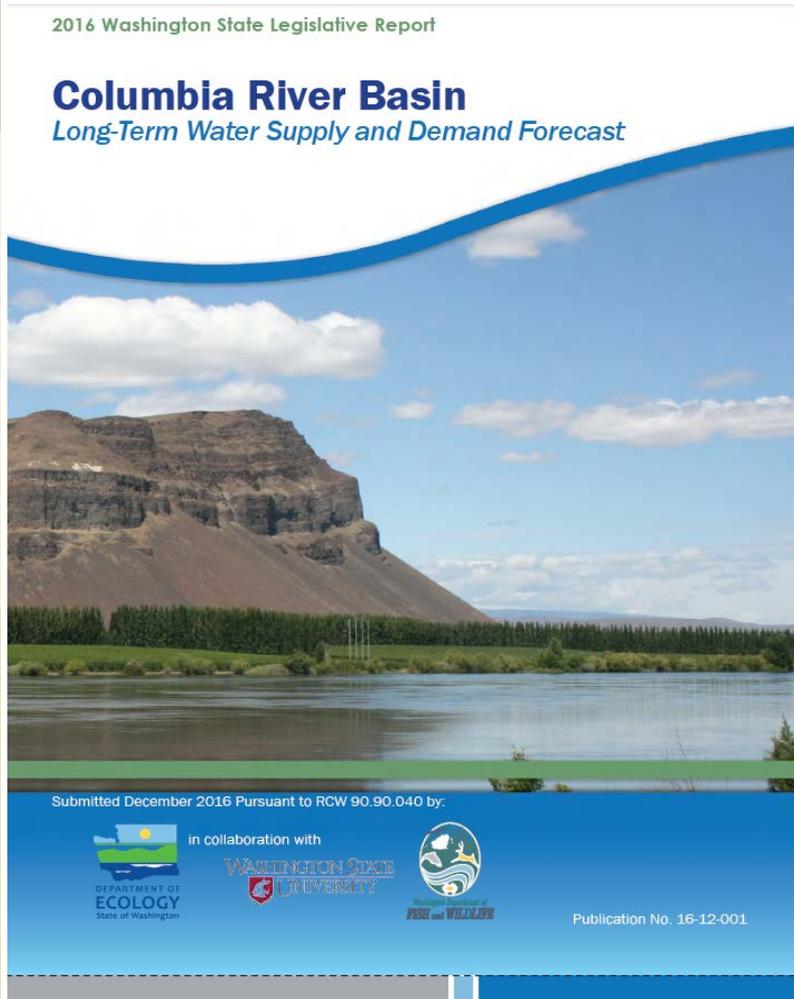
- Multiple competing water uses in the CRB:
 - In-Stream: hydropower, flood control, fish flows, navigation, recreation
 - Out-of-Stream: agricultural, municipal, industrial

- Washington's Agriculture
 - 300 crop commodities (first in US for 11 commodities)
 - Livestock and crops: ~\$10B annually
 - 12% of the state's economy

(WSDA, 2017; WSFB, 2017)



2016 Columbia River Basin Water Supply and 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 (20-year) water supply and demand forecast to the State Legislature
- Washington State University (WSU) was assigned to develop the 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

2016 Long Term Water Supply and Demand Forecast

ORGANIZATIONAL CHART

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COST EFFECTS OF WATER



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WEST SIDE SCOPING



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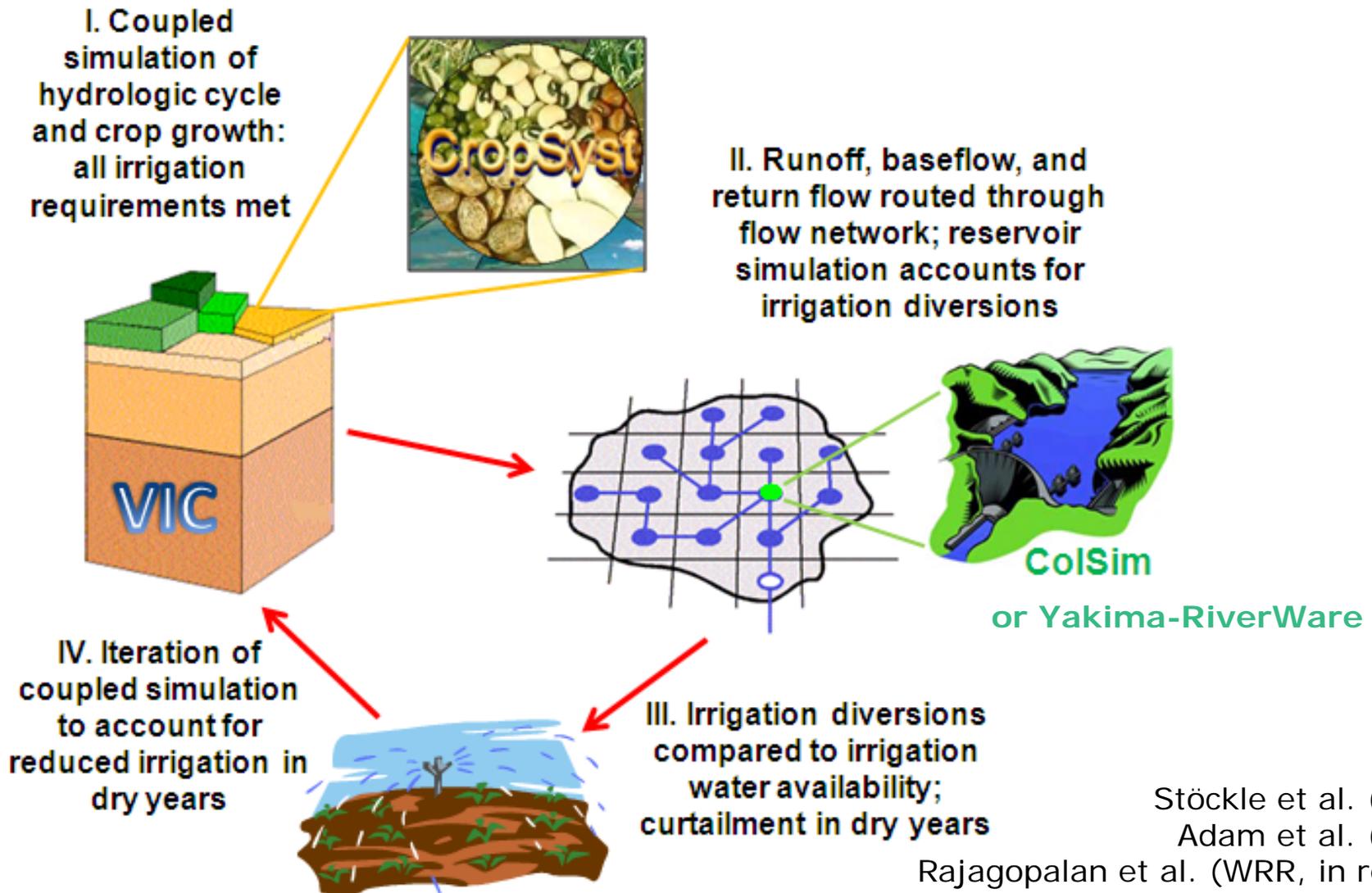
Judy Enyeart
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Approach



Integrated Hydrology, Cropping Systems, and Water Management



Stöckle et al. (2014)

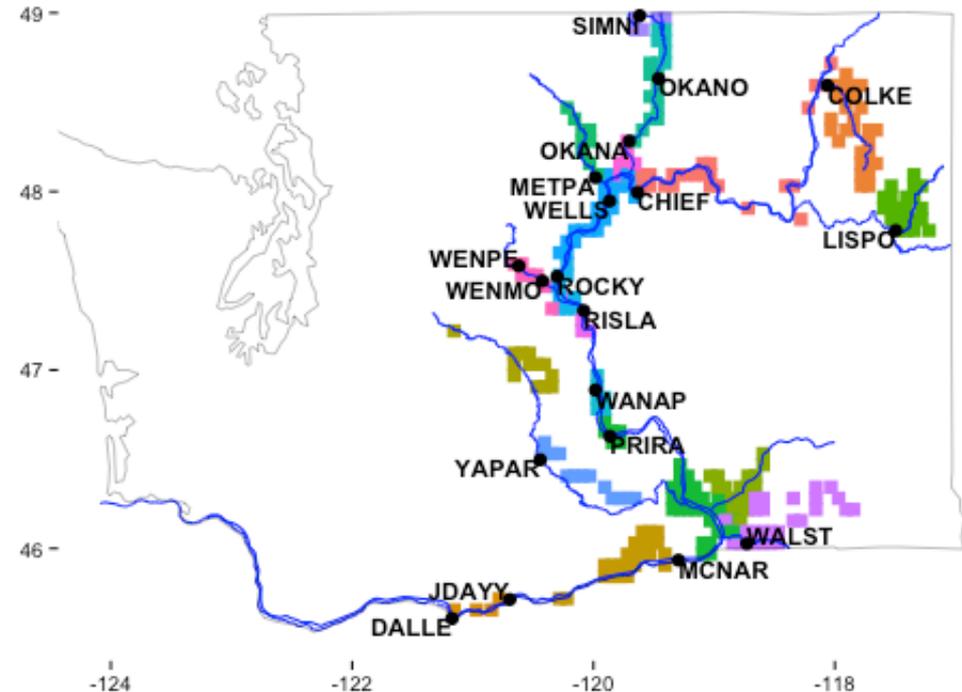
Adam et al. (2014)

Rajagopalan et al. (WRR, in review)

Types of Water Rights Curtailment

- ❑ Columbia River Mainstem – interruptibles
 - ❑ captured
- ❑ Yakima River Basin – prorationing
 - ❑ captured
- ❑ Non-Yakima tributaries – interruptibles
 - ❑ captured
- ❑ *Non-Yakima tributaries – non-interruptibles*
 - ❑ *Not captured*

Eastern Washington Interruptible Rights



Crops Modeled

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

Other Lentil/Wheat Type

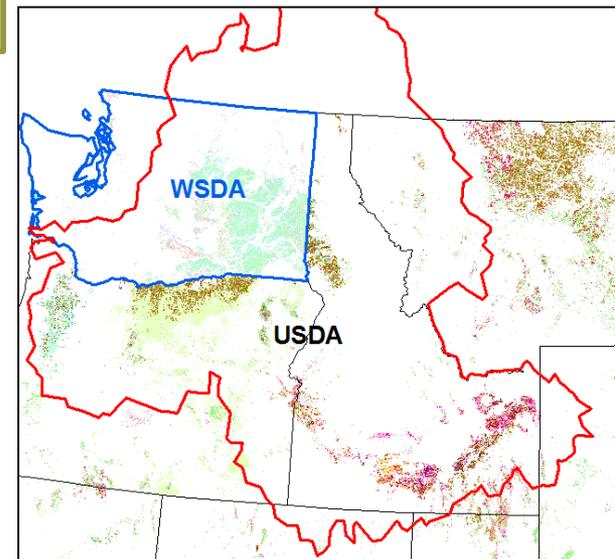
- ❑ Oats
- ❑ Bean, green
- ❑ Rye
- ❑ Barley
- ❑ Bean, dry
- ❑ Bean, green

Berries

- ❑ Caneberry
- ❑ Blueberry
- ❑ Cranberry

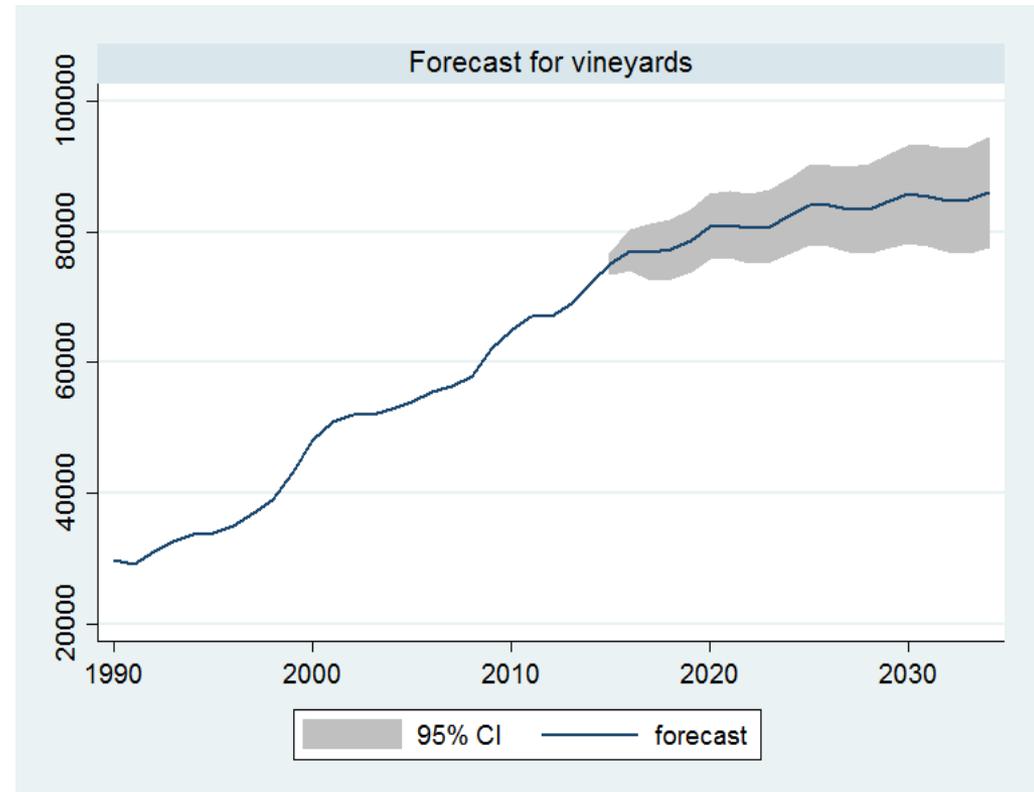
Other Tree Fruits

- ❑ Pear
- ❑ Peaches



Economic Modeling: Forecasting Future Crop Mix

- ❑ Changes in crop mix can affect overall water demand due to differences in crop water requirements.
- ❑ Data on recent trends in the irrigated crop mix in Eastern Washington were used in a statistical model to forecast future crop mix.
- ❑ This approach has been shown to produce more accurate forecasts than complex economic models.



Results



- Impacts on water supply and demand
- Impacts on crop yield

Summary of Changes in CRB Water Supply and Demand (2030s Ensemble Mean)

Supply:

- Average annual increase: **+14.6%** (+/-8.3%)
- Average shift in seasonality:
 -  **-10.3%** (+/-7.9%) between **June and October**
 -  **30.8%** (+/-9.4%) between **November and May**

Demand:

- Average decrease in eastern WA irrigation demand:
 - **-5.1%** (+/-1.0%) (historical crop mix)
 - **-6.9%** (+/-1.0%) (future crop mix)
- Average shift in seasonality (future crop mix):
 -  **5.7%** between **March and June**
 -  **-13.3%** between **July and October**

Causes of 2030s Projected Decrease in Irrigation Demand

In Response to Climate Change

- ❑ Water Supply: Springs are getting wetter
- ❑ Water Demand: Shifting of irrigation requirements earlier in the season
 - Earlier planting and shorter irrigation season for most crops
 - Higher water-use efficiencies due to increases in CO₂

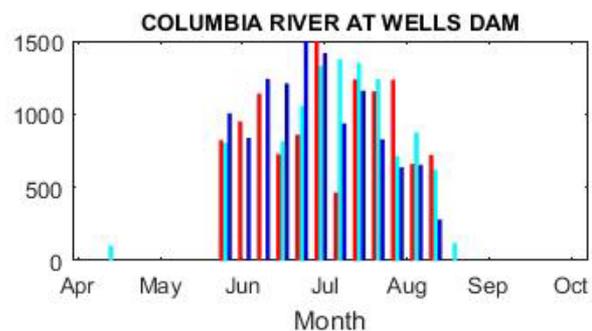
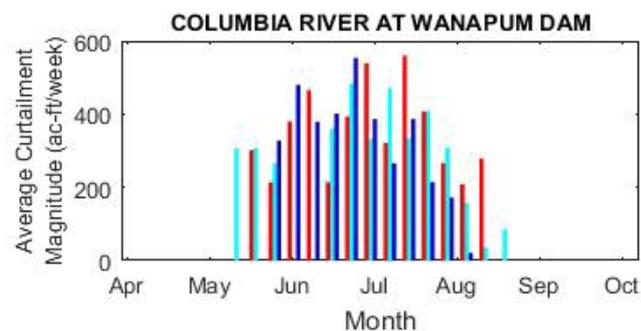
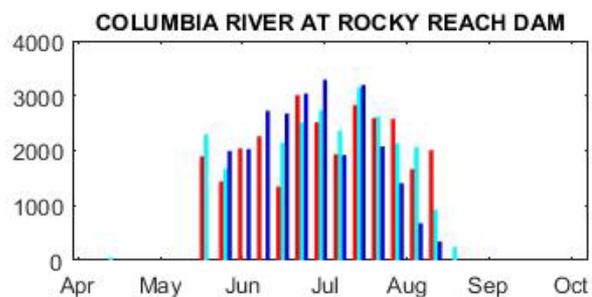
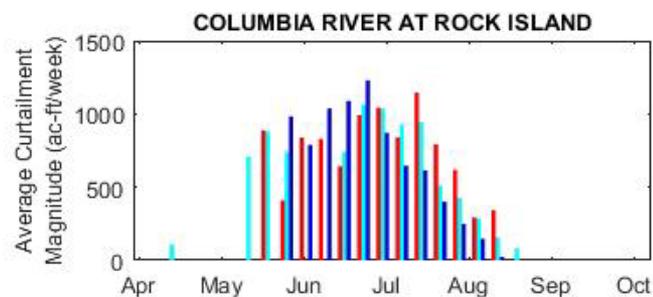
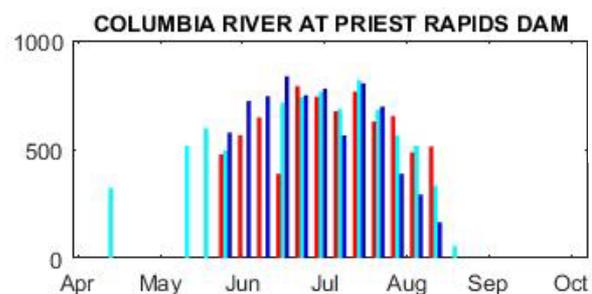
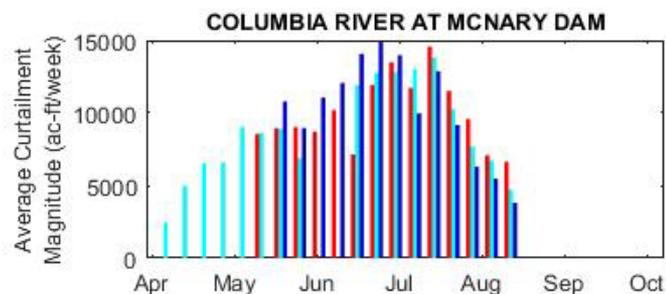
In Response to Economic Drivers

- ❑ Shift towards more water-use efficient crops

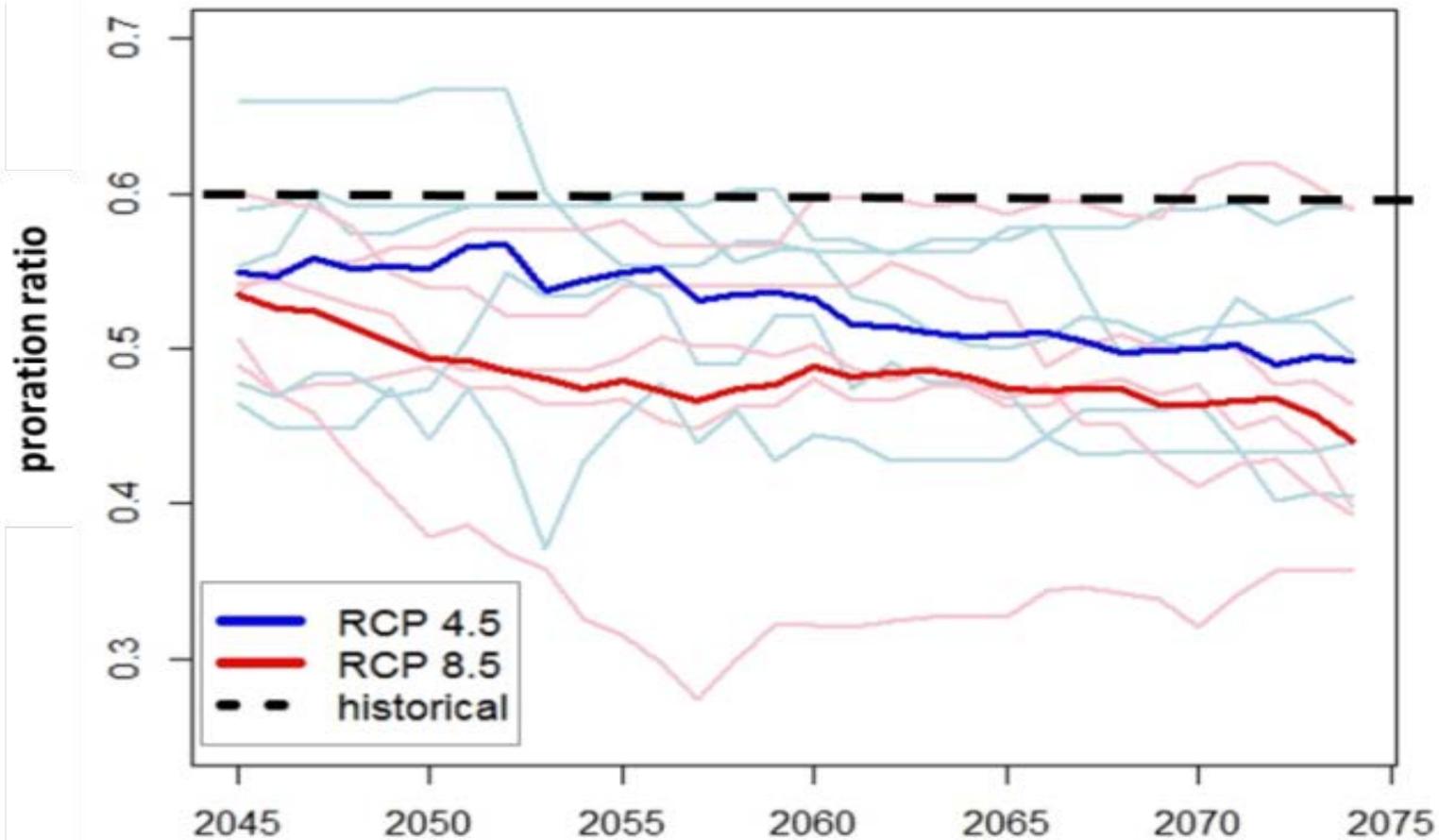
Note that many adaptive actions were not considered

- ❑ Increases in double/cover cropping
- ❑ More slowly-maturing crop varieties (e.g., corn)
- ❑ Expanded irrigated acreage
- ❑ Changes in irrigation technology/management

2030s Columbia Mainstem Water Rights Curtailment



Impacts on Proration Ratios in the Yakima River Basin



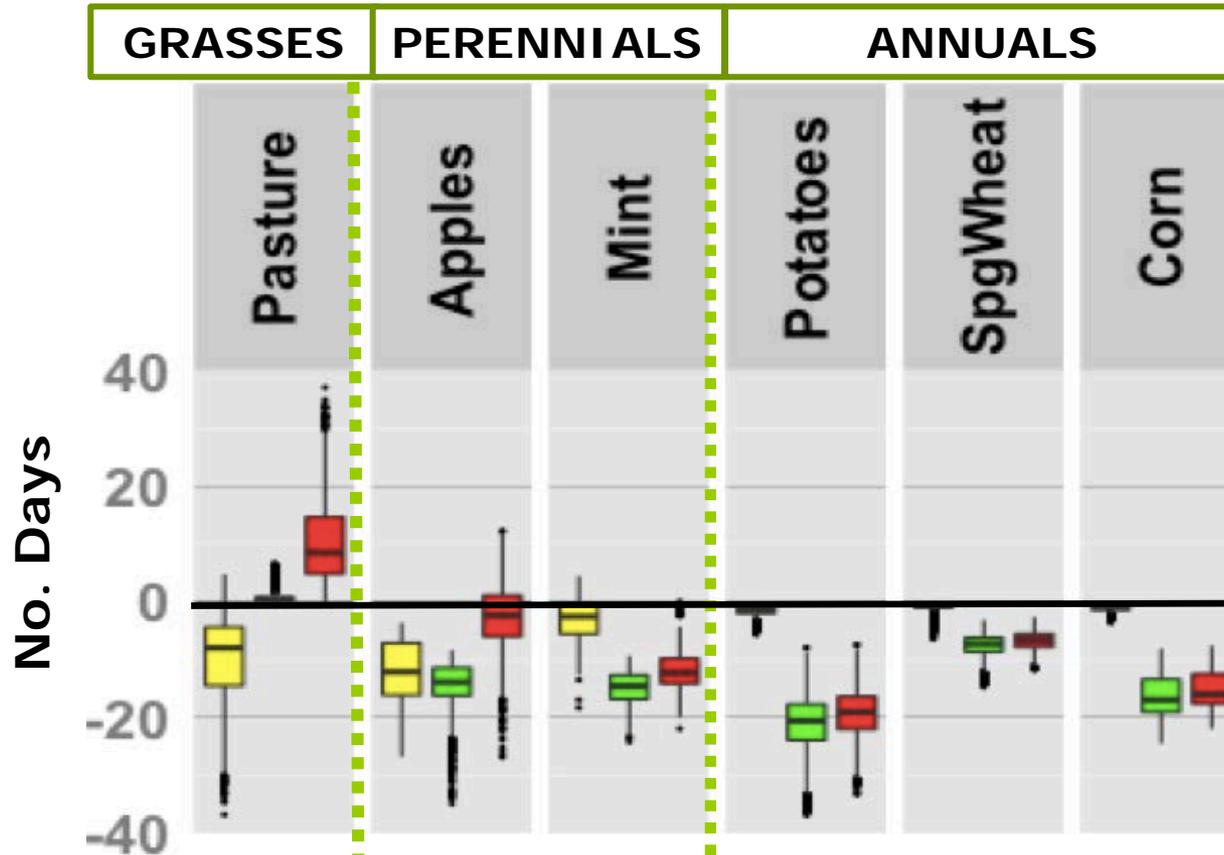
Proration Ratio = Percent of Water Right Allowed for Irrigation Season

Irrigated Crop Yield Impacts

- ❑ **Direct impacts** of near-term (20-year) changes on crop yields
 - ❑ CO₂: increases yield
 - ❑ temperature: mixed effects on yield
 - ❑ precipitation: no effects (assumption: full irrigation requirements met)

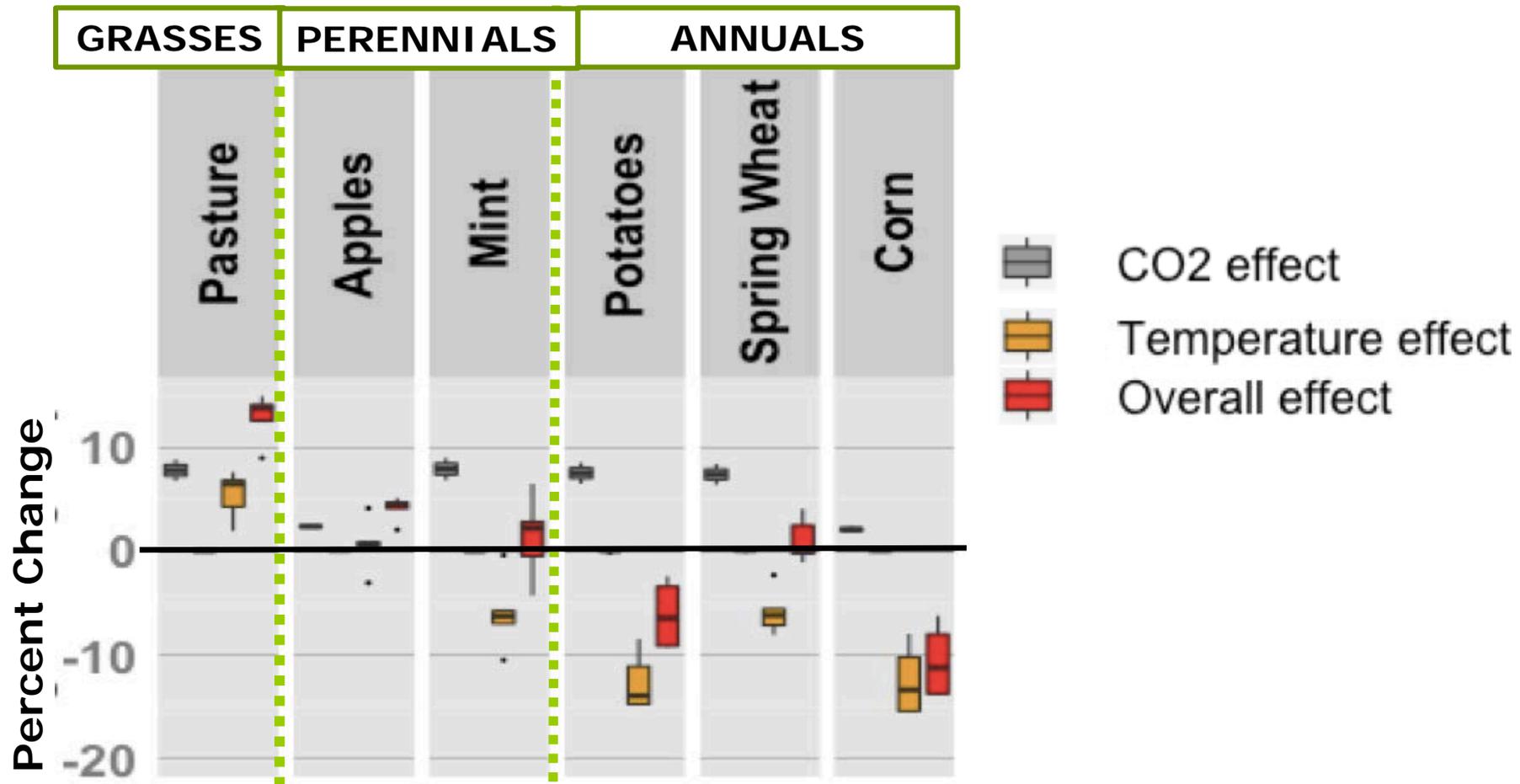
- ❑ **Indirect impact** of near-term (20-year) changes on crop yields
 - ❑ water rights curtailment: decreases yield

Direct Impacts: Growing Season Length (2030s)



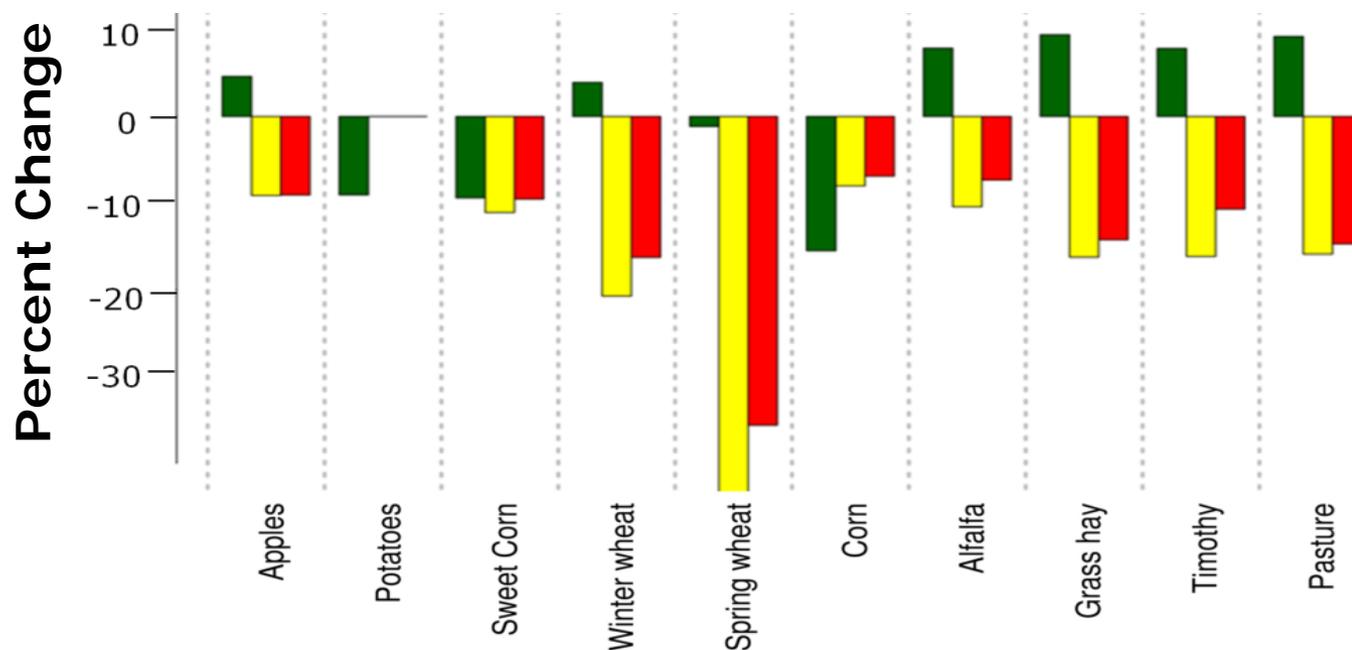
- Yellow box: Growing season start (Emergence)
- Green box: Growing season end (Harvest)
- Red box: Length of actual growing season

Direct Impacts: Irrigated Crop Yield (2030s)



Indirect Impacts: Irrigated Crop Yield (in eastern WA with interruptible water rights)

- Future – Historical Full Irrigation Yields (Climate Change and CO₂ effects)
- Historical Impact Due to Curtailment
- Future Impact Due to Curtailment



- Although curtailments are higher in the 2030s, impacts of curtailment on yields may be smaller than historical
- This is not likely to be the case
 - for longer projections
 - if certain adaptive actions are taken by irrigators

Rajagopalan
et al. (in prep)

Some Key Uncertainties and Data Gaps (not comprehensive)

Current Conditions

- ❑ Extent of current double and cover cropping
- ❑ Limitations with water rights information; not all categories of water rights were modeled
- ❑ Treatment of areas with declining groundwater levels

Future Conditions

- ❑ Response of crops to CO₂ fertilization, esp. tree fruit
- ❑ New water rights being granted – expansion of irrigated extent
- ❑ Future areas with declining groundwater levels
- ❑ Adaptive actions that may either alleviate or exacerbate water constraints

Summary of Impacts

- ❑ *Climate Change*: Climate change is associated with warming, changes in precipitation seasonality, changes in the frequency of extreme events, and increases in CO₂
- ❑ *Water Supply*: While changes in annual water availability is uncertain, availability will decrease during the later stages of the growing season without adequate reservoir storage
- ❑ *Water Demand*: Irrigation water demand may increase or decrease depending on producer actions taken; it will also shift earlier in the growing season
- ❑ *Agriculture*: Irrigated crop yields are impacted by these changes
 - Warming: mixed effects
 - CO₂ fertilization: increases
 - Curtailment: decreases but future decreases may be less than expected, at least in the near-term
- ❑ *Uncertainties*: Adaptation actions may alleviate impacts for some users at the expense of other users

Thank you!

