Transitioning Cereal Systems to Adapt to Climate Change

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Direct and Indirect Effects of Climate Change on Cereal Productivity in the Pacific Northwest Region of the U.S.

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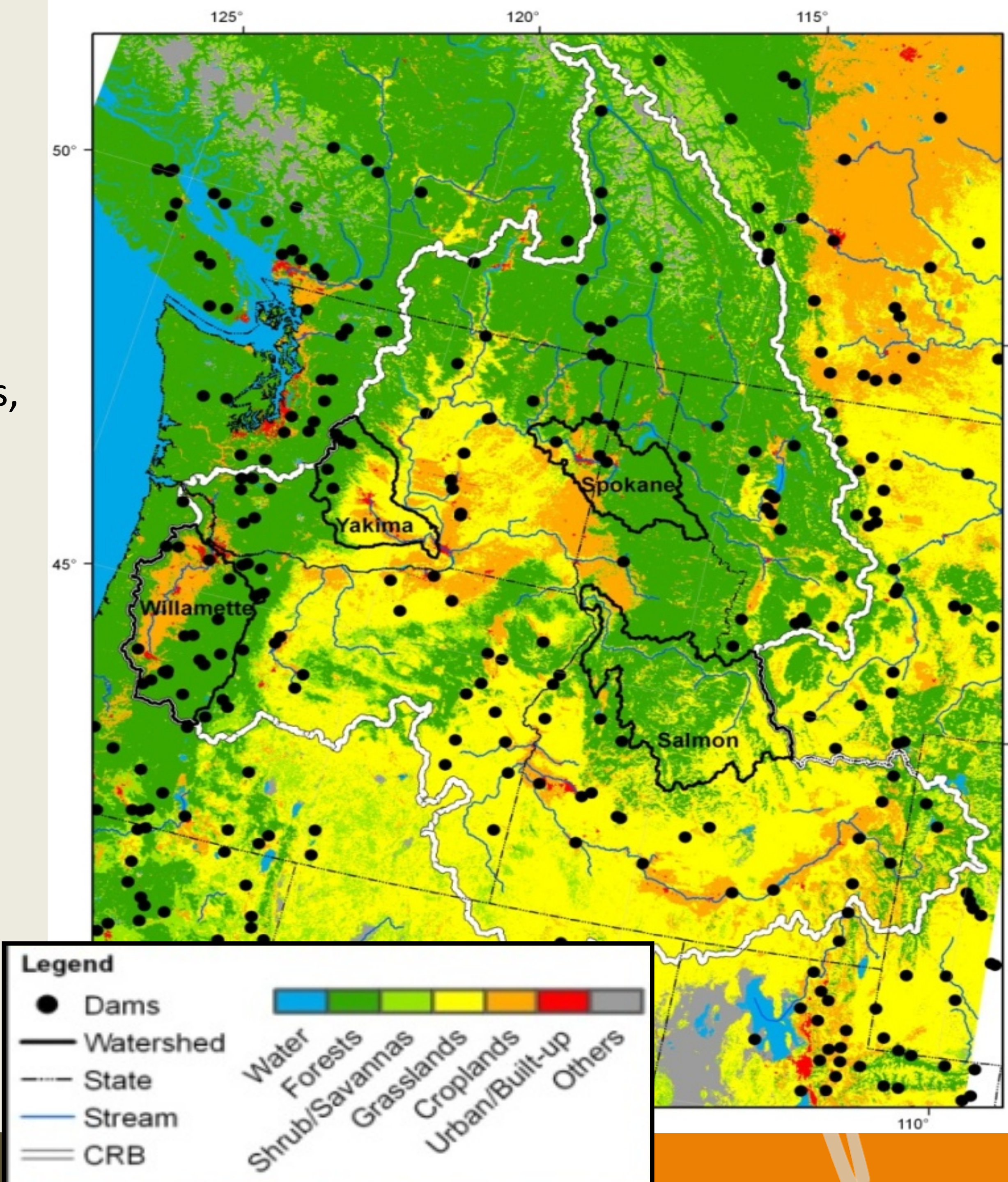
The Columbia River Basin as a Resource

- Air, water, crops, forests, rangeland
- Intensifying issues: fish and habitat, tribal considerations, renewable energy, etc.
- Global change impacts:
  - Water quantity/quality
  - Population growth
  - Loss of biodiversity
  - Invasive species
  - Fire risk



Major Cereal Crops in the CRB

Crop	Total Acres	% Area in Cereals
Winter Wheat	4,139,189	63.7%
Spring Wheat	1,269,965	19.6%
Barley	670,517	10.3%
Grain Corn	392,685	6.0%
Oats	21,365	0.3%

Source: USDA Cropland Data Layer

Percent Irrigation for Major Cereal Crops in Washington State

Crop	Total Acres	Irrigated Acres	% Irrigation
Winter Wheat	2,788,823	91,265	3%
Spring Wheat	713,621	36,417	5%
Barley	224,948	2,768	1%
Grain Corn	124,385	124,385	100%
Oats	6,332	2,679	42%

Source: Washington State Department of Agriculture (WSDA)

Potential Impacts of Climate Change on Crop Productivity

- Direct Impacts of Climate Change
  - Warming
    - lengthens the available growing season, but…
    - shortens time to maturity
  - Growing season precipitation changes (non-irrigated crops)
  - Changes in frequency of extreme events
- Direct Impacts of Increasing CO_2
  - Increases radiation and water-use efficiencies (C3 crops primarily)
- Indirect Impacts of Climate Change through Water Rights Curtailment (irrigated crops)
- Indirect Impacts due to Changes to Pests, Weeds, Diseases, and Crop Quality

Objectives of this Talk

1. Assess direct impacts of climate change (precipitation, temperature, CO_2) on cereal and non cereal yields in the Columbia River basin
2. Describe strategies that can be used to assess indirect effects of climate change on irrigated systems (water rights curtailment)
3. Discuss blue water strategies for adapting to drought

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Integrated Modeling Approach

CropSyst

Cropping Systems

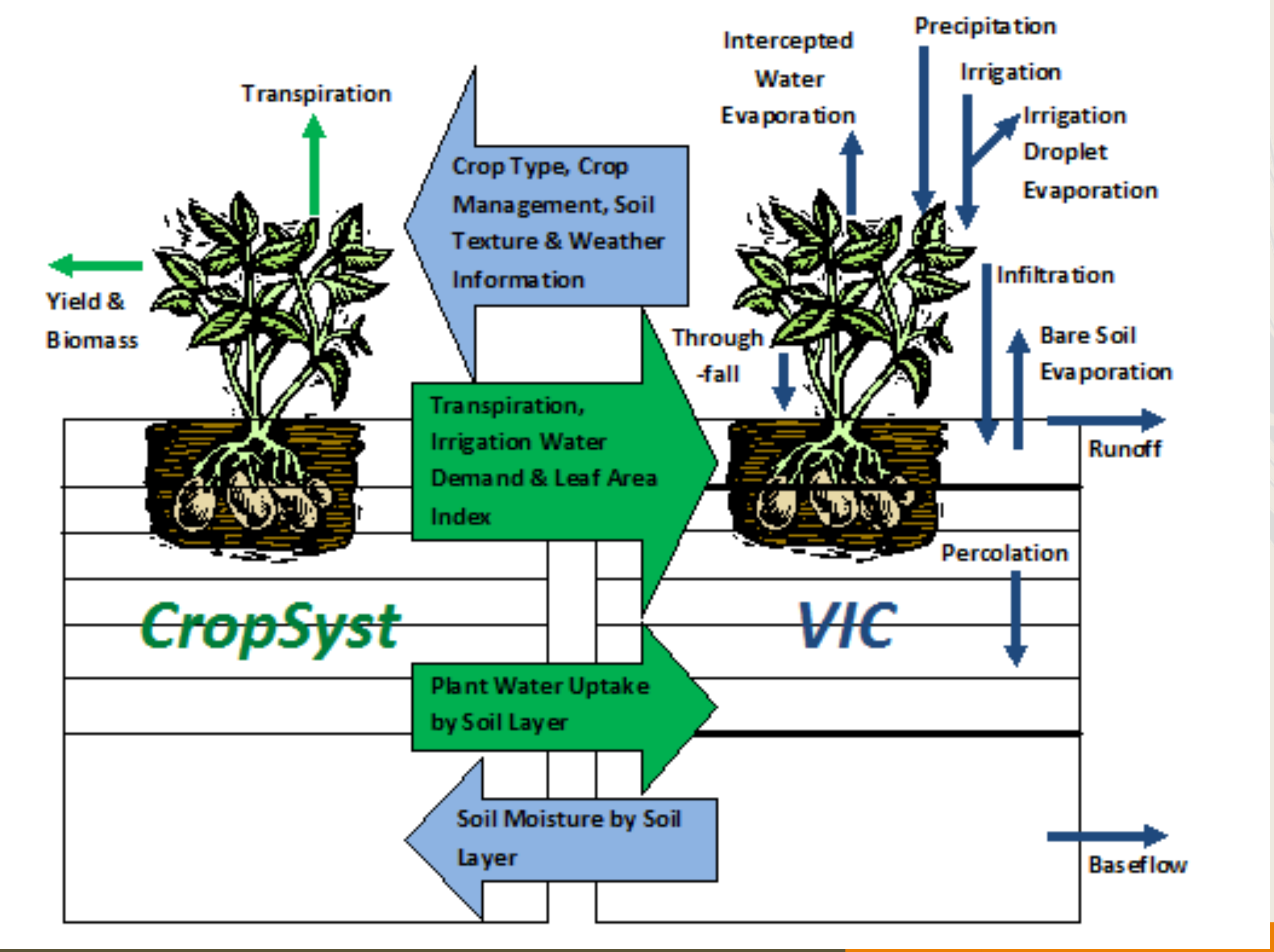
Stöckle and Nelson 1994

VIC

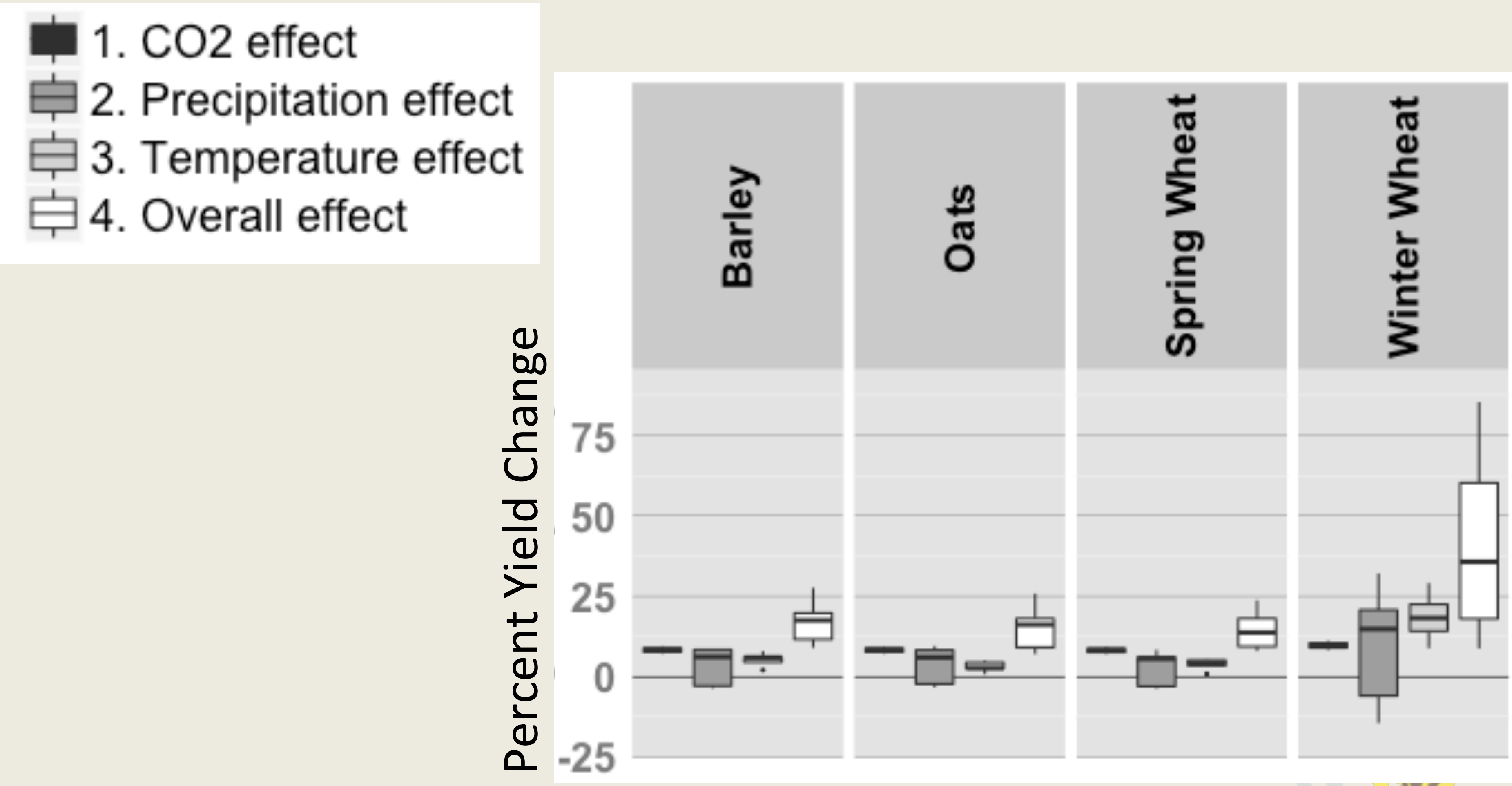
Macro-Scale Hydrology

Liang et al, 1994

Malek et al. (in prep)



Projected Changes in CRB Non-Irrigated Yields (2030s)



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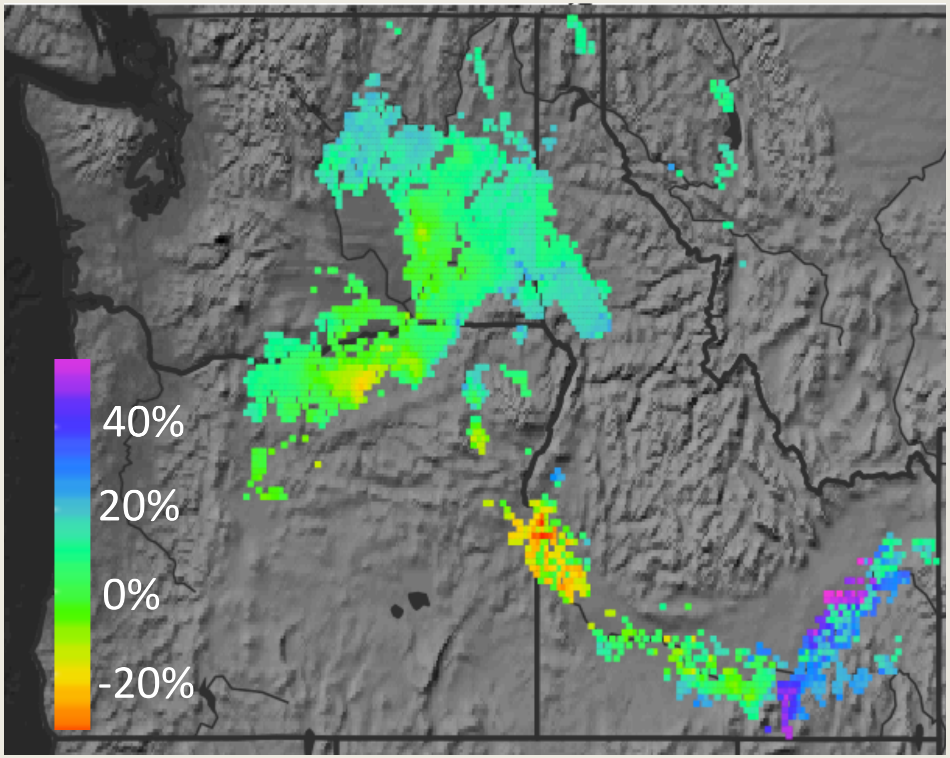
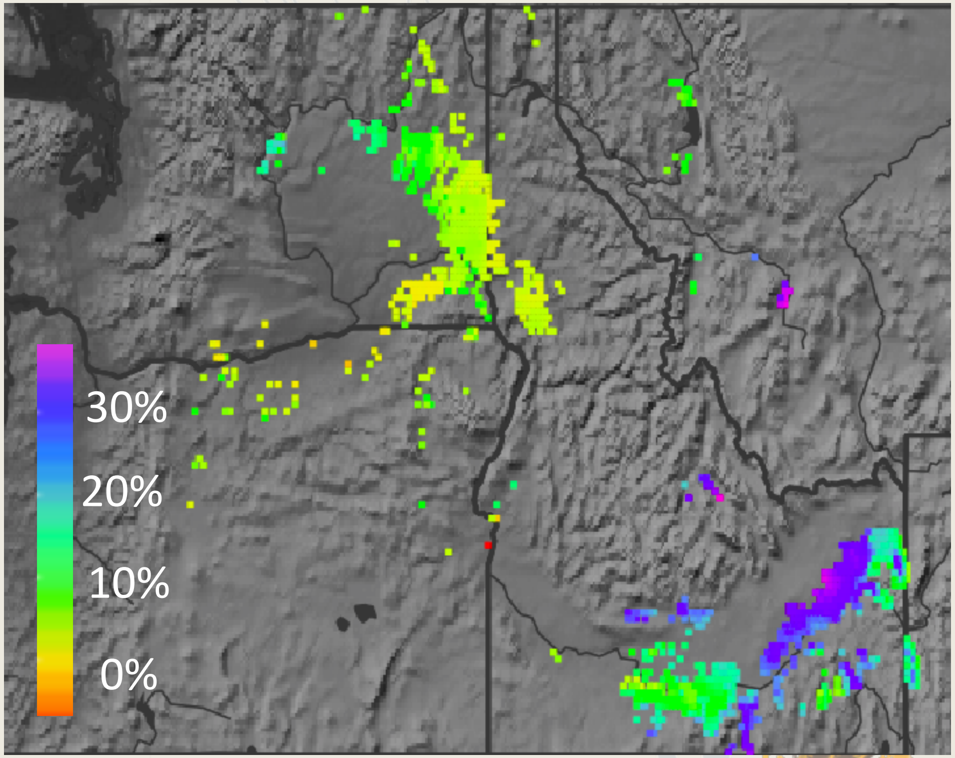
Winter Wheat



Barley



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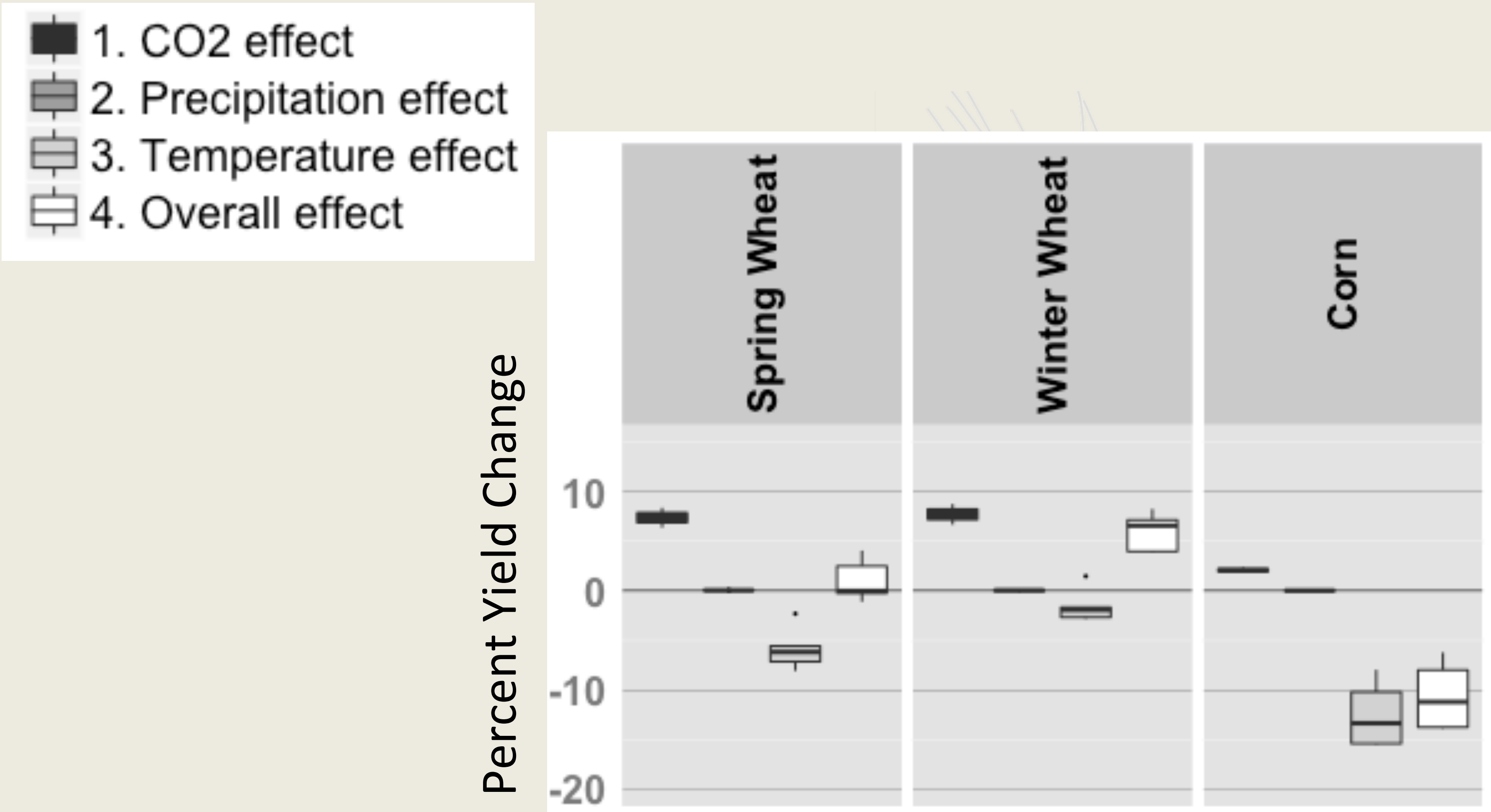
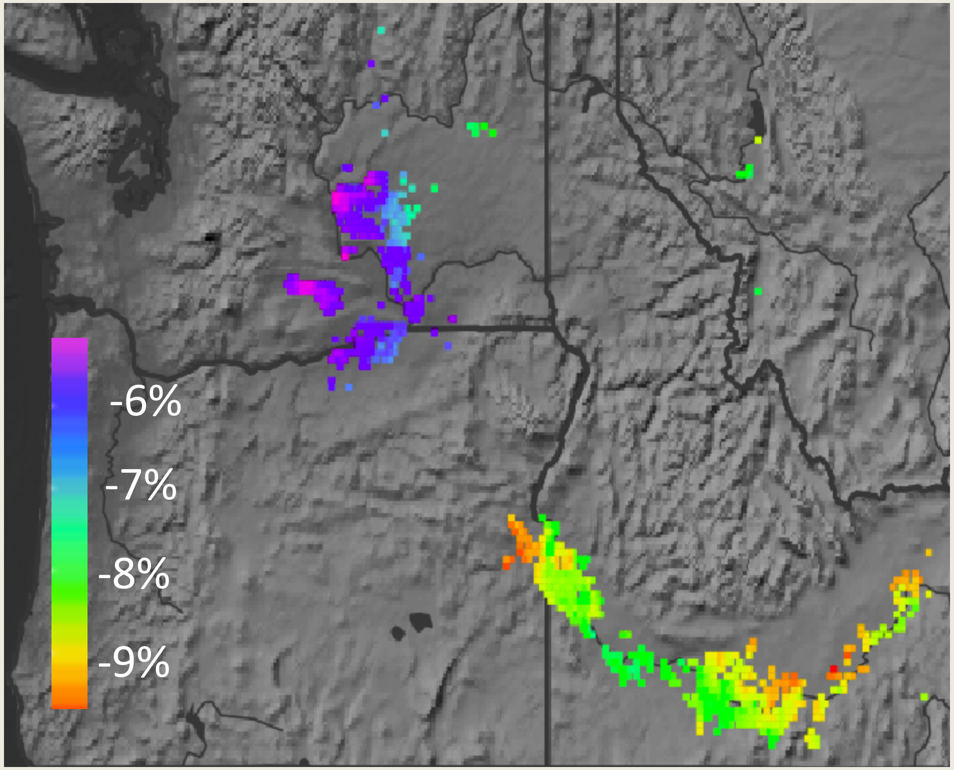
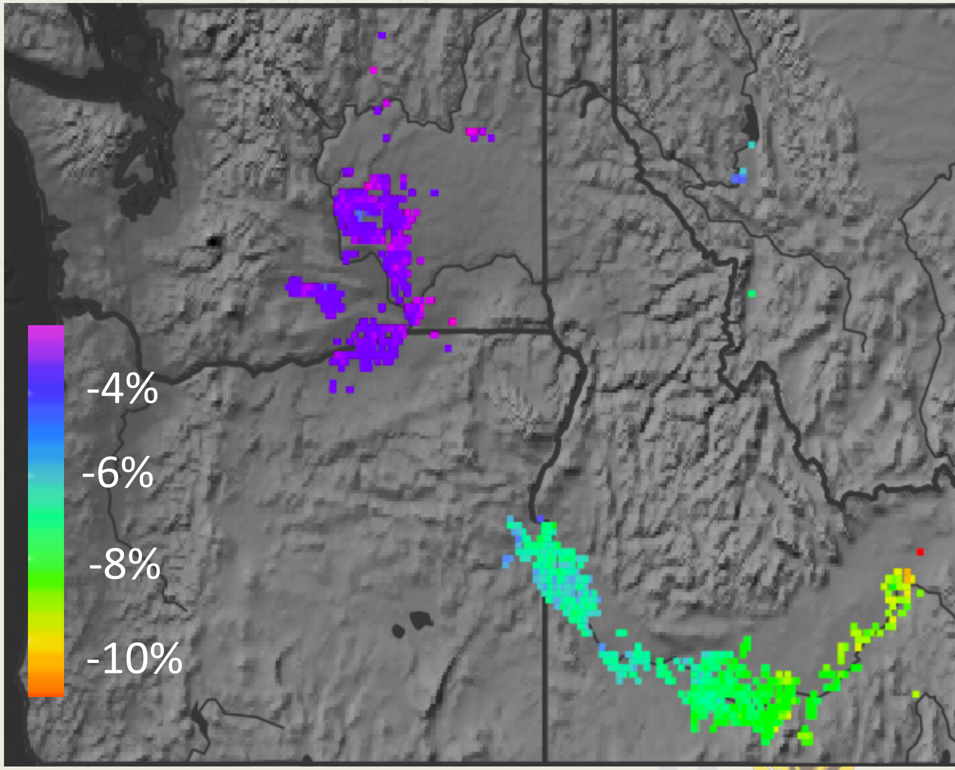


Projected Changes in CRB Yield and Irrigation Water Requirement (2030s): Grain Corn

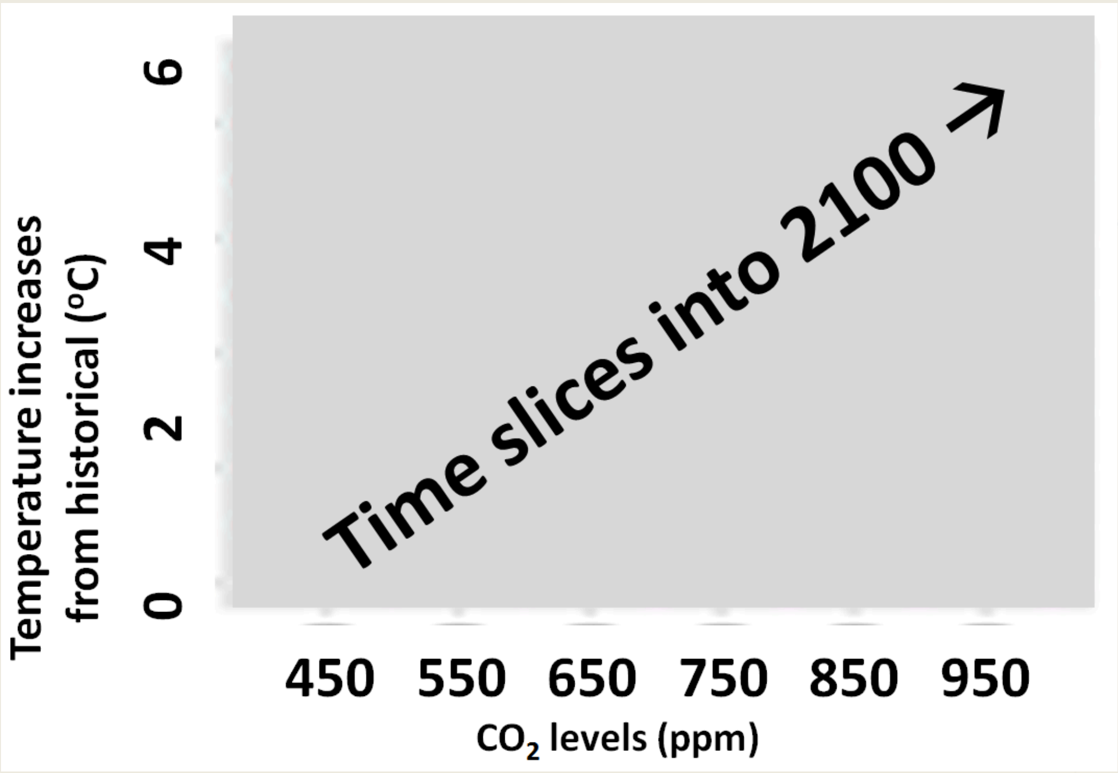
Yield



Water Requirement



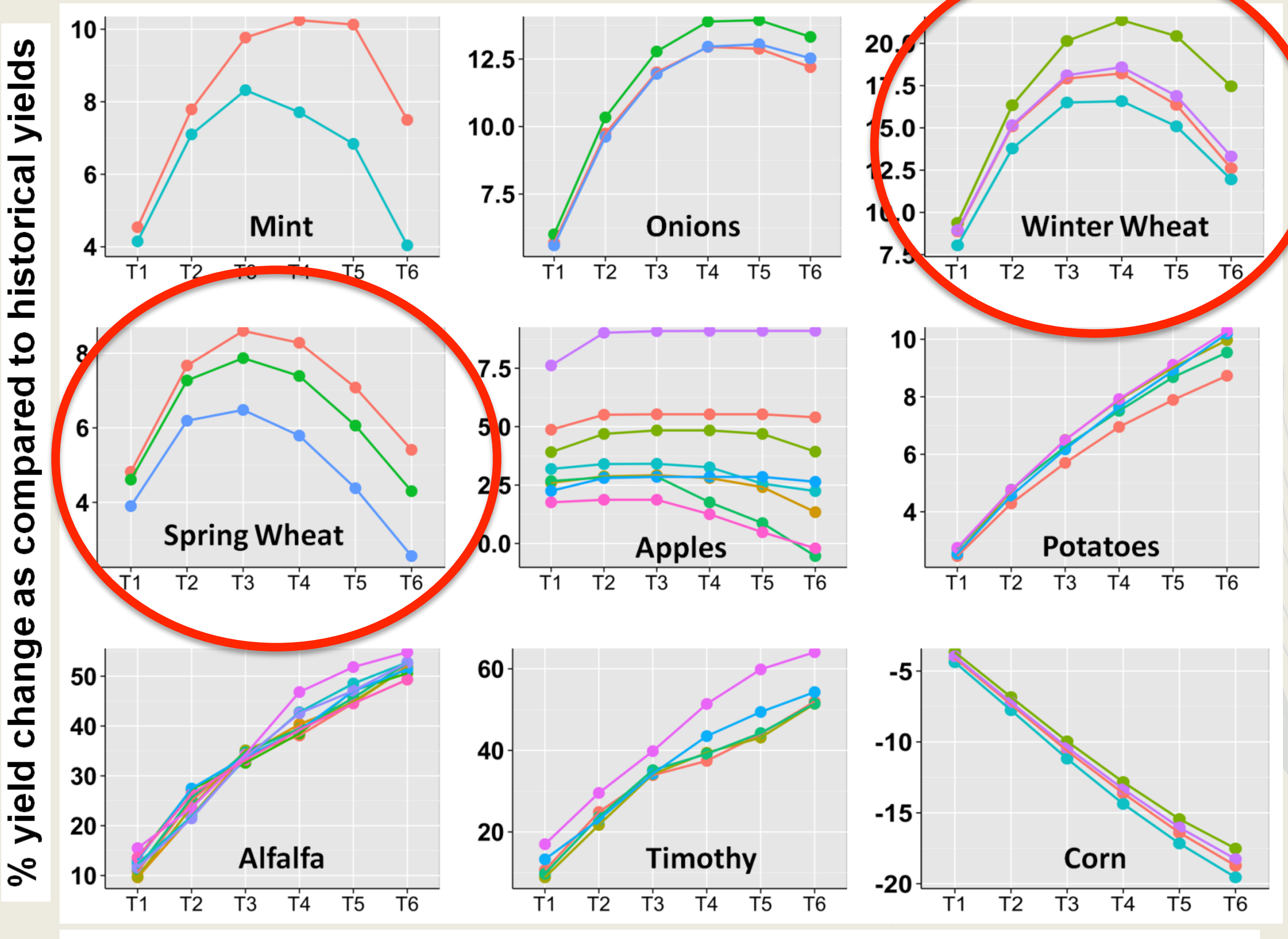
Changes in Crop Yield Response over Time



Rajagopalan et al. (in prep)

- Temperature increase and CO_2 level gradients
- These represent the range of projections from historical to the 2100s
- Diagonal band can be a proxy for time
- Sensitivity approach

Changes in Crop Yield Response over Time for Counties in WA State



Time slices into the future (until 2100) based on temperature and CO_2 gradients

These results do not include the effects of future droughts

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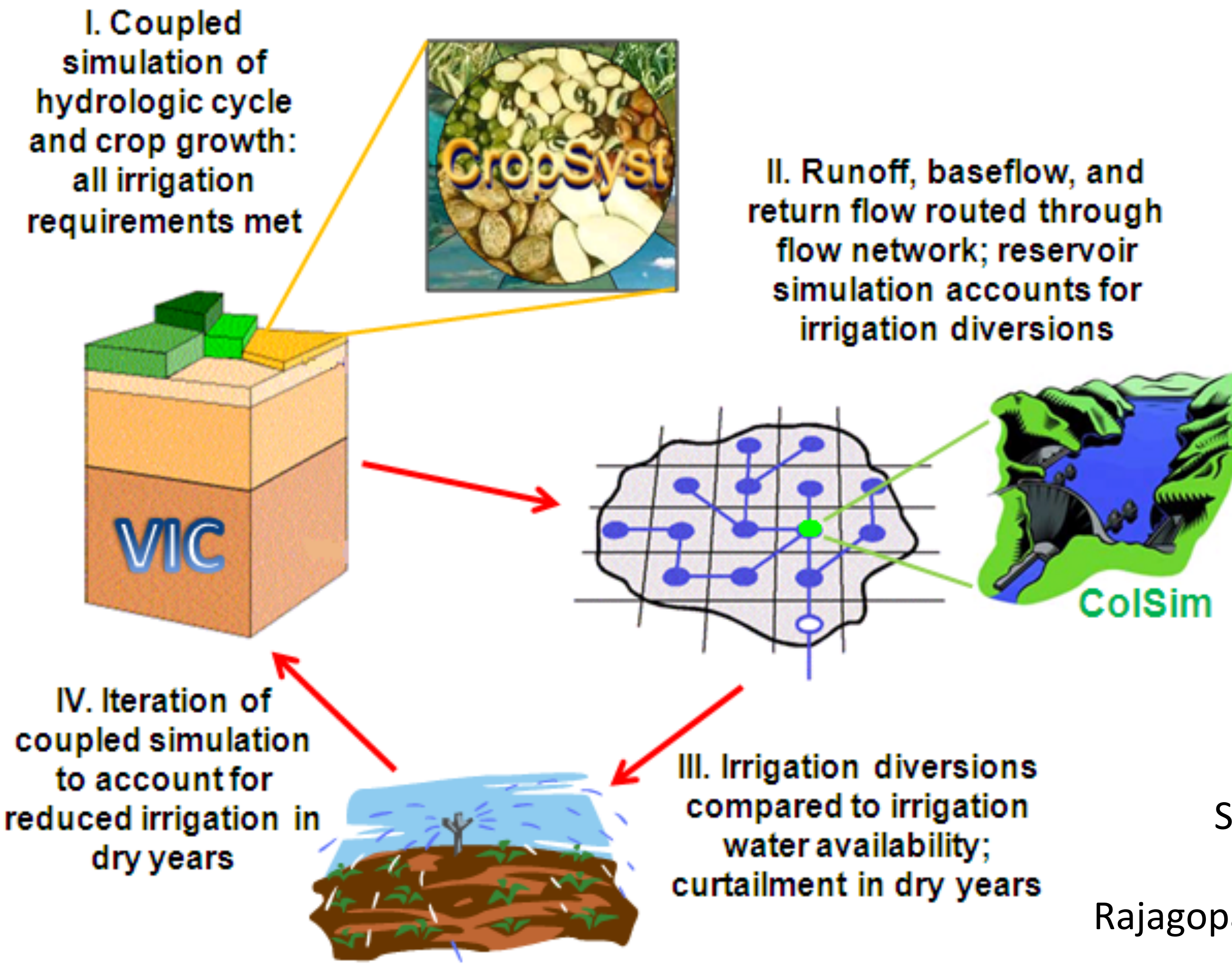
Understanding Blue Water Scarcity

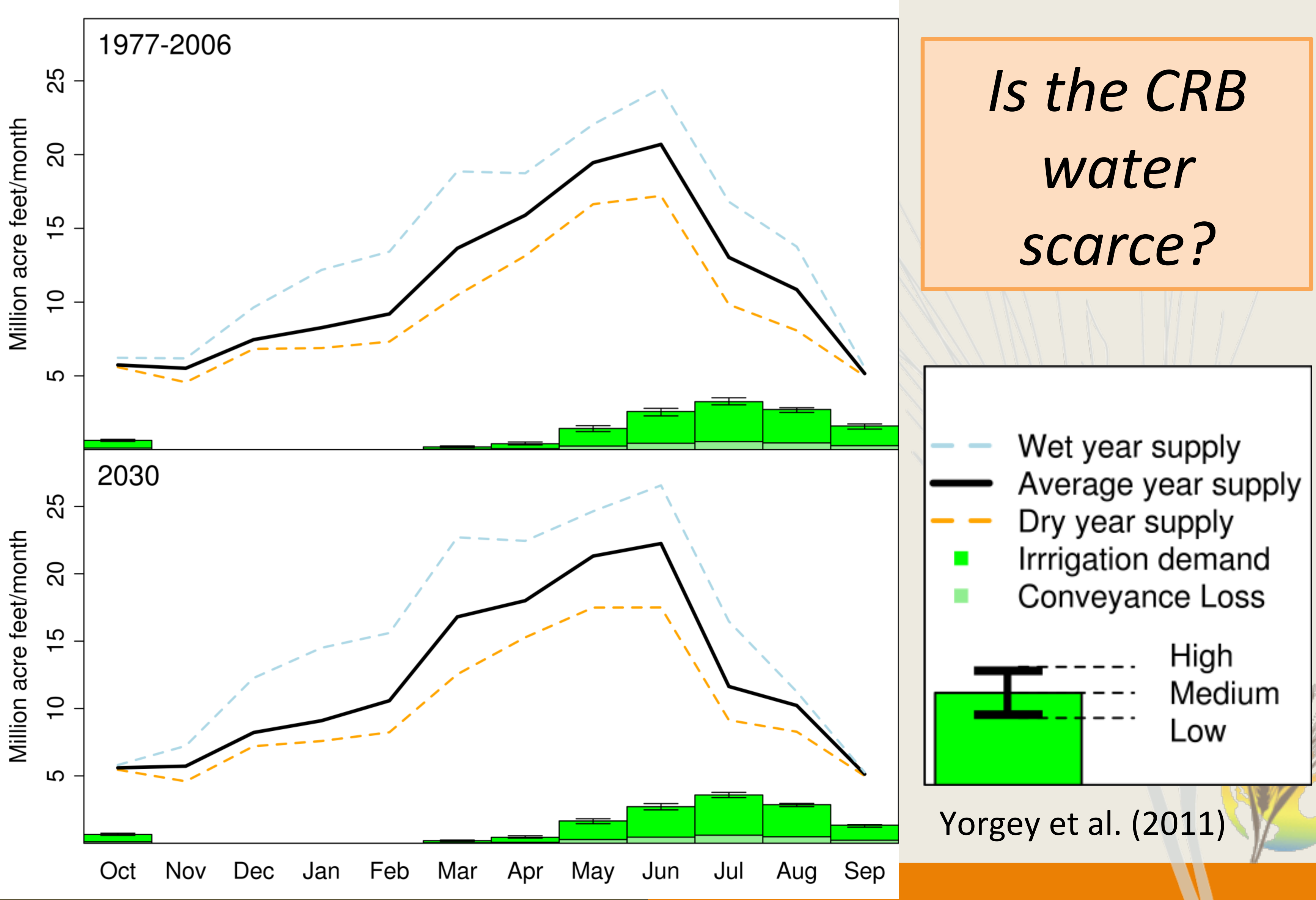
- Most water scarcity metrics do not consider (Rijsberman 2006)
  - Type of need (municipal, environmental, industrial, etc.) and competition between them
  - The fraction of the resource that is or can be made available (physical, economic, legal constraints)
  - Temporal and spatial scales that define scarcity

Incorporating Water Management into Integrated Modeling



Stöckle et al. (2014)
Adam et al. (2014)
Rajagopalan et al. (in prep)

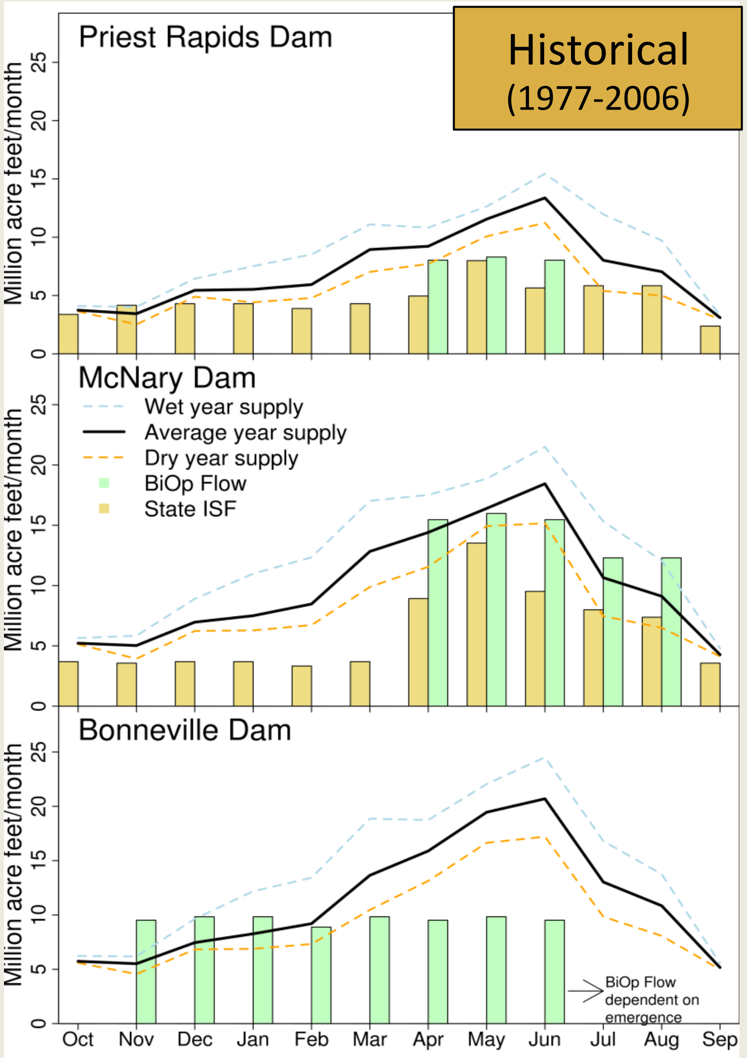
Regulated Supply and Demand at Bonneville (near CRB outlet)

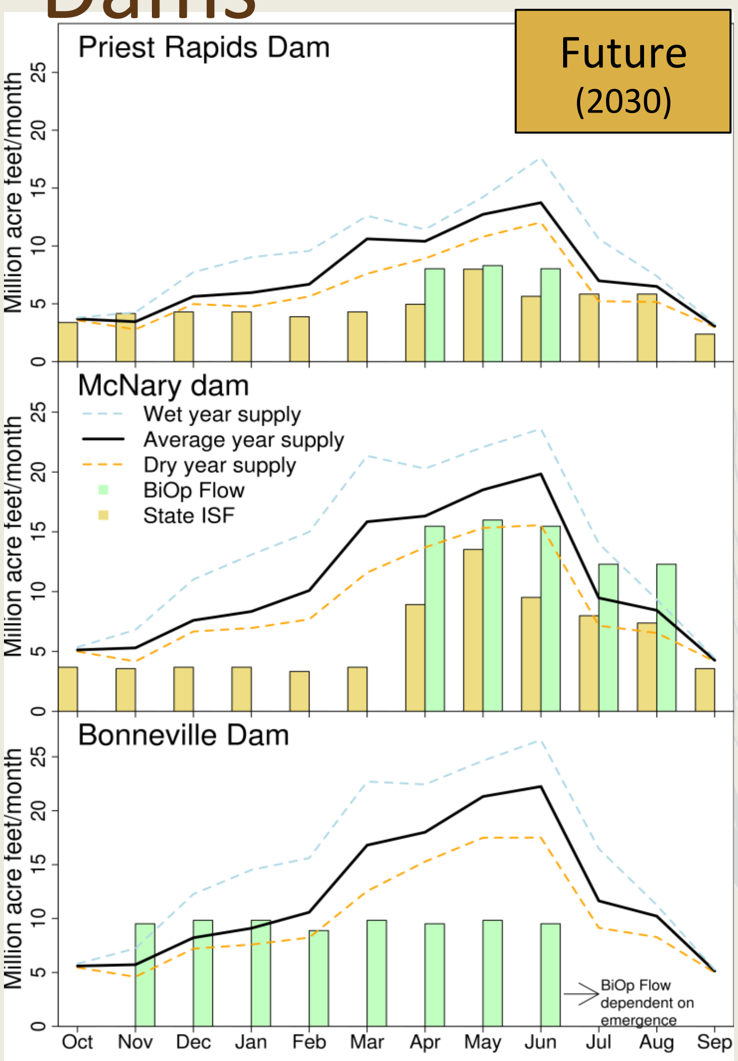


Is the CRB water scarce?

Yorgey et al. (2011)

Regulated Supply and In-Stream Flow Requirements at Columbia Mainstem Dams

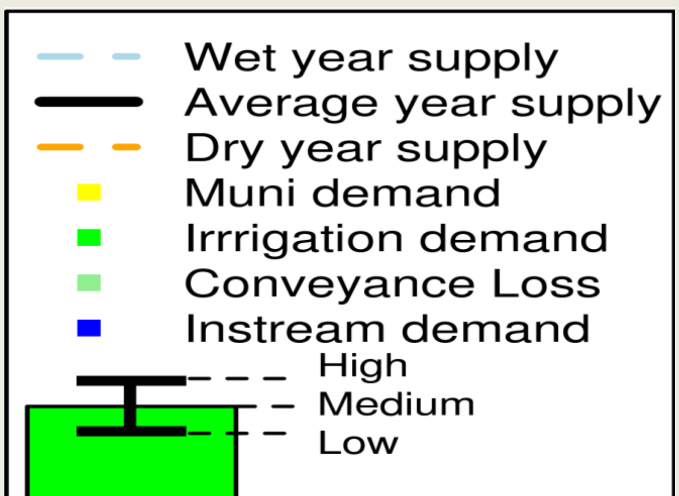


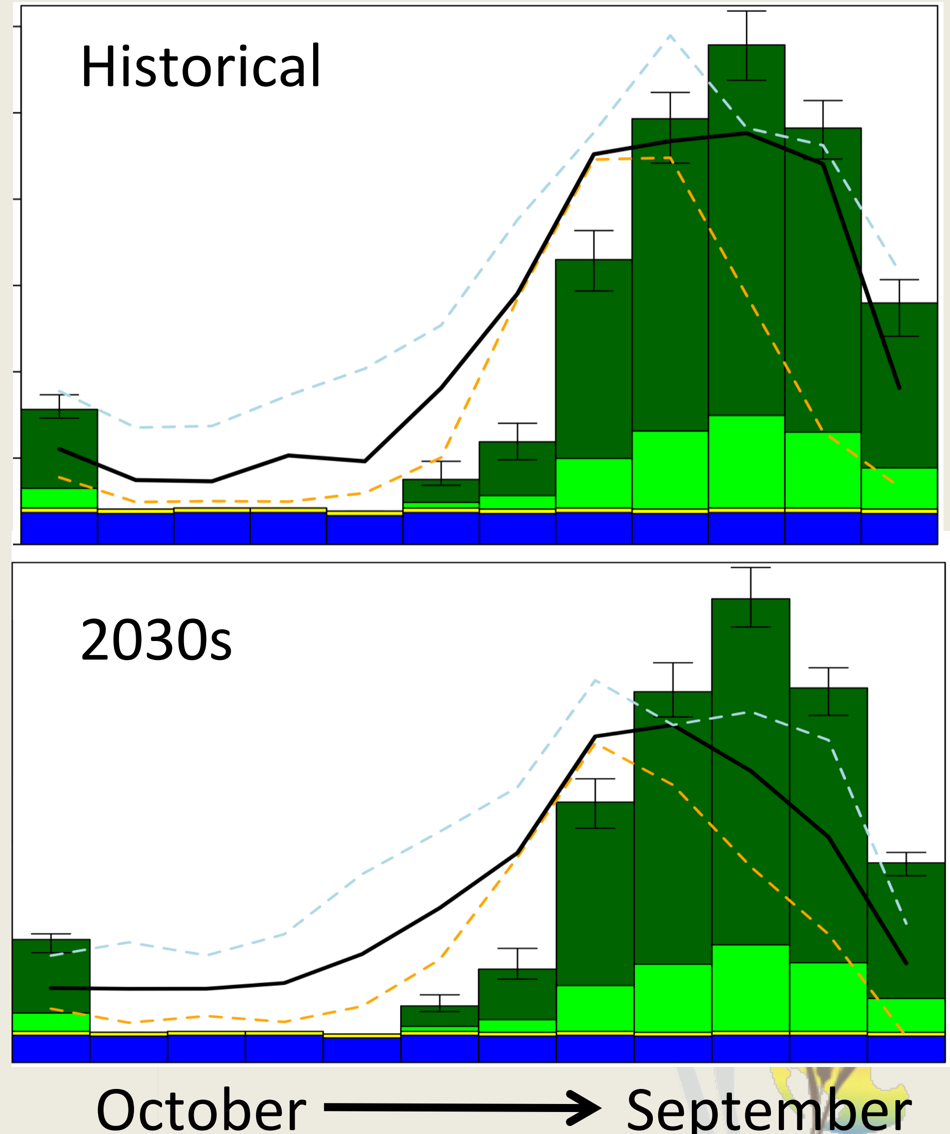


Yorgey et al. (2011)

Yakima River Basin Supply and Demand

- 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





Summary: Climate Change Impacts on Water Supply and Demand over the CRB

- Average annual supply increase at Bonneville: **+3%**
- Average shift in seasonality:
  - ↓ **14%** between June and October
  - ↑ **18%** between November and May
- Average increase in WA irrigation demand **+5.0%**
- Amount of water right curtailment increased in all watersheds with interruptible rights by as much as **150%**
- Most severe impacts at smaller scales, i.e., for specific watersheds

Yorgey et al. (2011)

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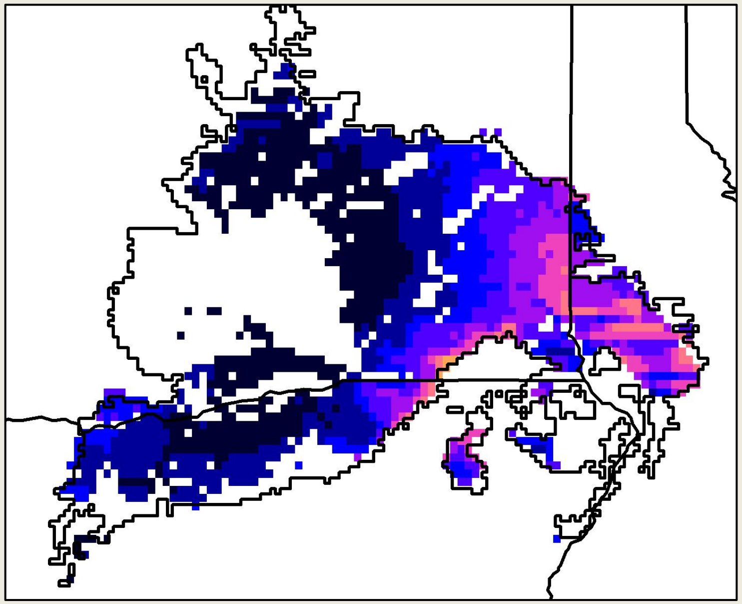
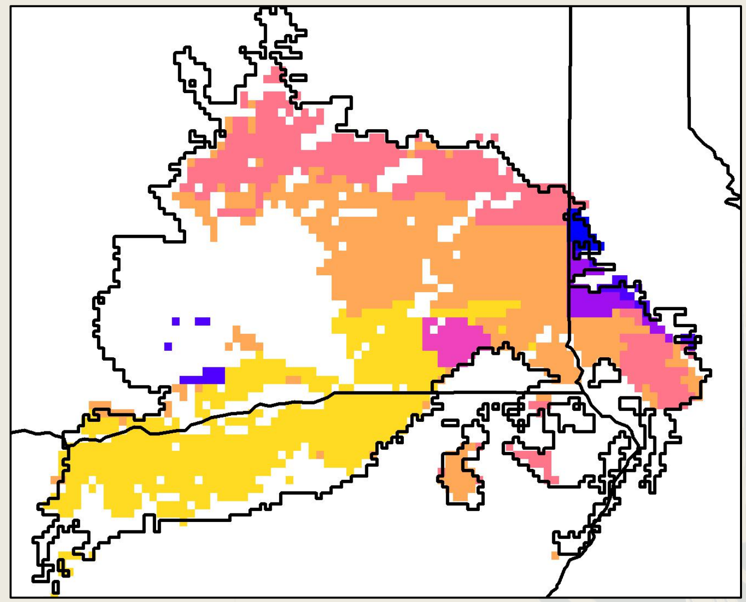
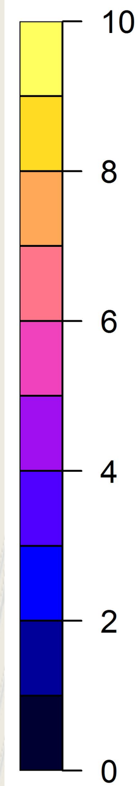
Simulated Increase of Yields with Irrigation: Winter Wheat

Non-Irrigated Yields



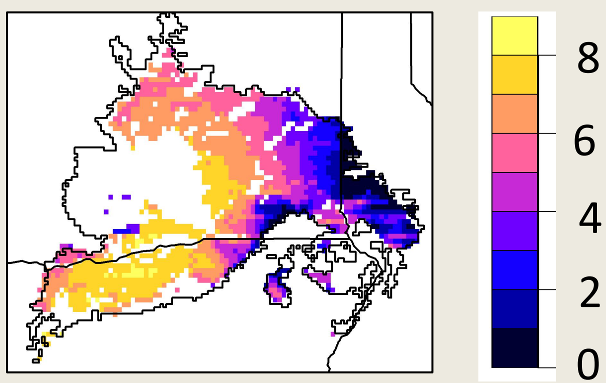
Irrigated Yields





T/ha/yr

Yield Increase (T/ha/yr)



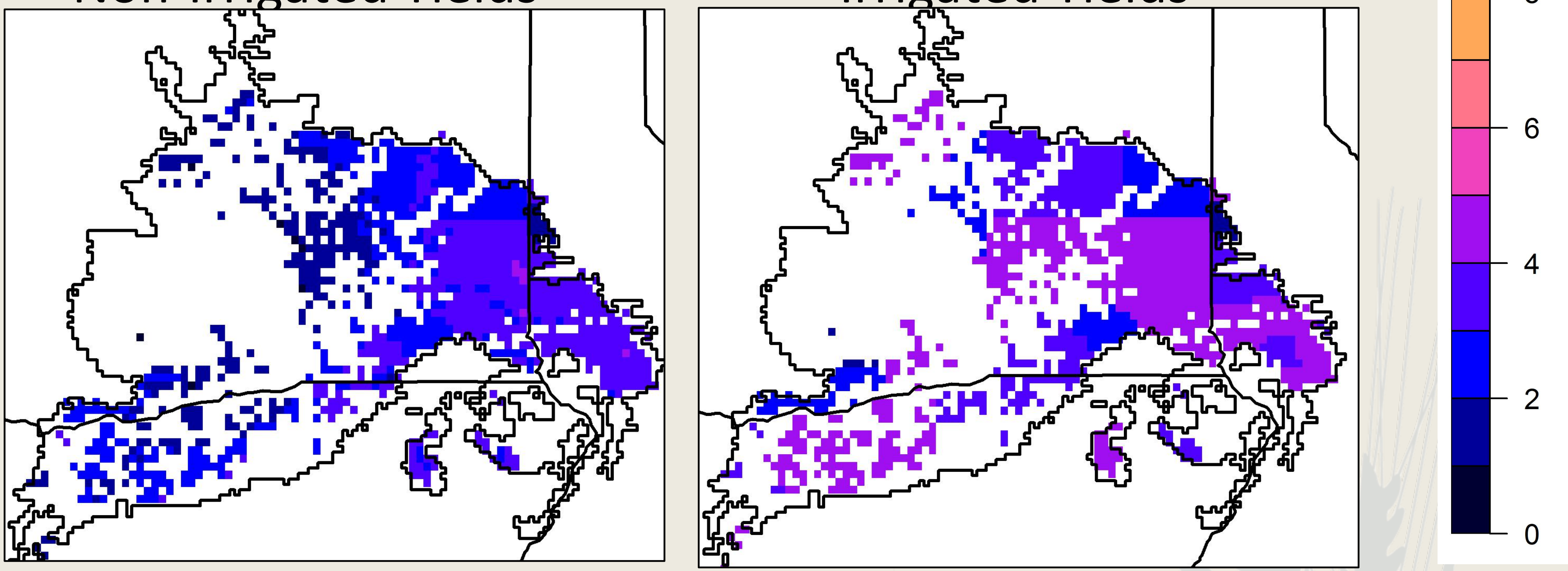
Water required: 0.7 m/year

Simulations courtesy M. Barik

Simulated Increase of Yields with Irrigation: Spring Wheat

Non-Irrigated Yields

Irrigated Yields



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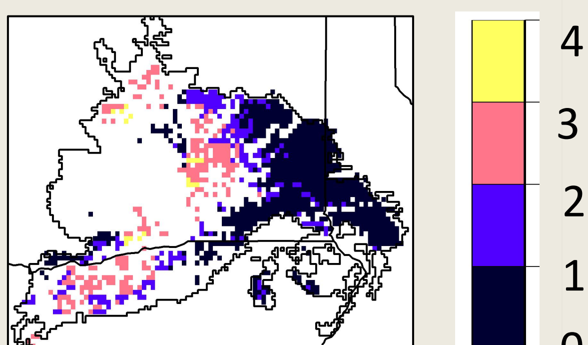
Yield Increase (T/ha/yr)



Water required: 0.5 m/year

Simulations courtesy M. Barik

Use of Blue Water for Adapting to Drought

- New Irrigation:
  - Source type (surface vs groundwater)
  - Source supply (in space and time): current and future
  - Physical, legal, economic constraints
- Existing Irrigation:
  - Irrigation technology and management
  - Fallowing versus deficit irrigating during droughts
  - Use of water banks and markets

Conclusions

- How climate change impacts cereal crop productivity depends on
  - Crop type and whether or not it is irrigated
  - Location
  - Time period
- The indirect impacts of climate change (through water rights curtailment) on irrigated agriculture can be assessed with integrated frameworks that capture
  - Water rights and competing uses
  - Reservoir management (temporal shifting of water availability)
  - River and channels (spatial shifting of water availability)
- The introduction of irrigation as a drought adaptation strategy can also be assessed using these integrated techniques

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Thank you!

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Washington State University

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