Integrated modeling for informing agricultural decision making in the Columbia River basin and relevance to the water management component in BioEarth

Kirti Rajagopalan, Kiran Chinnayakanahalli, Jennifer Adam, Roger Nelson, Claudio Stöckle, Michael Brady, Michael Barber, Shifa Dinesh, Keyvan Malek, Georgine Yorgey, Chad Kruger

WASHINGTON STATE UNIVERSITY
World Class. Face to Face.

- **Objective and Background**
- Modeling Framework
- Results
- Relevance to BioEarth

Objective and Background

The Washington state legislature requires a water supply and demand forecast for the Columbia River basin every five years.

The objective of this work is to use an integrated biophysical and economics model to forecast the water supply and demand in the Columbia River basin in the 2030s.

The primary focus is on irrigation demand.

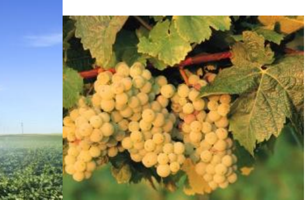
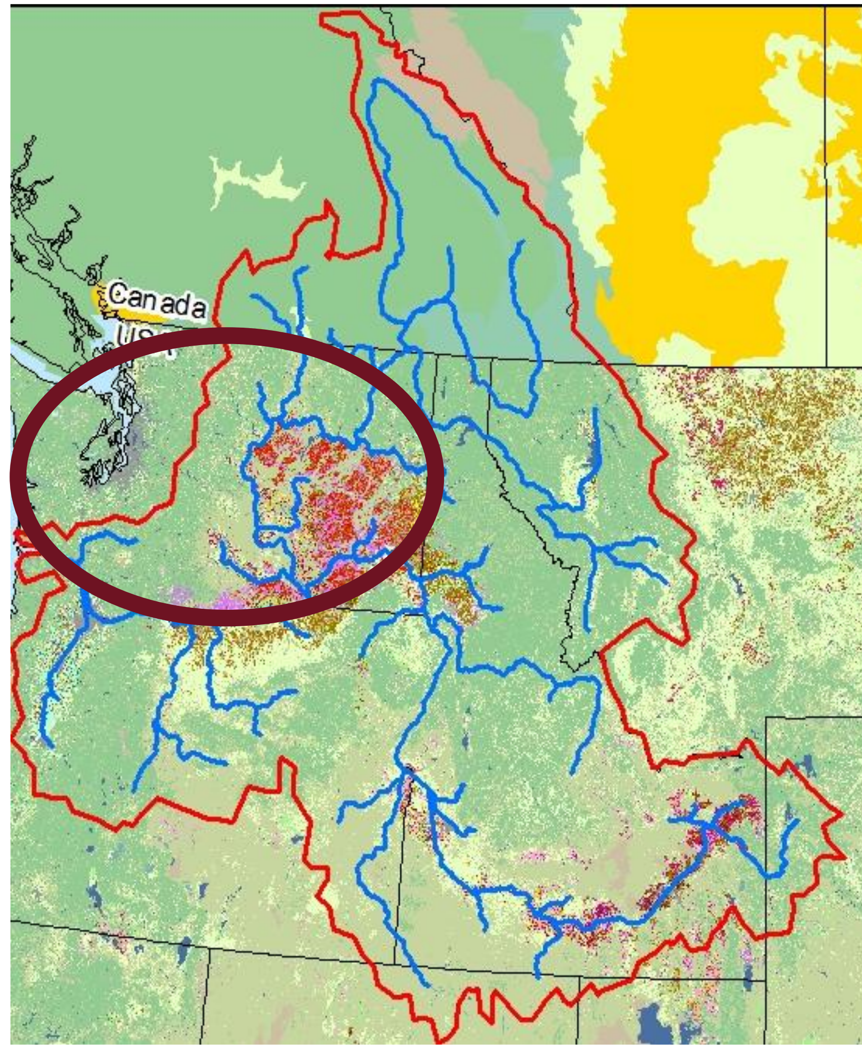
Columbia River basin Agriculture

- Agriculture is a significant part of the region’s economy
- Diverse crop mix

Annual value of over $5 billion in Washington state alone





Predicted Changes to Climate

Temperature

- Annual temperature increase
- Summer increases are greater than other seasons

Precipitation

- Annual precipitation: less agreement among Global Climate Models
- Summer precipitation decreases; other seasons increase

Net effect on stream flow

- Shifting of water availability away from summer season of peak irrigation water demand

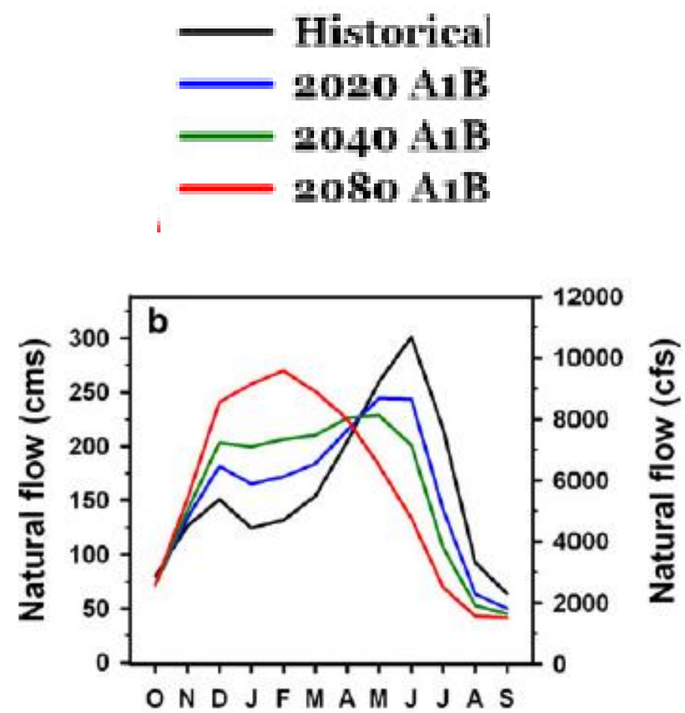


Figure from Elsner et al., 2010

- Objective
- Background
- **Modeling Framework**
- Results
- Relevance to BioEarth

The UW CIG Supply Forecast

Introduction for New Users

Project Report

Climate Scenarios

Site-specific Data

Primary Data

Reservoir Model Input Data

Hydrologic Climate Change Scenarios for the Pacific Northwest Columbia River Basin and Coastal Drainages

Pacific Northwest water resources are projected to be materially affected by a changing climate. This two-year collaborative project is designed to provide free public access to hydrologic scenarios needed to support long-range water planning for the 21st century. The menus to the left provide access to a comprehensive suite of climate change hydrologic data bases and summary products for approximately 300 streamflow locations in the Columbia River basin and selected coastal drainages west of the Cascades.

The hydrologic data produced by the study are based on climate change scenarios produced for the IPCC Fourth Assessment effort (link to climate scenarios at left). Information on the methods and modeling tools used in the study is provided in a summary report (link to project report at left). For new users of the site, a guide to the website and the data resources contained within it is also provided (link to introduction for new users).

Our Study Partners

- UW Climate Impacts Group
- WA State Department of Ecology
- Bonneville Power Administration
- Northwest Power and Conservation Council
- Oregon Department of Water Resources
- British Columbia Ministry of Environment

http://www.hydro.washington.edu/2860/

Slide courtesy of Alan Hamlet

Application of the UW CIG Water Supply Forecast

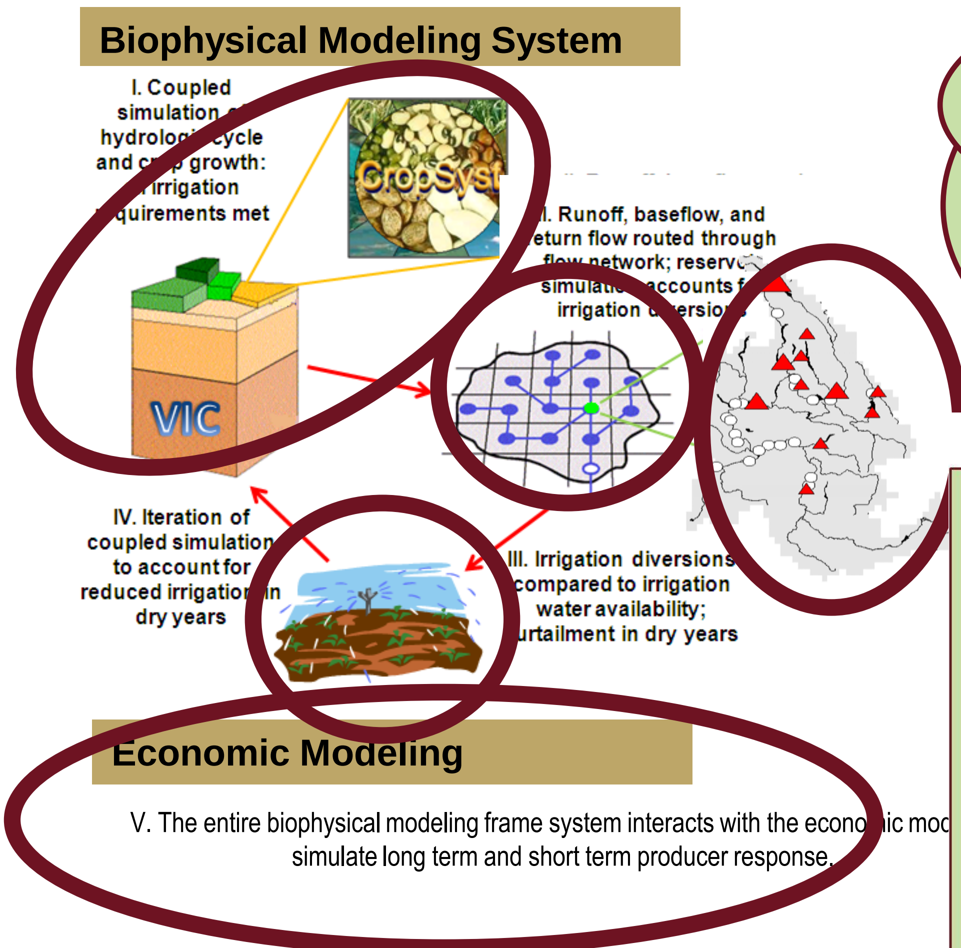
WSU is building directly off of the UW water supply forecasting effort (Elsner et al. 2010) by starting with these tools that were developed by UW Climate Impacts Group:

- Implementation of the VIC hydrology model over the Pacific Northwest at 1/16th degree resolution
- Reservoir Model, ColSim
- Historical climate data at 1/16th degree resolution
- Downscaled future climate data at 1/16th degree resolution

WSU added elements for handling agriculture:

- integrated crop systems and hydrology
- irrigation withdrawals, curtailment modeling
- economic modeling of producer response

Modeling Framework



Streamflow routing

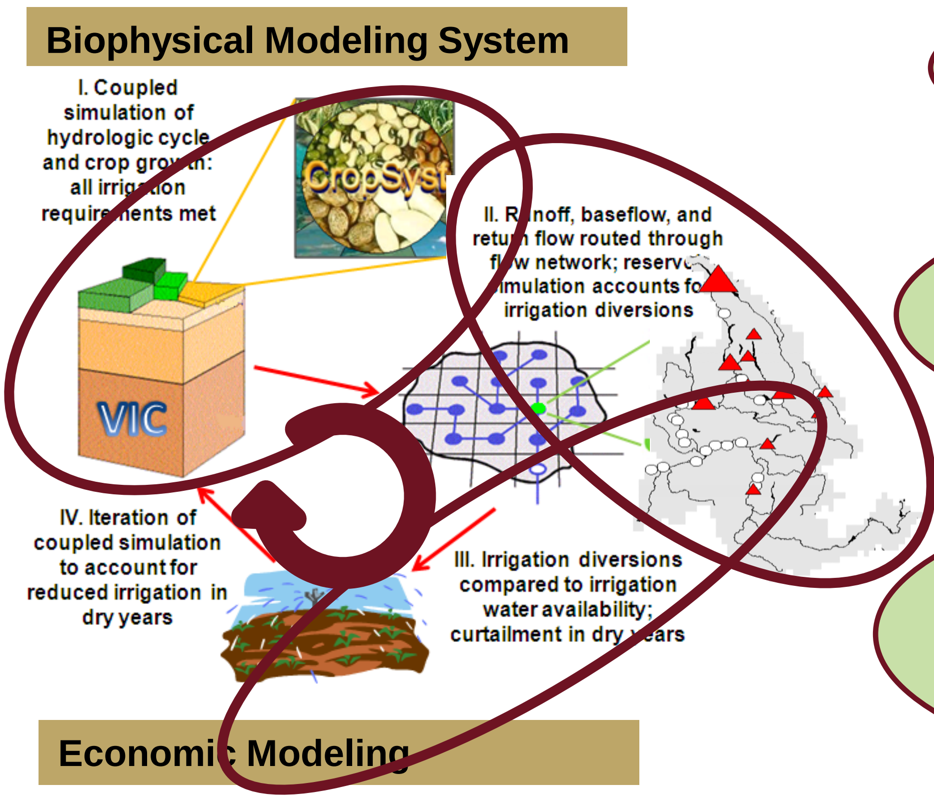
--CropSyst (1994)

--long term p response

(Change in crop mix due to domestic growth and international trade)

VIC	CropSyst
1. Weather (D) 2. Soil Soil layer depths Soil water content 3. Water flux (D) Infiltrated water 4. Crop type Irrigation water = Crop Water Demand /irrigation efficiency	Sow date Crop interception capacity Crop phenology Crop uptake (D) Water stress (D) Current biomass (D) Crop Water demand (D) Harvest day Crop Yield

Modeling Framework



V. The entire biophysical modeling frame system interacts with the economic model to simulate long term and short term producer response.

Full irrigation demand

Water availability

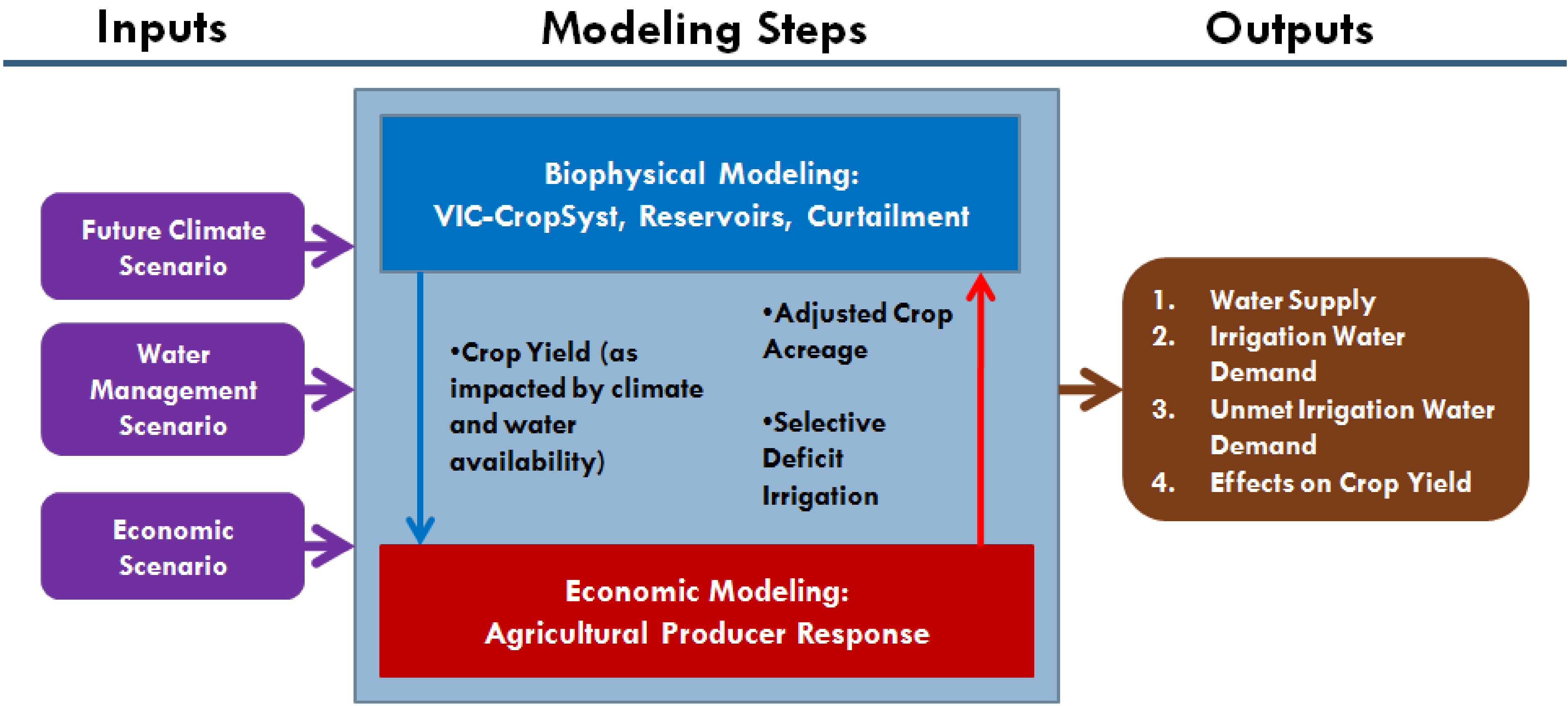
Compare demand against water availability and in stream flow targets

Compare excess demands against demands from interruptible grid cells

Calculate deficit by crop

Iterate to account for deficit irrigation

Model Application



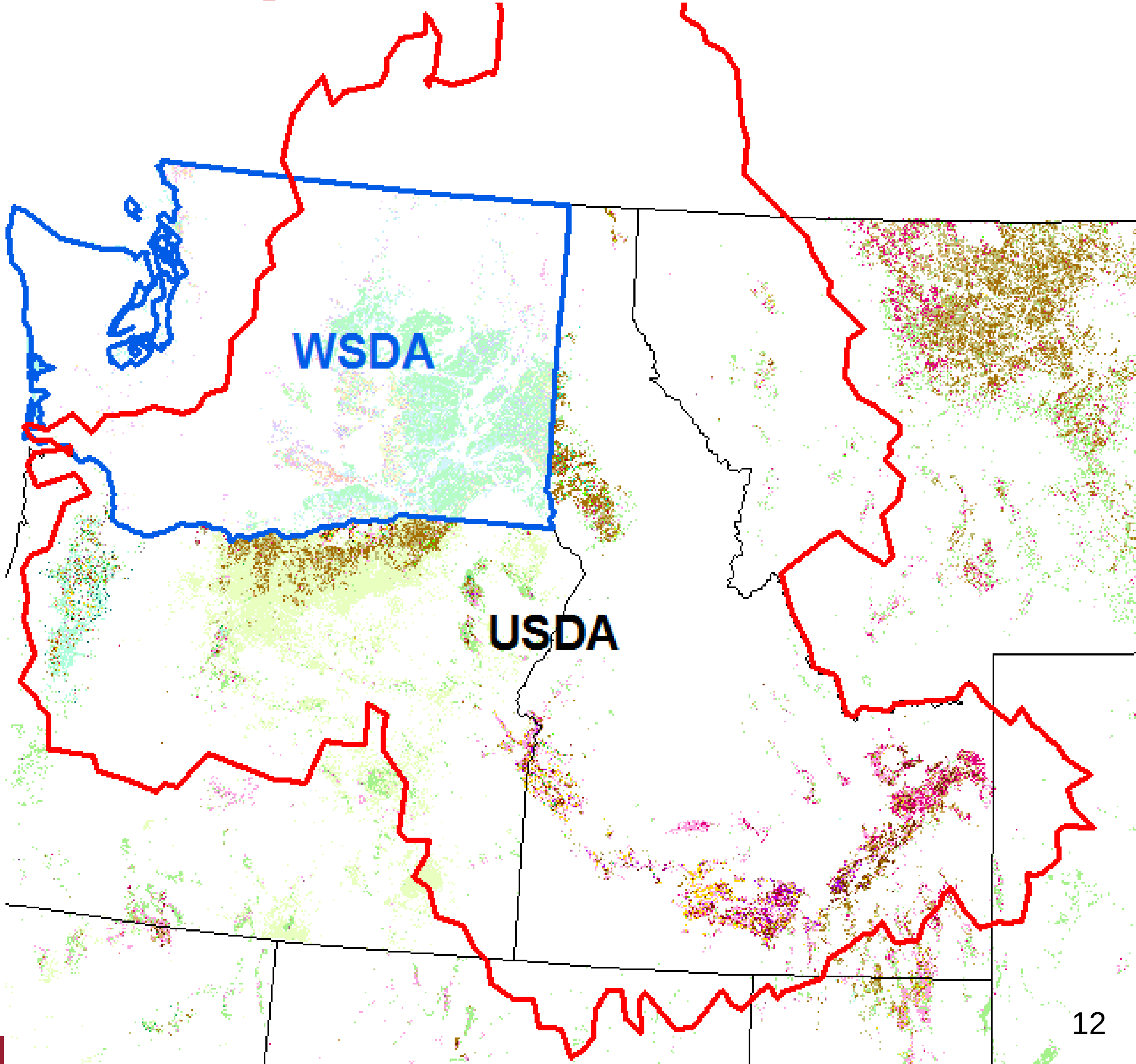
Cropland Data Layer

WSDA – Washington State Department of Agriculture

USDA – US Department of Agriculture

Over 40 different crop groups simulated

Non-crop land cover from Elsner et al. 2010



- Objective and Background
- Modeling Framework
- **Results**
- Relevance to BioEarth

Overall Summary

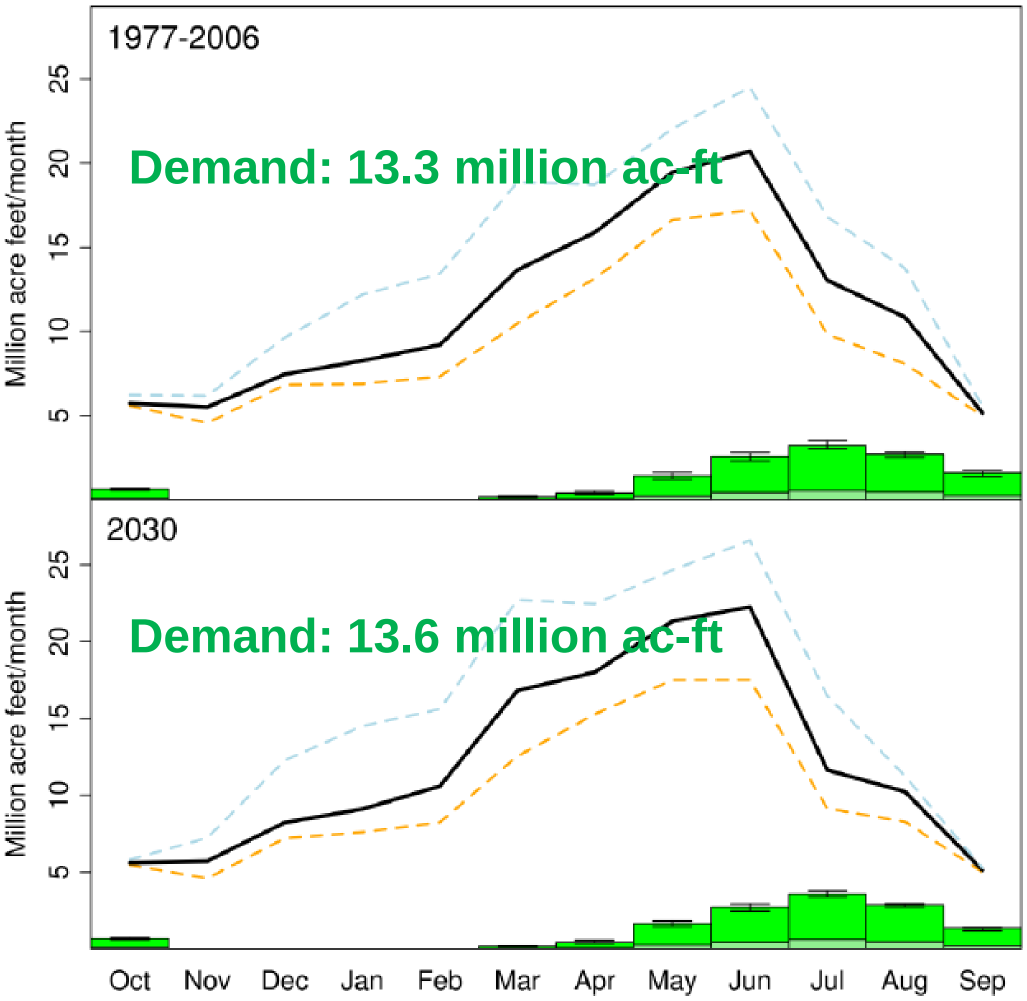
- A small increase of around **3.0 (±1.2)%** in average annual supplies by 2030 compared to historical (1977-2006)
- Unregulated surface water supply at Bonneville will

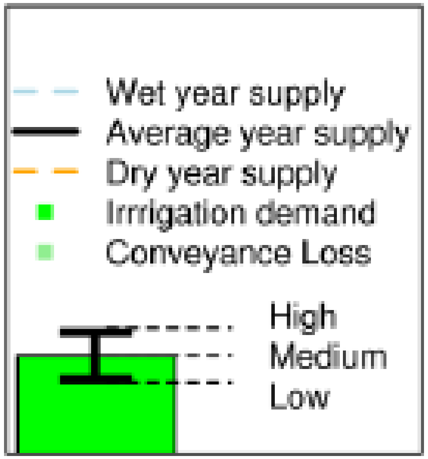
  14.3 (±1.2)% between June and October

  17.5 (±1.9)% between November and May

- The irrigation demand under 2030s climate was roughly 2.5% above modeled historic levels under average flow conditions

Supply (regulated) versus demand for the entire Columbia River basin

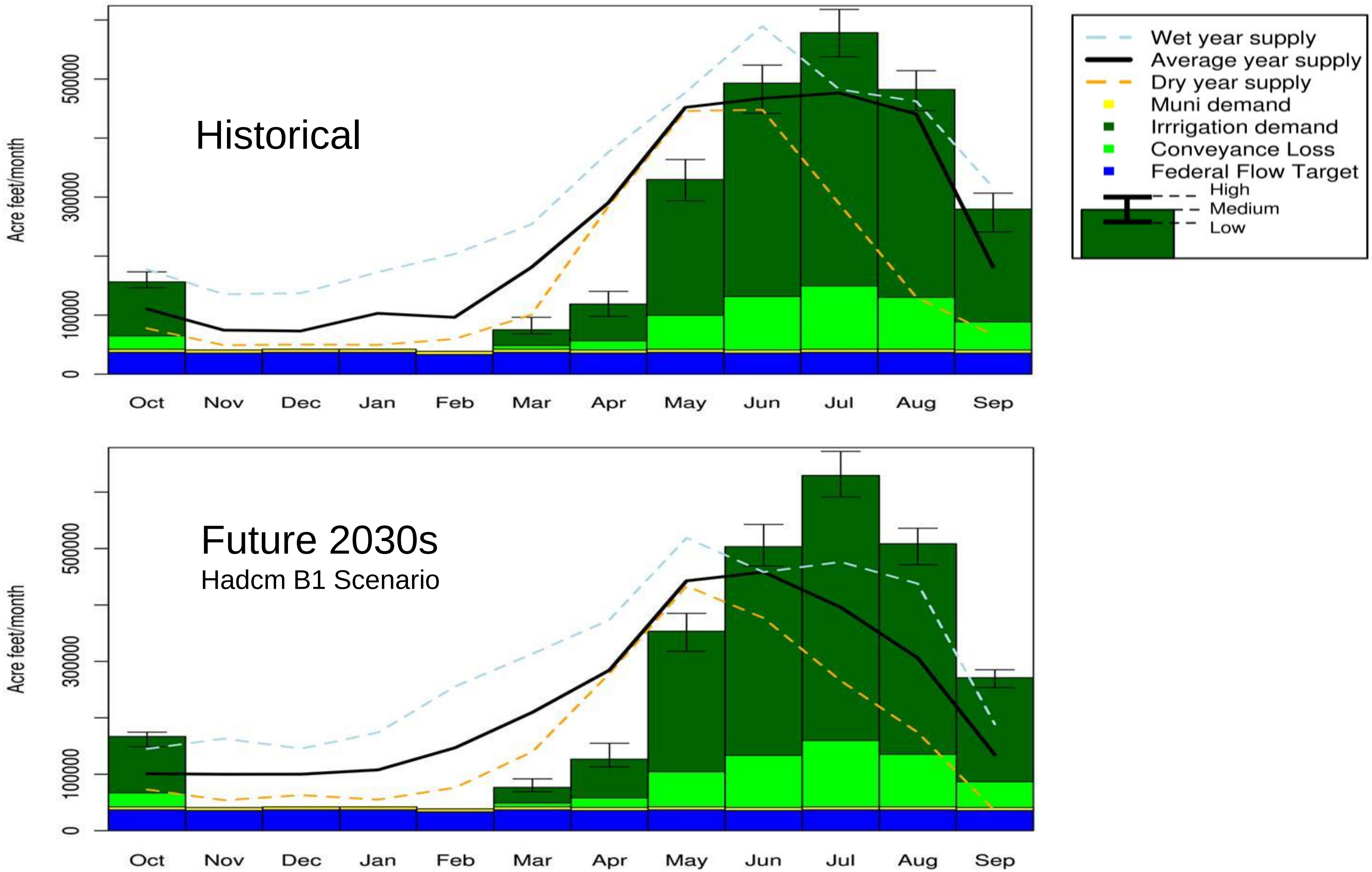




2030 results are for
- HADCM_B1 climate scenario
- average economic growth and trade

Note: Supply is reported prior to accounting for demands

Supply (regulated) versus demand for the Yakima River subbasin

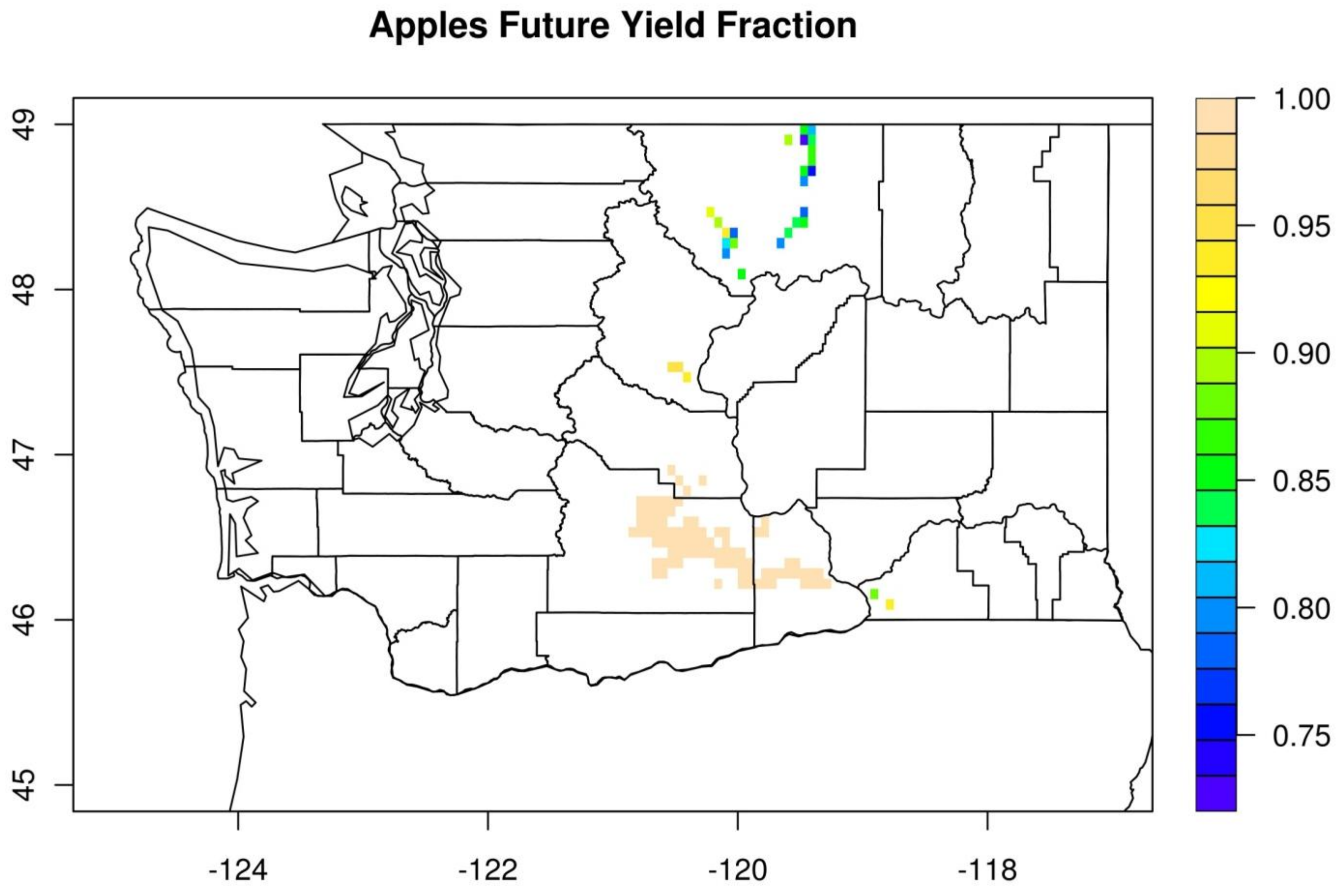


So what does this translate to in  ?

Our rough estimates place the loss between

$68-$159 million/year

assuming no changes in efficiency and little adaptation of cropping practices.



Summary

- Increased irrigation demand, coupled with decreased seasonal supply poses difficult water resources management questions

- Some watersheds more impacted than others

- Ability to integrate land and water resource decision making into regional-scale Earth system models

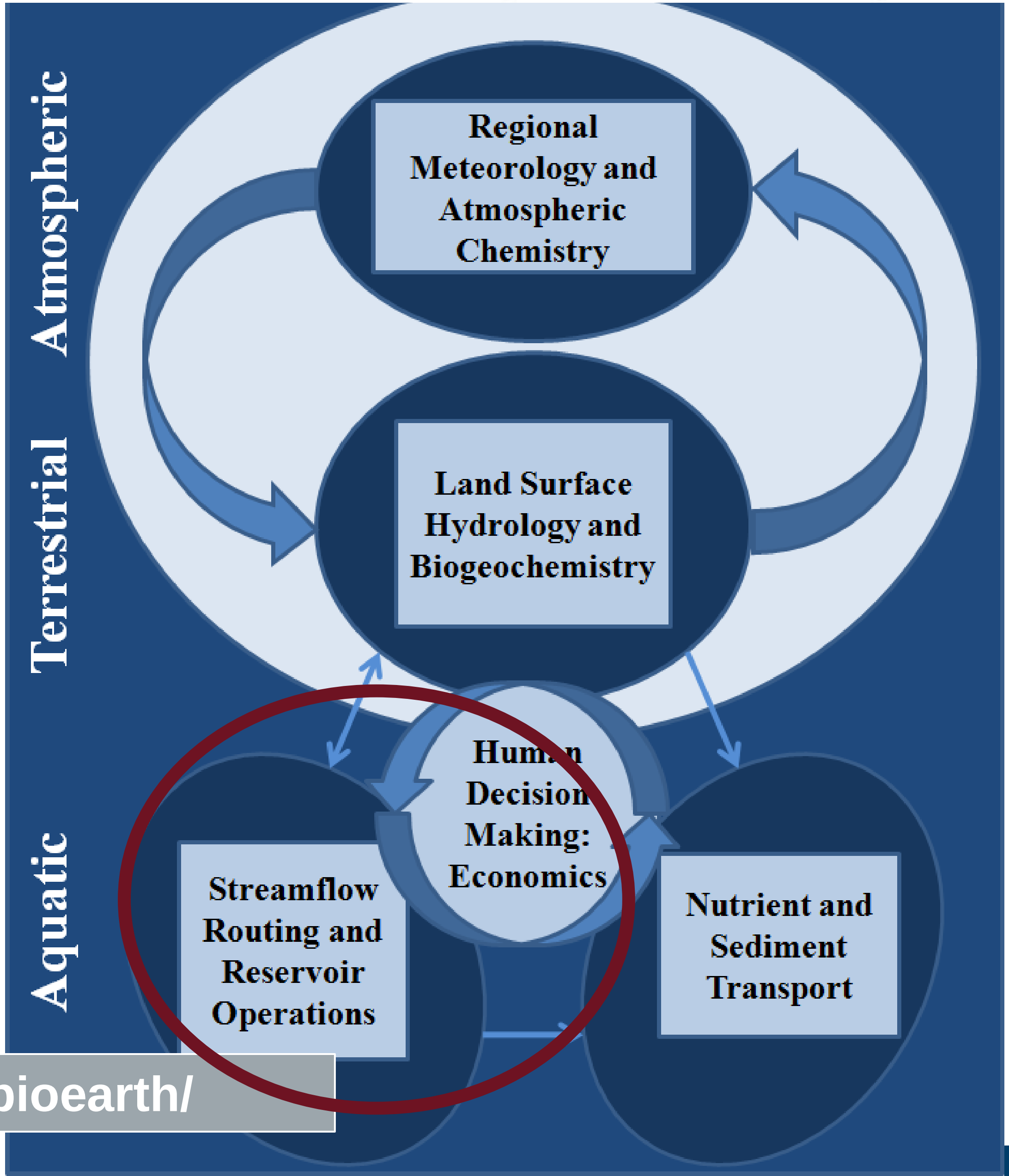
Relevance to Earth System Modeling

Reservoir modeling

Diversions

Curtailment

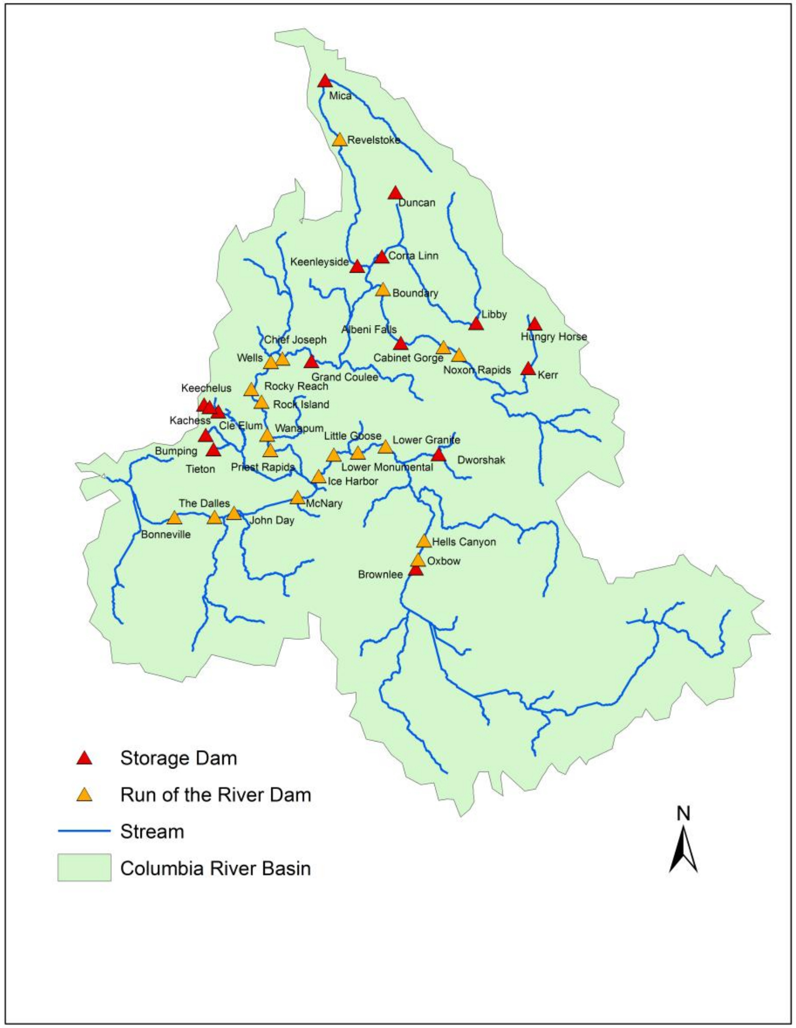
Ag producer responses



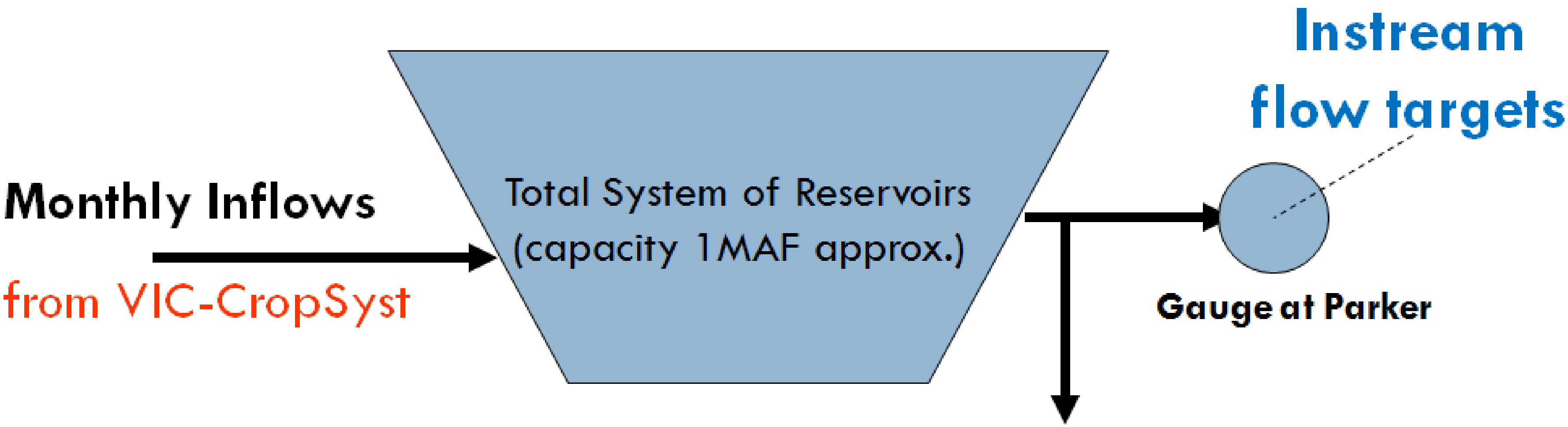
http://www.cereo.wsu.edu/bioearth/

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

- Reservoir simulation model for the Columbia River mainstem and its Snake River tributary
- The main storage and run of the river dams in the Columbia River mainstem are simulated; Snake River is approximated as sets of composite reservoirs
- Assumes a perfect forecast of runoff
- Runs at a monthly time step.



Yakima Reservoir Model



Irrigation demand from VIC/CropSyst

Curtailment rules

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

Objectives:

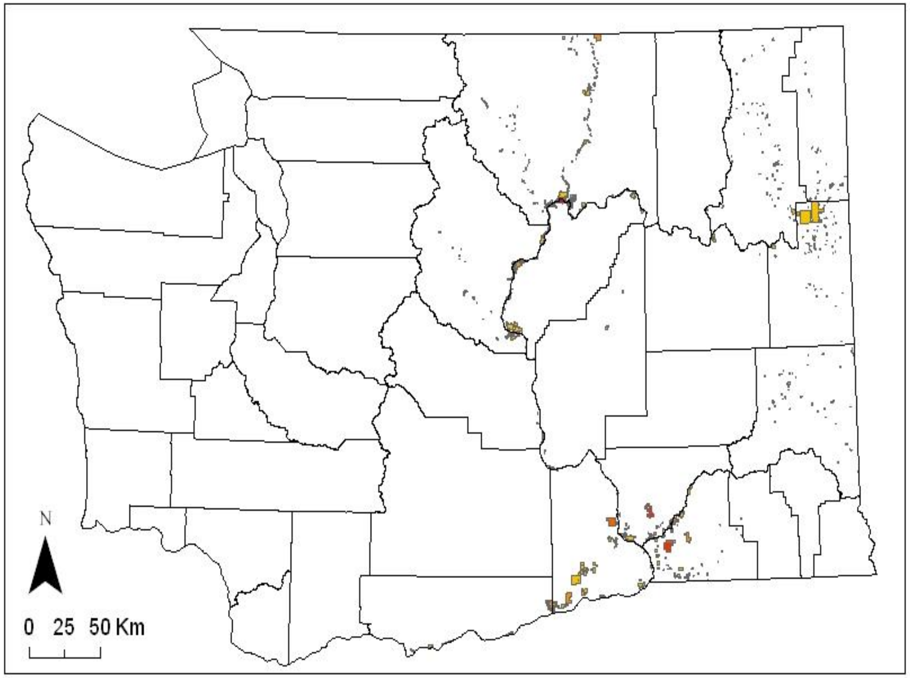
- Reservoir refill by June 1st
- Flood space availability

Water Rights Data and Curtailment

- Places of use
- Points of diversion

Interruptible surface water rights

- Columbia Mainstem
- Central Region (Methow, Okanogan, Wenatchee)
- Eastern Region (Walla Walla, Little Spokane, Colville)
- Proration in Yakima



Surface Water Versus Ground Water split of Sources and its Spatial Disaggregation

Conveyance Loss Assumptions

1) **Yakima** - 25% (literature, USBR)

2) **Columbia Basin Project Area** -15% (based on modeled demand versus withdrawal data, WA DOE)

3) **Methow** - 40% (Water shed plan)

4) **Columbia mainstem 1 mile corridor** - 10% (WA DOE)

5) **Outside Washington** 20%

Model Evaluation

Lack of data to evaluate diversions

USBR withdrawals from Bank’s Lake (catering to the Columbia Basin Project area in central Washington)

Modeled top of crop estimates for this region were within 15% of the withdrawal records

Plan for BioEarth
How much coupling? Two Pronged approach.

Standard Equilibrium Model

Spatially aggregated
--f(growing conditions, water availability)
Temporally aggregated
Sequential integration

This is the snowpack for this year. This is the pattern of water availability/curtailment in the last few years.
What should I do?
Plant crop X in Y acres this year. There is an increase in curtailment expectancy. Change the crop mix.

Agent Based Model

Spatially disaggregated
Temporally disaggregated
Tight coupling

At this time step, I have only X amount of water available, although I need Y. These are crops that have been planted. What should I do?

Selective deficit irrigation or fallowing

The first step for this is already implemented.

Plan for BioEarth

Create a more automated (perhaps simpler) reservoir model

- may be an optimization approach

- might need to model this offline and have a dummy storage/release in reservoir cells for the space before time version of the hydrology model in BioEarth

Plan for BioEarth

Create a more optimized AG producer response

- choose between "selective deficit irrigation" and "fallowing" in the short run

- model producer response to a wider range of factors than domestic growth and international trade in the long run

Plan for BioEarth

Perhaps incorporate water rights information outside of WA

World Class. Face to Face.

Questions and Discussion !

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

Generic Vegetables

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

Other Pastures

- Grass hay
- Bluegrass
- Hay
- Rye grass

Other Crops

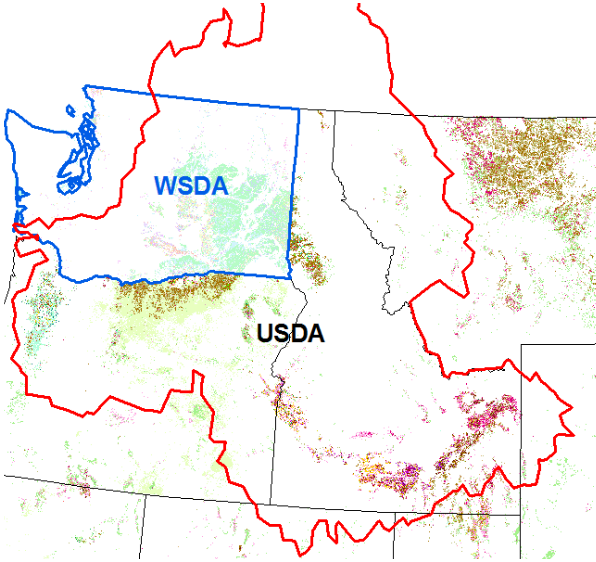
- Oats
- Bean, green
- Rye
- Barley
- Bean, dry
- Bean, green

Berries

- Caneberry
- Blueberry
- Cranberry

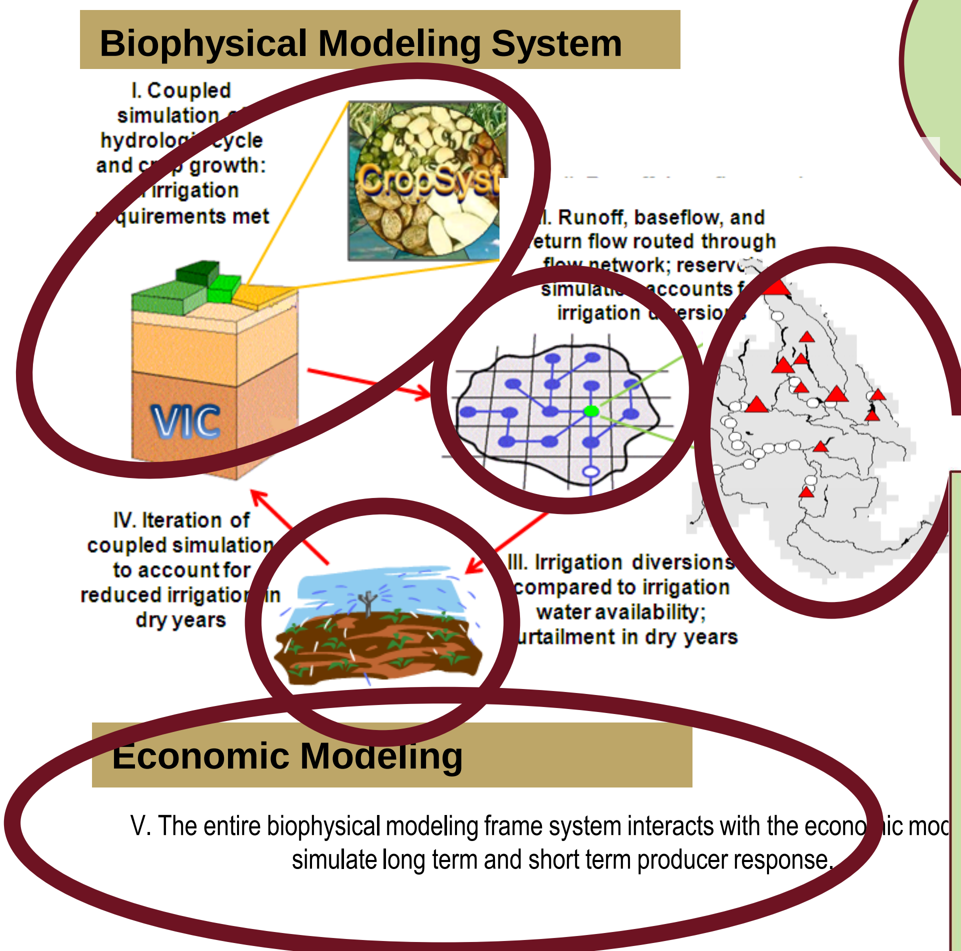
Other Tree fruits

- Pear
- Peaches



Limitations

Modeling Framework



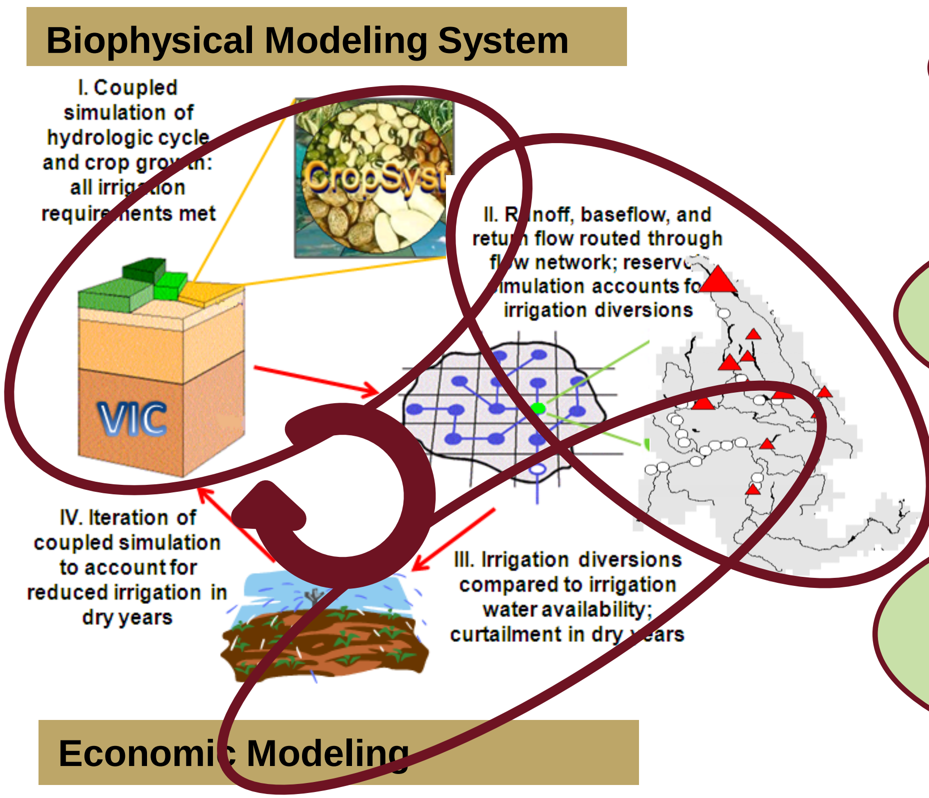
Economic Modeling

--short term producer response
(Selective deficit irrigation)

--**long term producer response**
(Change in crop mix due to domestic growth and international trade)

VIC	CropSyst
1. Weather (D) 2. Soil Soil layer depths Soil water content 3. Water flux (D) Infiltrated water 4. Crop type Irrigation water = Crop Water Demand /irrigation efficiency	Sow date Crop interception capacity Crop phenology Crop uptake (D) Water stress (D) Current biomass (D) Crop Water demand (D) Harvest day Crop Yield

Modeling Framework



V. The entire biophysical modeling frame system interacts with the economic model to simulate long term and short term producer response.

Full irrigation demand

Water availability

Compare demand against water availability and in stream flow targets

Compare excess demands against demands from interruptible grid cells

Calculate deficit by crop

Iterate to account for deficit irrigation