Integrated Modeling to Assess the Impacts of Changes in Climate and Socio Economics on Agriculture in the Columbia River Basin

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Introduction

Rising temperature and changes in the frequency and magnitude of precipitation events due to climate change (IPCC-AR4 report) are anticipated to affect crop production, water availability and quality, and flood risk in the Pacific Northwest (PNW) (Stockle et al 2009, Elsner et al 2009, Hamlet and Lettenmaier 2007).

Agriculture is a vital part of the economy in the PNW, with an annual value over $5 billion in Washington State alone. In 2008, PNW wheat production alone accounted for $1.7 billion, the third largest value in the United States (NASS, 2009) .

The eastern side of the Cascade Mountains, which receives only 5-25" of rain annually, is particularly vulnerable to drought. In the last decade, there have been 10-20% yield losses during severe drought years, with an average of $90 million/year (NASS, 2009).

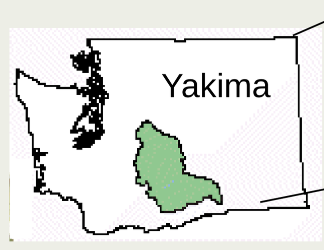
The challenge is to anticipate the probable effects of climate change on the hydrological cycle and make sound land use, water use, and agricultural management decisions that will best serve the needs of agricultural production while protecting our freshwater resources.

Objective

To apply an integrated modeling framework (coupled hydrology and cropping systems model, reservoir model and economics model) to assess impacts of climate and socio economics on water supply , irrigation demand and crop yields in the Columbia River basin.

Basin Description

The Columbia River basin (CRB) in the Pacific Northwest has a drainage area of about 670,000 square kilometers covering all or parts of seven states in the US as well as British Columbia.



The Yakima River basin is a sub watershed of the CRB in the state of Washington. This watershed currently experiences water shortages on a regular basis and is an important sub region of the study area.

Water resources in the CRB are managed to meet several competing demands including hydropower generation, irrigation, navigation, recreation, and fish flows.

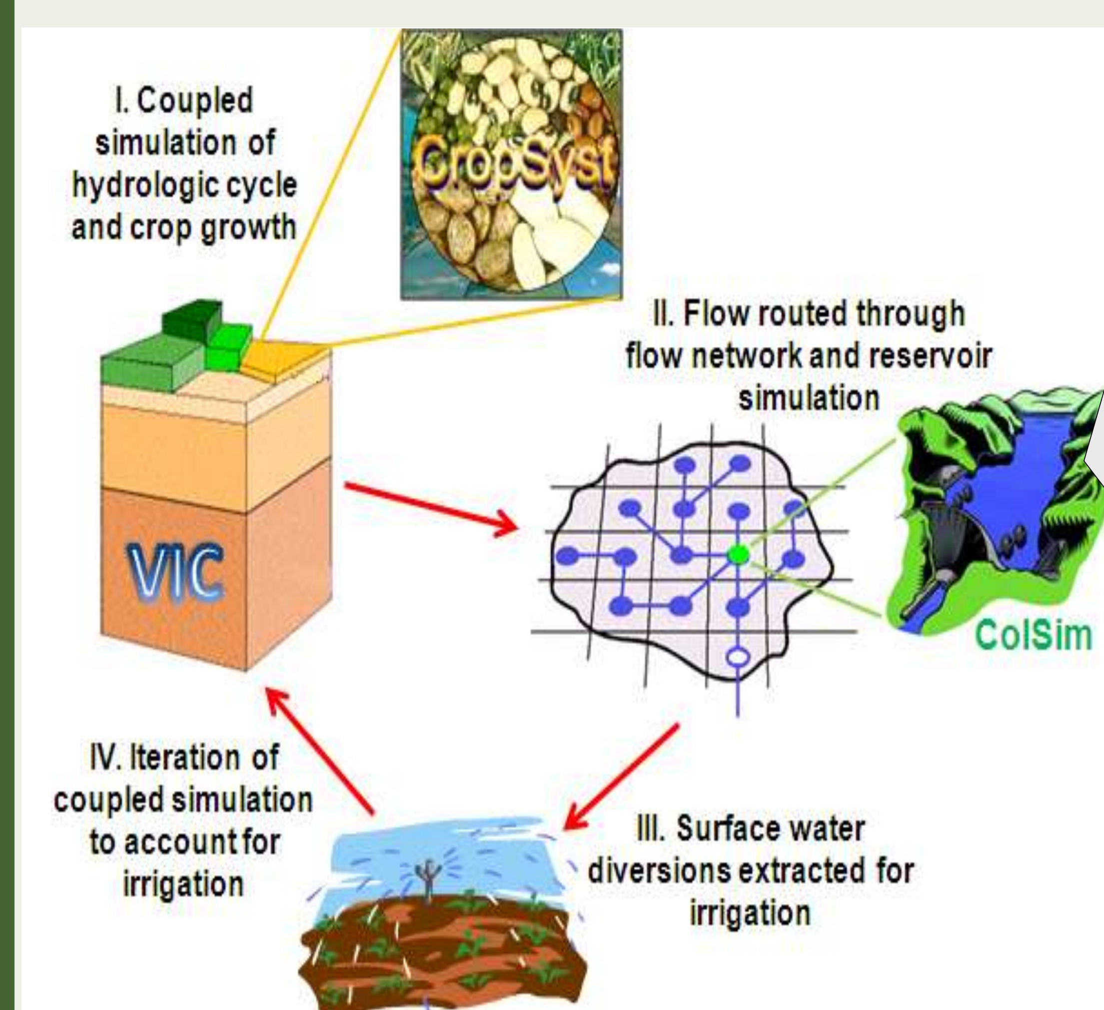
Irrigated agriculture is an important part of the economy. Crops of high economic value like tree fruits, wine grapes and hops are grown in the region.

Water allocation for irrigation water right holders have been regularly curtailed historically in several parts of the basin. This situation is expected to be exacerbated by climate change.

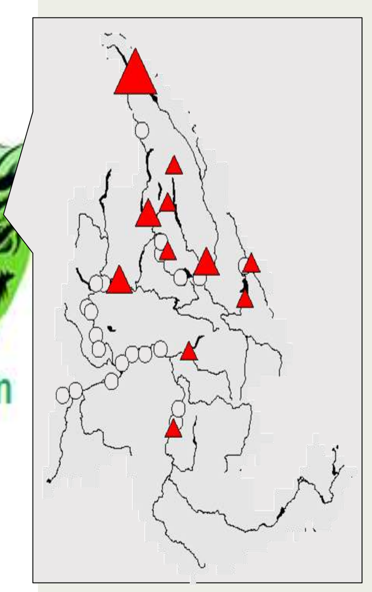
Modeling Framework

- We applied our newly-developed system of linked models, including the VIC hydrology model (Liang et al. 1994), a dynamic crop systems model (CropSyst: Stockle et al. 2003), reservoir models for the Columbia River Mainstem (ColSim: Hamlet et al. 1999) as well as select tributaries, and an economics model.
- Irrigation demand and crop yield for each crop type in the basin as well as supply are simulated using VIC-CropSyst, while water management (reservoirs and curtailment) are simulated as a separate process. If curtailment occurs, VIC-CropSyst simulations with reduced irrigation are repeated to examine the effects of curtailment.

Biophysical Modeling System



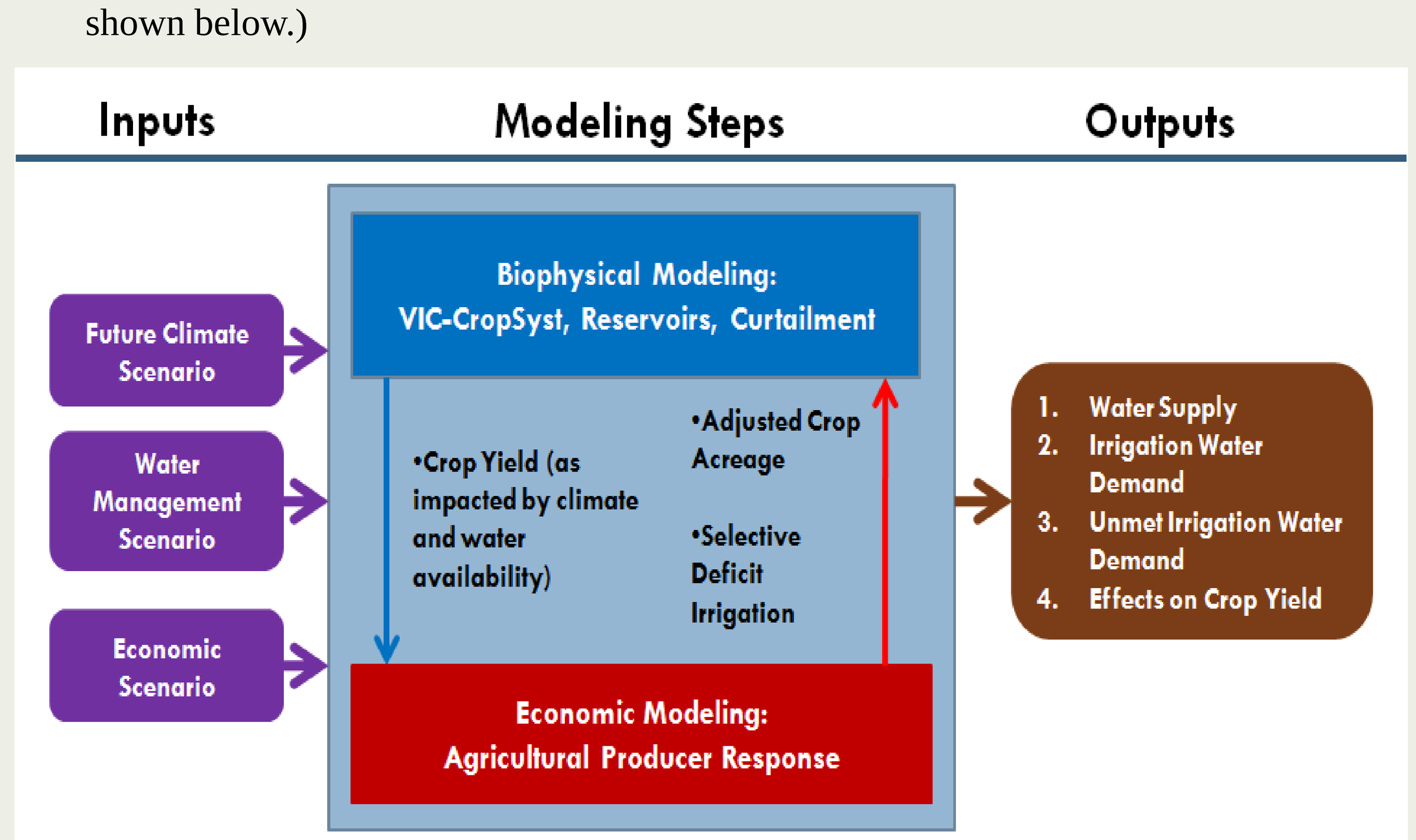
Physical System of Dams and Reservoirs



Economic Model

V. The entire biophysical modeling frame system interacts with the economic model to simulate long term and short term producer response. The long term response is a change in crop mix and the short term response is selective deficit irrigation of crops.

- This interactive modeling framework is run under three sets of scenarios. (Details shown below.)



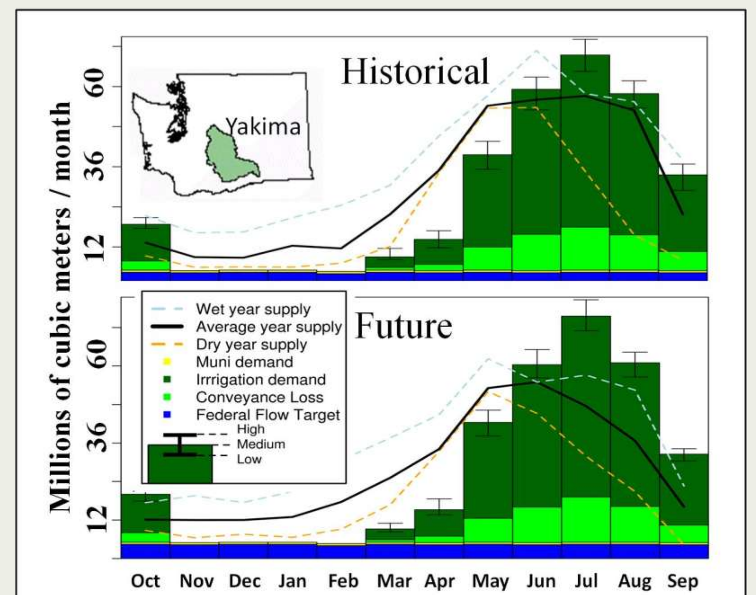
Results

A small **increase of 3.0 (+/-1.2)% in annual surface water supply** at the outlet of the basin in the 2030s.

Shift in timing away from the times when demands are highest. (**Decrease in supply of 14.3 (±1.2)% during the irrigation season** and increase of (17.5 (±1.9)% in other seasons.)

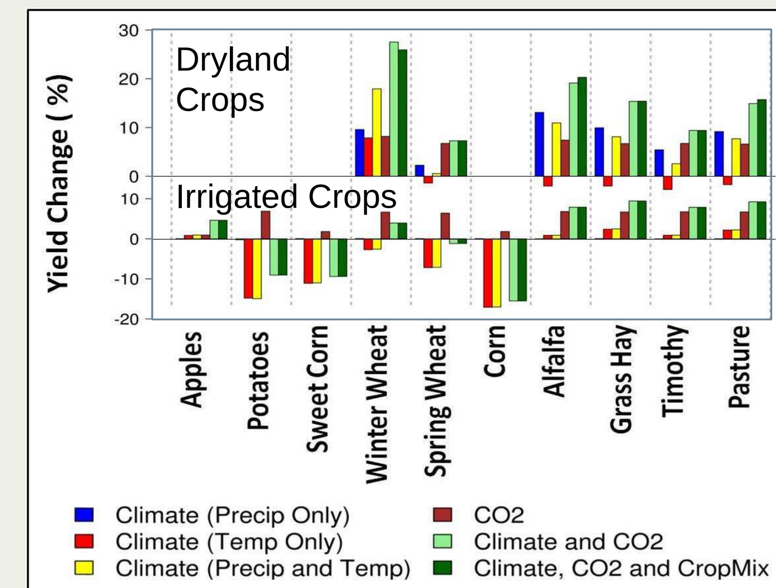
Irrigation water demand **increases by 3.7%** in the 2030s when accounting for the effects of change in precipitation and temperature alone. When the effects of a change in crop mix due to economics is also factored this **increase is reduced to 1.9%.**

Water rights curtailment amounts in Washington State **increase by as much as 150%** in the 2030s.



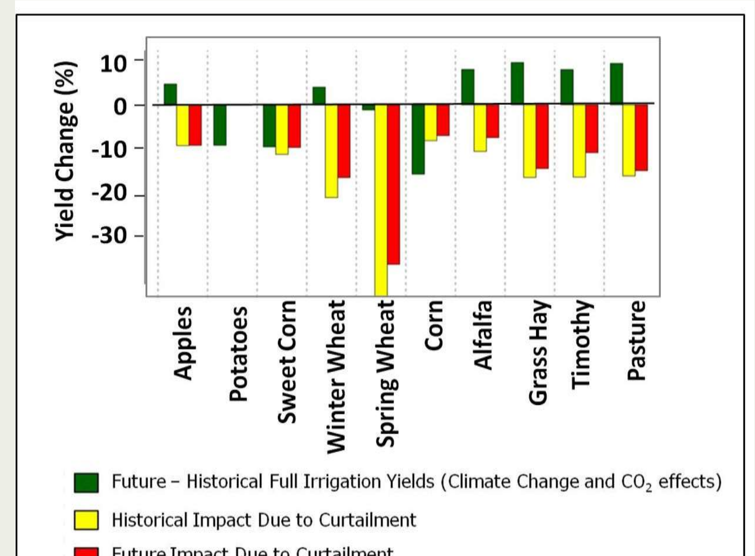
Water Supply and Demand

Comparison of surface water supply and demand for historical and future baseline economic scenarios for the Yakima watershed in Washington state which currently experiences water shortage for irrigation.



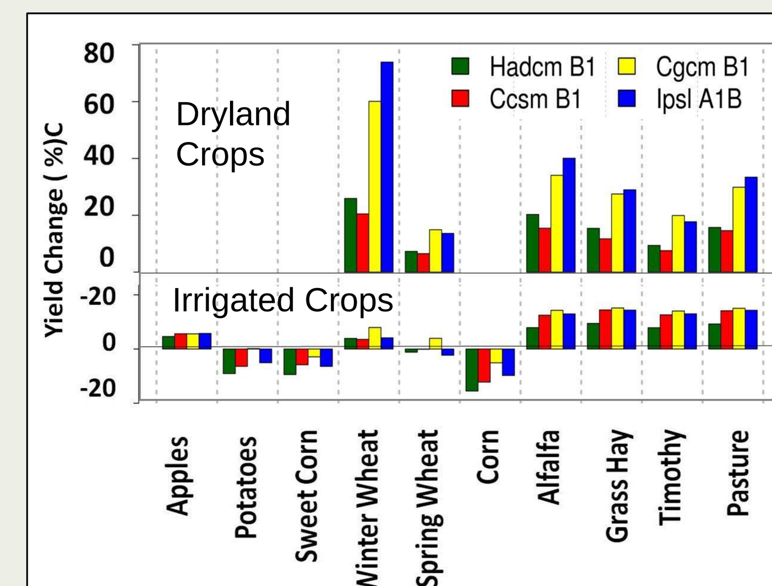
Yield changes in Washington State (WA)

Comparison of yield changes due to climate change, CO_2 enrichment and socioeconomics.



Impact of Curtailment in WA

Comparison of yield changes due to climate and economics with yield changes due to curtailment.



Sensitivity of Crop Yields to Climate

Comparison of yield changes due to different GCM /emission scenario combinations.

Conclusions

Although future annual surface water supply is associated with larger uncertainty, the seasonality of supply is projected with higher confidence to shift away from the summer irrigation season into the low demand winter season. This is due to some loss of the snowpack and changes in precipitation timing.

Irrigation demand is projected to increase in the 2030s. Although reservoir buffering will help manage this to some extent, unmet irrigation demand is expected to increase in tributary watersheds causing increased water stress in an already stressed system.

Climate change has a positive impact on yields for dryland crops (due to increased precipitation). CO_2 enrichment has a positive impact on yields (especially for C3 crops).

Although water shortages increase in the future, the impacts of shortages on yield do not increase. This could be because CO_2 enrichment leads to higher plant water use efficiency.

Acknowledgements

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