# Quantifying the impacts of climate change and farm management practices on crop yield and water use: a modeling approach


Andrea Leonard, Alejandro Flores, Bangshuai Han, Amy Steimke

Geosciences Department

BOISE STATE UNIVERSITY

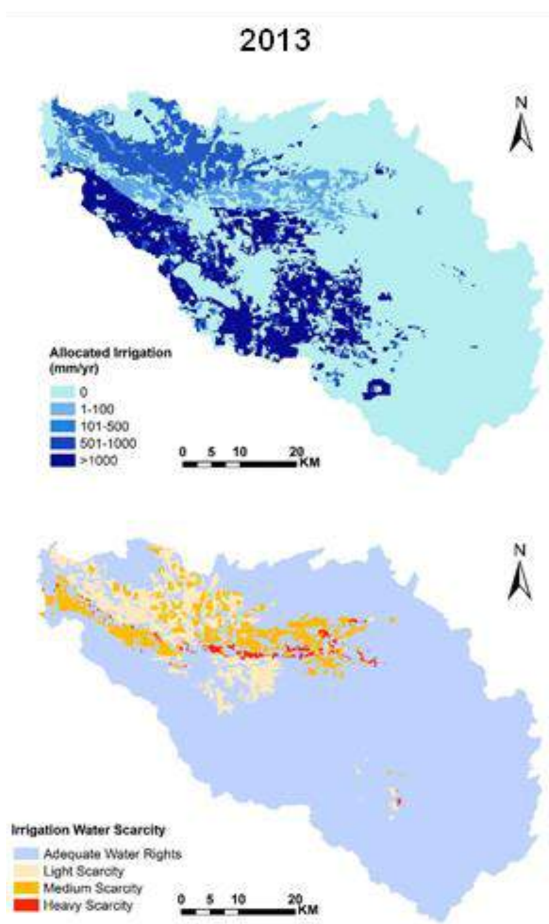

## Introduction

- Climate change will alter spatial and temporal water demands in areas of domestic food production, creating challenges for the agricultural sector
- The United States is currently the world's largest agricultural producer and exporter of agricultural commodities, suggesting global food security and prices are likely to be affected (Schlenker and Roberts, 2009).
- Socio-ecological Systems (SES) research can extend the knowledge of interactions and co-evolution between the social and biophysical systems involved in agriculture

## Research Questions

- **How does both agricultural management and climate change, individually and combined, affect agricultural water use and crop yields in the Treasure Valley?**
- **What are the factors that influence management decisions on a farm scale, e.g. demographics, political ideology, farm size?**
- **How will an increase in population in the Treasure Valley affect water use per capita?**

## Connections, Integration and Synergies within the MILES project




**Bangshuai Han**

Spatially distributed simulation of water availability in the Treasure Valley. Outputs from my model will be used to calibrate irrigation use specific to crop needs

**Amy Steimke**

Assessing the impacts of future climate change on the hydrology of the Upper Boise River Basin. This information is critical in knowing when and how much water is delivered to agricultural lands

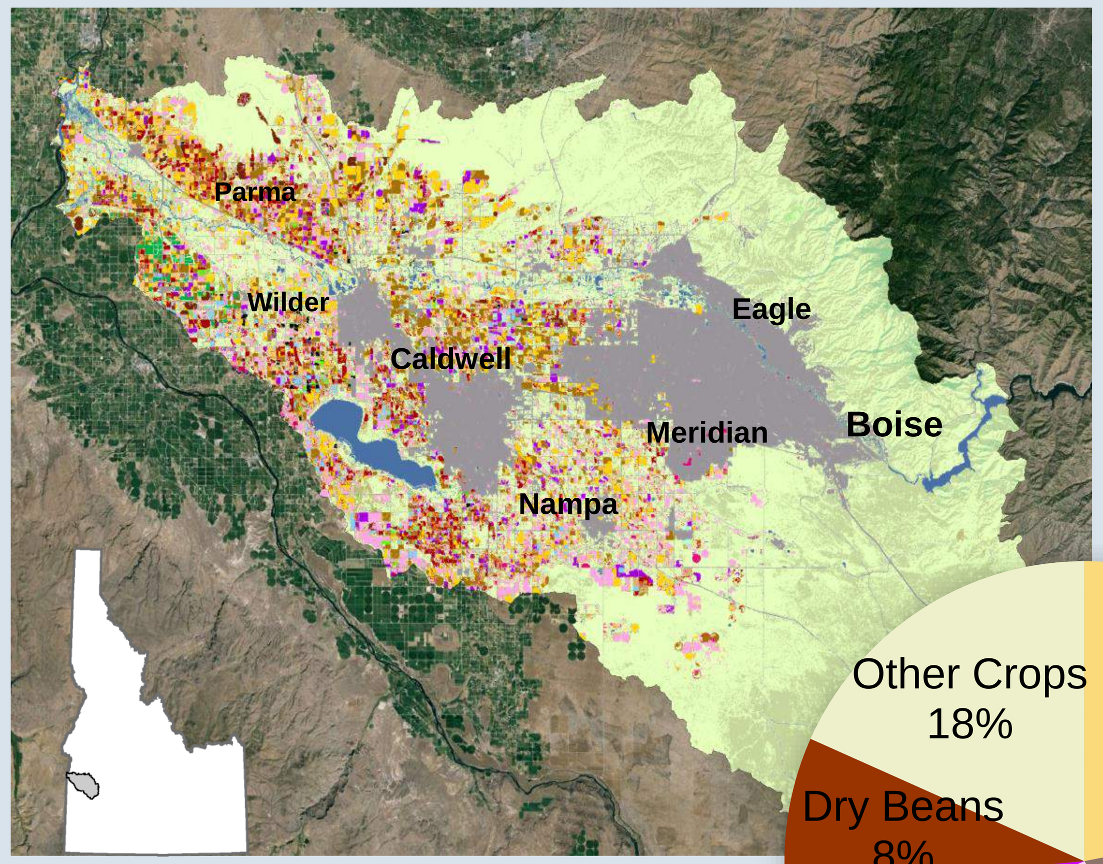
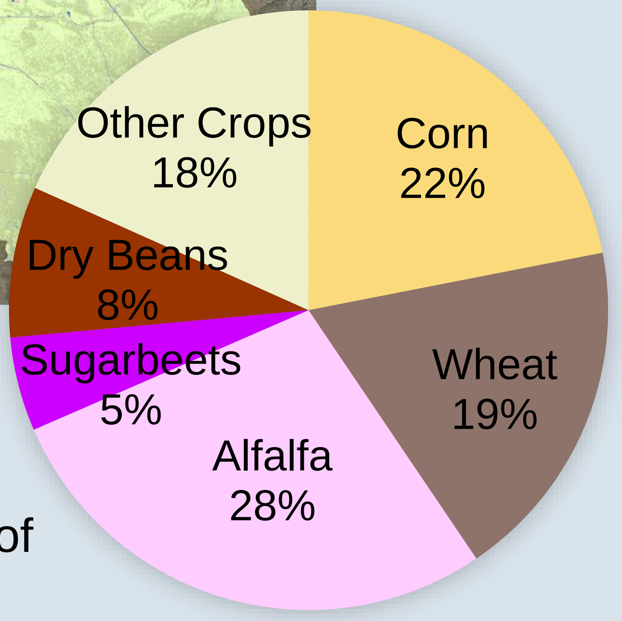



**Figure 1:** Study area. Colored polygons represent cultivated crops. The pie chart below is an overview of crop totals for the particular year shown here (2014).




2014 Treasure Valley crop data (National Agricultural Statistics Service)

## Study Area

- Lower Boise River Basin, or the Treasure Valley
- The area contains a diverse array of agricultural products.
- Rapid population growth and displacement of agricultural lands
- Relies on irrigation to water crops

## Methods

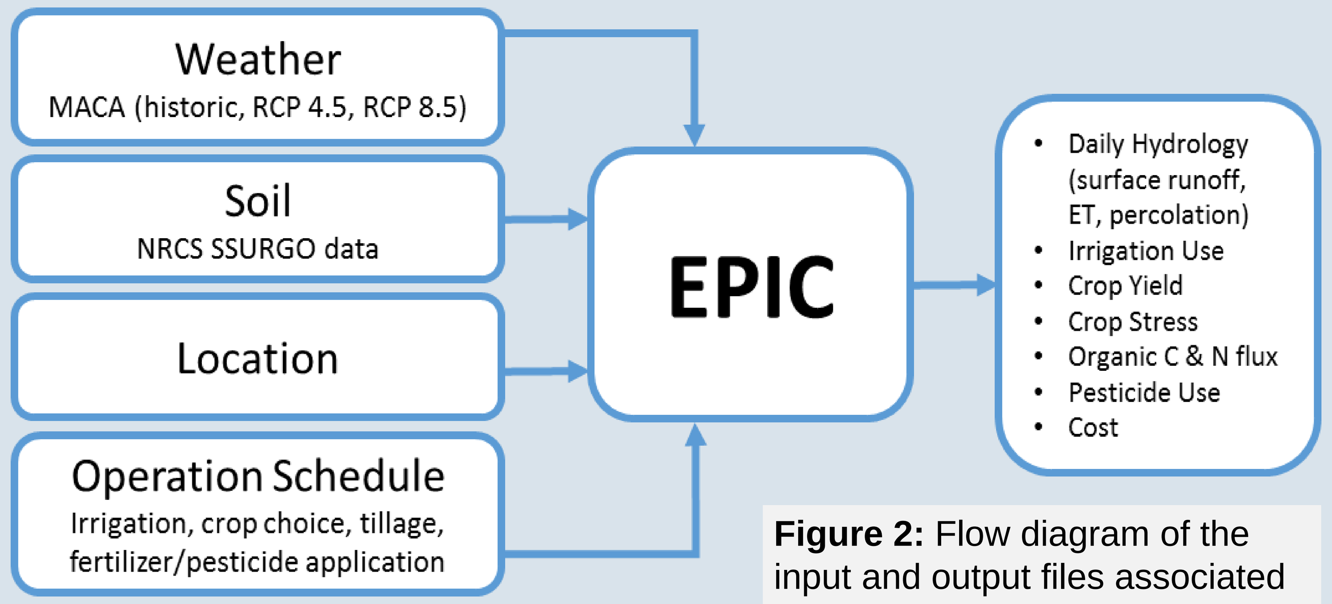
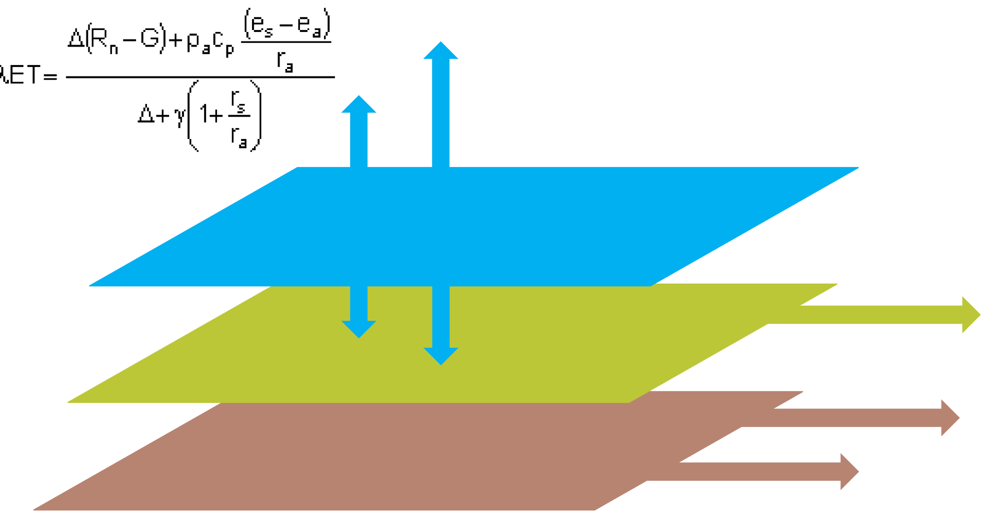



**Figure 2:** Flow diagram of the input and output files associated with the EPIC model

- Utilizing a crop simulation model (EPIC) to run point-based simulations of farms in the Lower Boise River Basin (LBRB)
- Process-based model that simulates biophysical and chemical processes that occur in the soil and water of an agricultural field or watershed (Sharpley and Williams, 1990)
- By alternating climate projections (historic, RCP4.5, and RCP8.5) and management in the model, we develop a suite of scenario analyses that represent a range of alternative futures
- Management capabilities include irrigation type, fertilizer application, crop rotations, pesticide application, and tillage
- Uses 57 crop growth parameters to model 137 different crops

**Evapotranspiration:** Penman-Monteith

$$\lambda ET = \frac{\Delta(R_n - G) + \rho_a c_p \frac{(e_s - e_a)}{r_a}}{\Delta + \gamma\left(1 + \frac{r_s}{r_a}\right)}$$



**Irrigation**: scheduled or based on soil moisture deficit (can choose between drip, sprinkler, furrow, or on-site reservoir irrigation)

**Crop Growth:** based on daily heat unit accumulation

**Surface Runoff:** NRCS TR-55 peak runoff rate equation

**Infiltration:** Green and Ampt

$$\int_0^{F(t)} \frac{F}{F + \psi\,\Delta\theta}\,dF = \int_0^t K\,dt$$

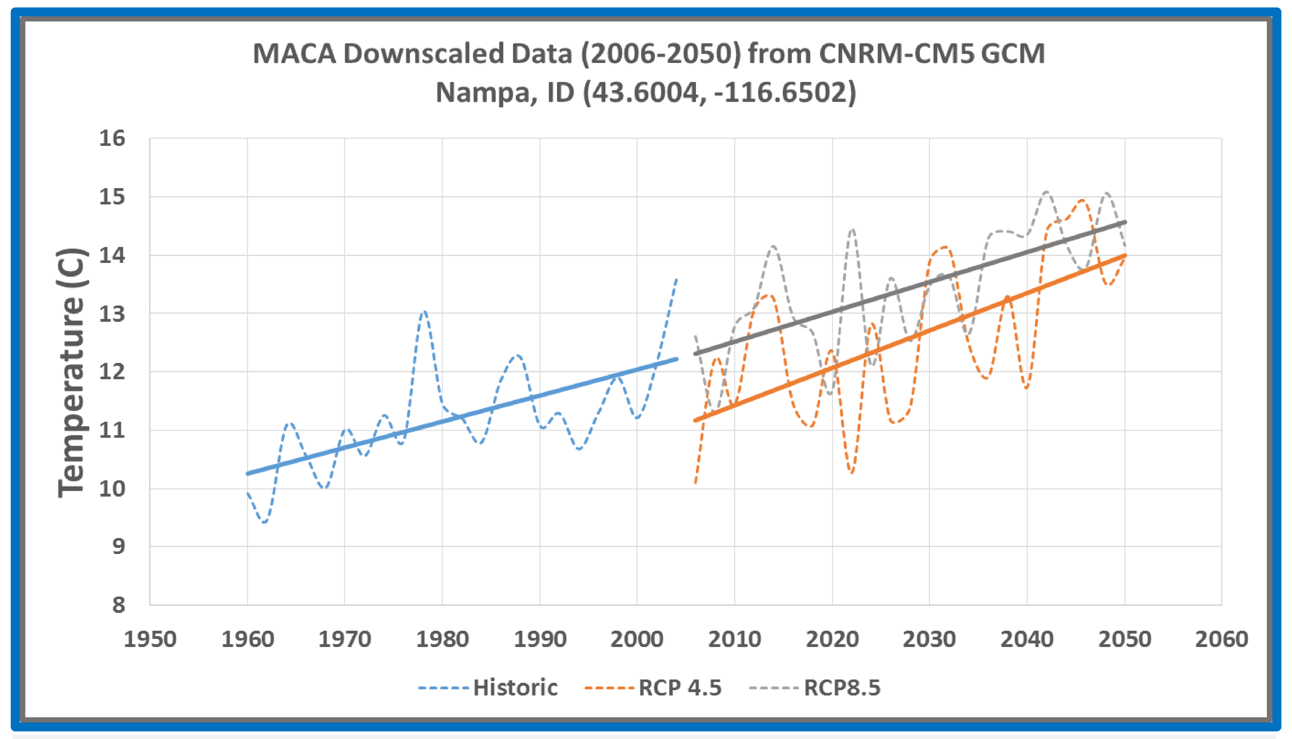



**Figure 3:** Average Temperatures with RCP 4.5 and RCP 8.5 climate projections using the CNRM-CM5 GCM. Plotted with downscaled historic trends from point-based MACA data.

We apply statistically downscaled (MACA) climate data using the CNRM-CM5 Global Climate Model, which is cited to be the most predictive of Pacific Northwest climate (Rupp et al., 2013).

Our model will be validated using observed historic yield data from the National Agricultural Statistics Service (NASS)

## Future Work

## Broader Impacts

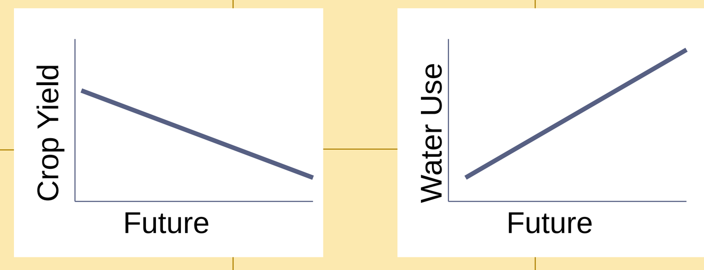
| | Historic Trends | RCP 4.5 | RCP 8.5 |
|---|---|---|---|
| Management Scenario 1 | **Crop yield** and **water use per unit area** under differing **management** and **climate** | | |
| Management Scenario 2 |  | | |
| Management Scenario 3 | | | |



**Figure 4:** Chart of alternative future outputs of our EPIC model. Each permutation of management and climate will have an associated crop yield and water use per unit area

- In order for our model to be useful to stakeholders, it is important to include management activities that are being implemented in the TV
- Irrigation requirements for the future need to be quantified in order to alter and allocate water rights in the TV
- The ability to quantify these changes is crucial in order to address adaptation plans and on-farm conservation efforts to keep up with food consumption


Sharpley, A.N., and Williams, J.R. (1990). EPIC- Erosion/Productivity Impact Calculator: 1. Model Documentation. *U.S. Department of Agriculture Technical Bulletin*. no.1768

Rupp, D.E., Abatzoglou, J.T., Hegewisch, K.C., and Mote, P.W. (2013). Evaluation of CMIP5 20th century climate simulations for the Pacific Northwest USA. *Journal of Geophysical Research: Atmospheres*. 118, 10,884-10,906

Schlenker, W., and Roberts, M.J. (2009). Nonlinear temperature effects indicate severe damages to U.S. crop yields under climate change. *PNAS* 106 (37) 15594-15598