Agricultural Production Decisions and the Welfare Effects of Changes in the Level and Timing of Snowmelt in the Western U.S.

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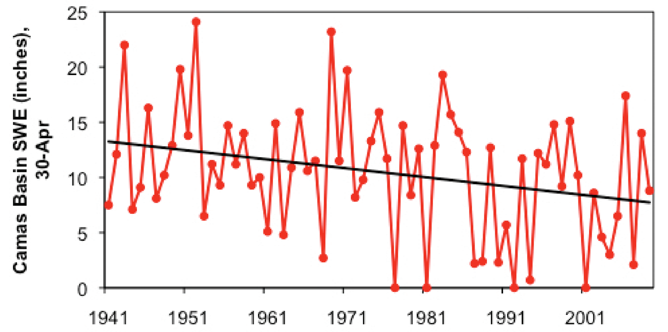
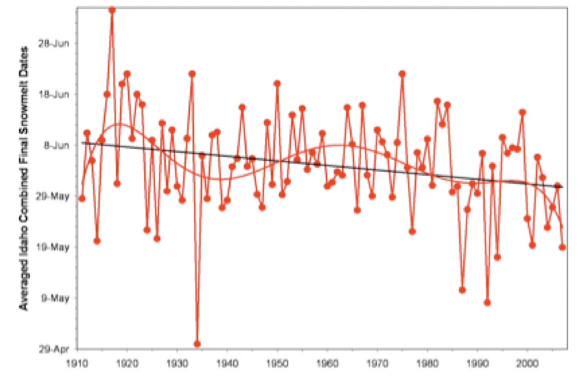
Introduction & Background

Agricultural production decisions in arid areas of the U.S. Intermountain West are highly dependent upon irrigation water availability during crucial portions of the growing season. Changes in the timing, type, and magnitude of winter precipitation events affect the availability of irrigation water throughout the growing season.

Climate change has two anticipated effects on snowpack:

1. Changes in the mix of winter precipitation events and in temperatures may affect snowpack **levels** and hence water available for irrigation.





(Figure Kunkel and Pierce 2010)

2. Climate change may concentrate snowmelt into a shorter period of time early in the season, altering the **timing** of water availability (Kunkel and Pierce 2010).

This second effect, changes in the timing of snowpack runoff, is hypothesized by climate change scientists to be the more salient impact of the two.

Changes to the timing and magnitude of stream flow affect irrigation water availability and, in turn, crop selection and management decisions. We use a model of individual producer decisions to examine adaptation to changing climatic conditions and the welfare effects of two types of water availability scenarios.

Problem Statement & Objectives

Climate change may alter the abundance and timing of water available for agricultural production. Producers may change land use, crop selection or irrigation choices to accommodate altered precipitation regimes.

Our objectives are to:

1. Develop a theoretical framework describing the optimal use of irrigation water under alternative water availability scenarios.
2. Create an empirical model of irrigation water use throughout a growing season.
3. Estimate changes in irrigation water use in response to changes in the level and timing of water availability.

Objective 1: Theoretical Framework

We begin with a discrete-time, finite horizon, dynamic water allocation problem for a single risk-neutral producer with a fixed land allocation.

The objective function is:

$$\max_{w_{c,t}} \sum_{t=0}^{T}\sum_{c=1}^{C}\left\{\left[\frac{1}{(1+r)^t}\right]\cdot \pi(y_{c,T},w_{c,t},t)\right\}$$

where $\pi(y_{c,T},w_{c,t},t) = A_c \cdot p_c \cdot y_{c,T} - \sum_{t=0}^{T} A_c \cdot m \cdot w_{ct}$

The producer maximizes discounted profit at harvest, which is a function of crop yield (*y*), the land allocation (*A*), and irrigation applications throughout the growing season (*w*).

Additional definitions:

- *c* indexes crops in the producer's choice set
- *t* indexes time periods during the growing season; harvest occurs at *T*
- *p* is the per-unit farmgate price of crop *c*
- *m* is the constant marginal cost of applying one inch of irrigation water
- *r* is the discount rate

Reducing irrigation from the amount that produces the maximum yield reduces yield in future periods via the equation-of-motion:

$$y_{c,t+1} - y_{c,t} = g(y_{c,t}, w_{c,t}, t)$$

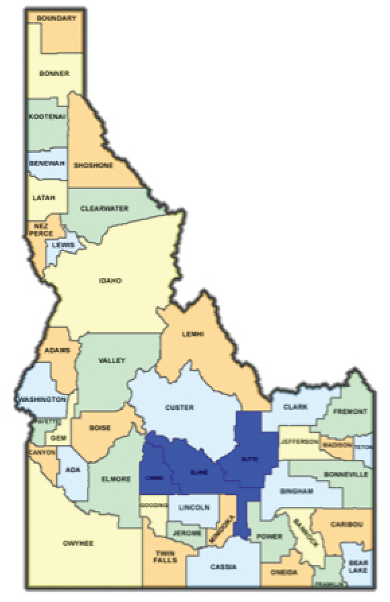
The producer also faces constraints on seasonal water use (due to water rights limitations) and period-specific water availability from snowmelt.

Objective 2: Empirical Model

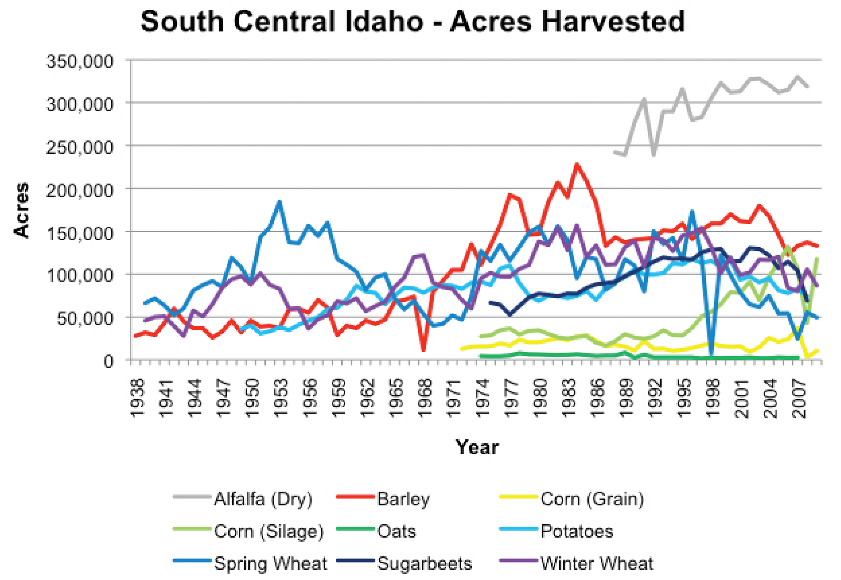
The theoretical framework is adapted to the South Central region of Idaho, an area that is heavily dependent on snowmelt for agricultural production. Crop production activities and initial allocation are chosen based on historical crop production and cost and return studies (Paterson and Gray 2009).

The representative producer cultivates 1,800 irrigated acres with a baseline allocation of land as follows: 450 acres in spring wheat, 450 acres in potatoes, 450 acres in sugarbeets, 150 acres in dry beans, and 300 acres in corn for grain.

The suite of potential enterprises are spring wheat (irrigated, dryland), potatoes (irrigated), beets (irrigated), beans (irrigated), corn for grain (irrigated), barley (irrigated, dryland) and alfalfa with 4 cuttings/year (irrigated, dryland).



Area of Study



Yield response functions by crop are specified as in Martin, Gilley, and Supalla (1989):

$$y = y_d + (y_m - y_d)\left[1 - \left(1 - \frac{I}{I_m}\right)^{\frac{1}{\beta}}\right]$$

Where y_d is dryland yield, y_m is maximum potential yield, I represents actual water applications, I_m is the water application that results in the maximum potential yield, and β is irrigation efficiency.

References

Kunkel, M.L. and J.L. Pierce. 2010. "Reconstructing snowmelt in Idaho's watershed using historic streamflow records," Climatic Change 98: 155-76

Martin, D.L., J.R. Gilley, and R.J. Supalla. 1989. "Evaluation of Irrigation Planning Decisions," *Journal of Irrigation and Drainage Engineering* 115(1): 58-77.

Patterson, P. and C.W. Gray. 2009. "Southcentral Idaho: Magic Valley Roundup Ready Field Corn," University of Idaho College of Agricultural and Life Sciences publication EBB3-FC-09.

Acknowledgements

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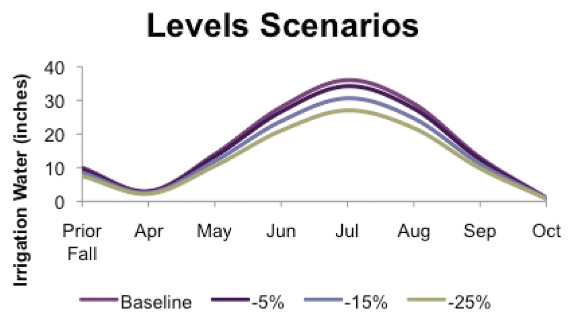
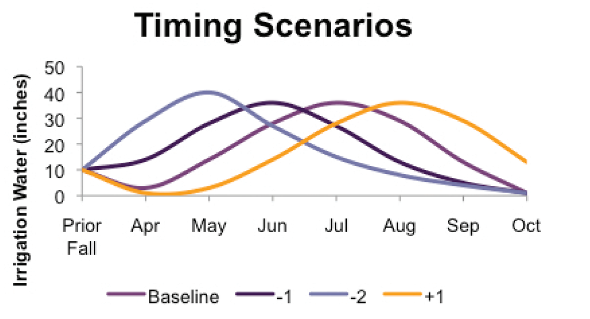
Objective 3: Results





Scenario		Total Water Availability (in.)	Water Use (in.) Spring Wheat	Potatoes	Sugarbeets	Beans	Corn	Total	Profit ($m.)
Baseline		134	22	28	33	19	32	134	1.96
Levels:									
	-5 %	127.3	21.85	28	32.95	19	25.5	127.3	1.78
	-15 %	113.9	21.45	28	32.85	19	0	113.9	1.72
	-25 %	100.5	0	0	32.75	19	0	51.75	0.52
Timing:									
	+1 month	134	0	28	0	19	0	47	1.12
	-1 month	134	22	0	32	19	0	73	0.73
	-2 month	134	22	0	0	19	0	41	0.29

Reducing water levels reduces irrigation of spring wheat and corn. Of the crops considered, corn yields the lowest return to irrigation. Spring wheat can be produced on dryland, with a yield of 17 bushels/acre compared to 110 with irrigation.

The timing scenarios shift the peak timing of water availability earlier (–) or later (+) in the season. Earlier timing leads to the elimination of irrigation for potatoes and corn (−1), followed by sugarbeets (–2). A dearth of water late in the season reduces the yield of potatoes, sugarbeets, and corn substantially. Beans have the lowest water requirement, the timing of which is concentrated mid-season, and so receive full irrigation in all scenarios.

Profit decreases relative to the baseline in all scenarios. The results suggest that the decline in profit from earlier snowmelt corresponds to the loss associated with a 20-25% decrease in water levels.

Discussion & Conclusions

Climate change and its impact on snowpack and surface water availability, alters the return to land in alternative cropping enterprises. Historically, snowpack levels have varied more than snowmelt timing. Since 1941, the snow water equivalent in the study area fell by greater than 25% below the long-run average 27.5 percent of the time. In contrast, snowmelt occurred one month earlier than the long-run average 5.8 percent of the time. Historically, the producer-welfare impacts associated with changes in water levels have dominated those associated with timing changes. The relative importance of these two effects in the future depends on anticipated changes in the relative frequency of the two events.