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Climate Change, Water Supply, and Agriculture in the Arid Western United States: Eighty Years of Agricultural Census Observations from Idaho

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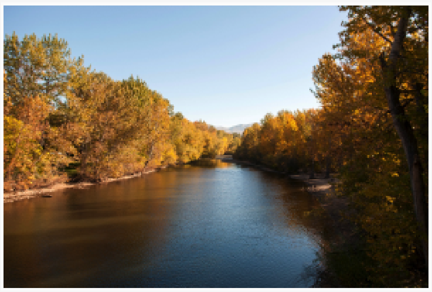

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As the population and agricultural development in the U.S. expanded west throughout the 20^{th} century, major water infrastructure projects were initiated in order to meet irrigation demand and to reduce the risk and uncertainty associated with highly variable water supplies.[2] Agriculture in the arid and semi-arid western U.S. is particularly vulnerable to variability in water supply, and has evolved to rely heavily on major water infrastructure projects.[3] In 2007, of the 57 million acres of irrigated cropland and pastureland in the U.S., nearly three-quarters was in the 17 western-most contiguous states; in 2008, irrigated agriculture applied 91.2 million acre-feet of water, with over four-fifths being used in the arid west.[4]

Although these water infrastructure projects were perceived to be a boon to agriculture, they also brought about a number of environmental concerns such as modifications to flow rates and impacts to native fish populations. Utilizing data from the state of Idaho, we evaluate the agro-ecological impacts of water infrastructure development in the Western U.S. We focus on economic impacts, such as land use and crop productivity, as well as ecological impacts such as in-stream flow rates.

Access to irrigation water in the arid and semi-arid west, based on the hierarchical system of appropriative water rights, resulted in a number of different economic outcomes. With additional water supplies, existing farms could potentially grow more water-intensive crops (changes in the crop mix), increase the productivities (yields per acre) of the crops that they were already growing, and expand their existing cropland acreage. In the long run, all else equal, farmers would be better able to respond to periods of drought with increased access to irrigation water sources.

However, as new dams were constructed, agriculture expanded and was established on lands that were otherwise not used for farming. Farmland expansion certainly increases the total acreage in production, but may have indeterminate effects on the productivity and variety of crops that are grown. In addition, the development of major water infrastructure could result in a spatio-temporal transfer of water resources from the cold (non-agricultural) season to the warm (agriculturally-intensive) season, which could exacerbate the infrastructure's already tenuous ecological impact.

It is important to note that the potential impacts of increased access to irrigation water could be strongly influenced by the seniority of the water rights that are held by irrigators.[5,6] This means that the additional water made available through increased storage capacity is not equally allocated to every water user, and thus we expect to see highly heterogeneous impacts on land use decisions of farmers.

To evaluate the role that major water infrastructure has played in altering agricultural composition and productivity levels, we specify models to estimate the impact of major water infrastructure on crop mixes, crop outcomes, and farmland values, using a rich dataset of county-level agricultural census observations over the past 80 years. We hypothesize, *ceteris paribus*, that following the completion of a major water storage project in the relevant county that the total cropland, cropland productivity and the portion of water intensive crops will increase. We also anticipate that the total revenue and farmland values will increase if the new water supplies are allocated to existing farms.

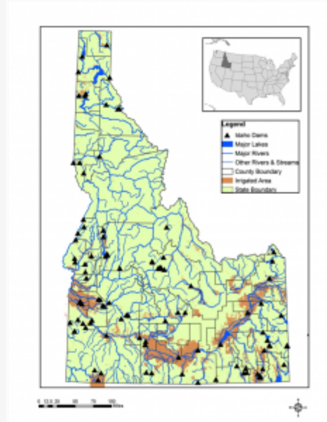

Figure 1. Spatial Distribution of irrigation dams in Idaho

However, at the other end of the spectrum, if the new water supplies are allocated to new farms on marginal lands, we may observe per-acre yields that are similar to or even below those of the existing water users with senior rights to surface water, and thus the mean value of the farmland may actually decrease. Finally, we hypothesize that the presence of a dam will result in reductions in stream flow and increased variability, which will severely impact ecosystem services and endanger the natural riparian habitats.

Our results indicate that the presence of major water storage infrastructure resulted in positive and statistically significant impacts on county-level crop water-use intensities, productivities, and on the total cropland acreage over time. We observe that when faced with increased water availability, both new and existing farms increased their share of higher-valued and more water intensive crops. We also observe that the presence of a major water storage project had a generally large, positive productivity effect, and that this effect was particularly strong during periods of severe droughts, for some, but not all crops in Idaho. For example, dams increased the productivity of barley production by 18.4% (or ~429.87 kg/hectare). This effect is economically significant. With an average of ~2,340 kg/hectare, and an average 2013 commodity price of $0.29/kg for barley, the total per-county revenue from barley is estimated to be $3.2M per year.

In contrast to the traditional literature, which posits that infrastructure improvements increased the value of farmland in the arid and semi-arid western U.S., our results indicate that the presence of a dam has a positive, but non-significant effect on farmland values.

In addition to financial benefits, we find that the construction of major dams in Idaho spatiotemporally transferred water resources between cold and warm seasons, reduced the portion of water resources available to in-stream uses, and increased the seasonal variability in water supplies, thus negatively affecting the natural environment.

Using descriptive statistics of stream flow by analyzing two reaches of the Snake River Basin–Neeley and Milner– we show that the observed stream flow have a narrower range of variation than the expected “natural flow” conditions if there were no dams and no water transfer across seasons. This is particularly true during the warm season (April-September), when we observe a significantly higher volume and narrower range of variation in stream flow. In contrast, the observed stream flow during the cold season is more volatile, with lower volumes. The dramatic differences in the seasonal features of stream flow reveal the role of dams in transferring water and stabilizing water supply, primarily for the purpose of irrigation.

In summary, the models that we present in this paper rely on major water infrastructure that was present or was constructed, and environmental outcomes that occurred during the 1920-2000 timeframe. We find that the presence of the dams is highly correlated with the spatial and temporal transfer of water resources, with increased volatility of water supply, and with the reduction in water supply made available for ecosystem uses. The interpretation of these models is that, given future climate scenarios and anticipated outcomes (for example, more variable streamflow volumes and runoff dynamics,) we expect these outcomes to continue. Moreover, under the direction of future infrastructure development in the state (Idaho is one of the few states in the arid western U.S. in which currently has new dams on the agenda,) our models would suggest that the human-induced volatilities in water supplies may increase.

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