A Field Level Economic Model of Regional Agricultural Production

A well implemented smart market for trading agricultural water rights has the potential to reduce transaction costs and incentivize ecologically beneficial trades. This research introduces a new field-level, calibrated economic agricultural production model for evaluating transfers of water rights within a district in response to a cut in water supply, under different water market structures.

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This research highlight is based on work in progress.

The differences across fields in crop response to water and fertilizer use have long been acknowledged but disregarded in aggregated data. Given the rapidly growing supply of geospatial information due to improvements in data handling and remote-sensing capabilities, we now have detailed field-level information on crops grown, the age of perennial crops, soil types, ownership, and water use by year and parcel. However, field-level economic data has not kept pace with the proliferation of field-level biophysical data. This has limited its application in calibrated economic modeling.

Advancements in geospatial data allow us to improve the spatial resolution of our calibrated economic models down to the field model, which allows us to evaluate resource and agricultural policy, including alternative water market structures, to support water management under increasing water scarcity. In this research manuscript, we develop an integrated modeling framework that extends the calibration methods for economic models of agriculture and water management in Howitt et al. (2012) to field-level physical outputs. This allows us to directly couple economic and physical outcomes, which is essential for designing effective water markets and water policy.

We developed a three-step process that calibrates a regional agricultural production model, applies that model to evaluate trading (or other resource policy), and couples the model with a field-level machine learning model. This allows us to evaluate the supply and demand for water, and resulting trades, and then extend those results down to individual fields.

The calibrated economic model applies improved methods for simulating permanent crops,

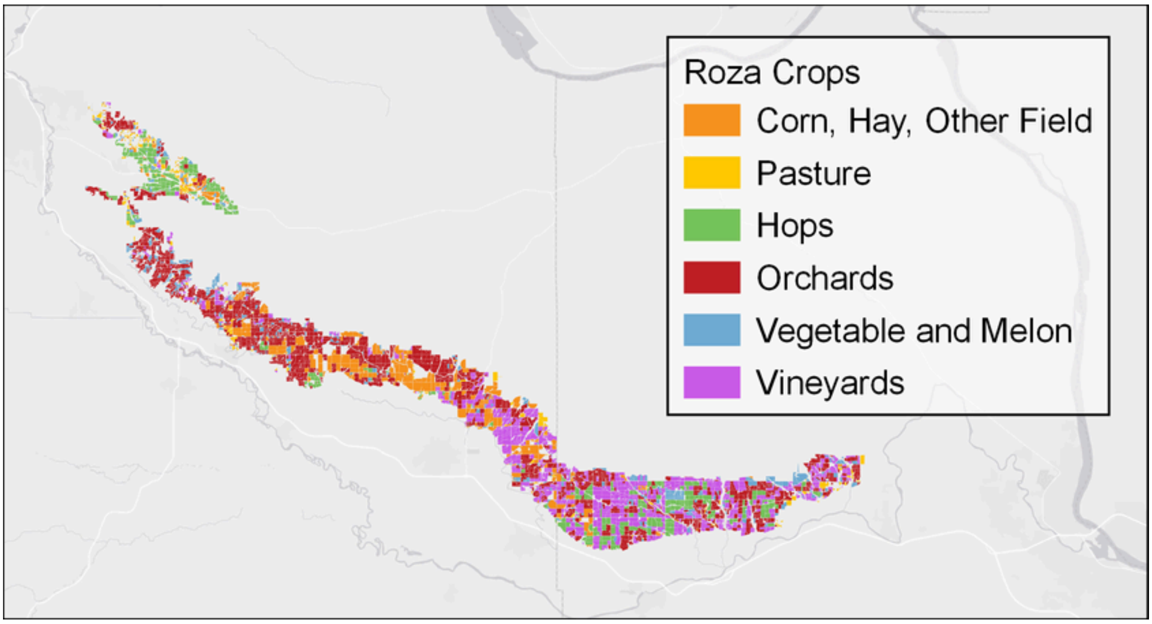

Figure 1. Spatial distribution of cropland allocation for major crop types in the Roza Irrigation District.

which explicitly incorporates the capital value of the orchard and its associated removal costs. The calibration method applies the most current advances in Positive Mathematical Programming. The formulation uses a CES crop production function specification for the farm with decreasing returns to scale.

The machine learning model uses geospatial field data to train a model that predicts where crops are likely to be grown as crop acreages change in response to water shortage and market conditions. The response to water shortage is evaluated using the calibrated economic production model. This combined model, which we call the Field Level Optional Water Allocation Model (FLOW), allows us to evaluate/design water markets in terms of economic and physical/spatial criteria. We illustrate the framework with an application to current policy/management issues in the Yakima Basin. We discuss natural ways to extend this framework as additional economic data (and more physical data) becomes available.

Figure 1 illustrates the spatial coverage of the FLOW model and crop mix in the region. The model coverage includes the entire Yakima Basin. The economic model is calibrated at the region (district) level. The machine learning model is trained/estimated using field-level data. The combined framework is applied to evaluate water trading policies between districts and by individual fields within districts.

The model framework is applied to the Yakima Basin to illustrate outcomes under different water trading/market structures. Since localized in-stream flow rates have substantial effects on local ecosystems, the environmental and economic benefits of different trades depend on the location of the trade as well as the volume of the trade. The Yakima River Basin Study has provided detailed information on the importance of certain stretches of river flow and the proximity of fields trading water to those stretches of river. We quantify these interactions with a “payment score” for comparing trades that occur at different times and stretches within the river. We apply the FLOW model to evaluate policies that incentivize environmentally preferential water trades.
A natural extension of the analysis described in the manuscript is trading within groundwater basins. California is implementing the Sustainable Groundwater Management Act (SGMA), which will limit groundwater extractions

in many parts of the state. Groundwater markets are being considered in some areas. Effective groundwater market design requires integrating the market response (trading and fallowing location) with hydrogeologic groundwater models of the subbasin. The groundwater models require spatial data about the location and timing of groundwater pumping. The FLOW model can provide this input and improve modeling of groundwater market outcomes, and groundwater market design. This will be explored as part of future research.

Richard Howitt is Professor Emeritus in the Department of Agricultural and Resource Economics and faculty member in the Center for Watershed Sciences at the University of California Davis. Richard co-founded ERA Economics in 2013 and has more than four decades of experience in agricultural, resource, and environmental economics. He has published extensively on water markets, hydroeconomic modeling, and resource management issues in California and across the western U.S.

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Michael P. Brady, Ph.D., is an Associate Professor and Extension Economist (specialty crops) at the School of Economic Sciences at Washington State University. Dr. Brady is interested in modeling coupled human and environmental systems related to water use and irrigated agriculture in an interdisciplinary framework. This includes farmland ownership, agricultural land values, and land use change for specialty crop (tree fruits, vineyards, vegetables, horticulture, and nursery crops) production.

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