Economics of Accounting for Groundwater Use Under Conditions of Climate Change

James "Jimmy" Palmer, University of Connecticut, and james.palmer_ii@uconn.edu

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Economics of Accounting for Groundwater Use Under Conditions of Climate Change

UCONN COLLEGE OF AGRICULTURE, HEALTH AND NATURAL RESOURCES

James "Jimmy" Palmer[a], Christopher Bruno[b], Farhed Shah[a]

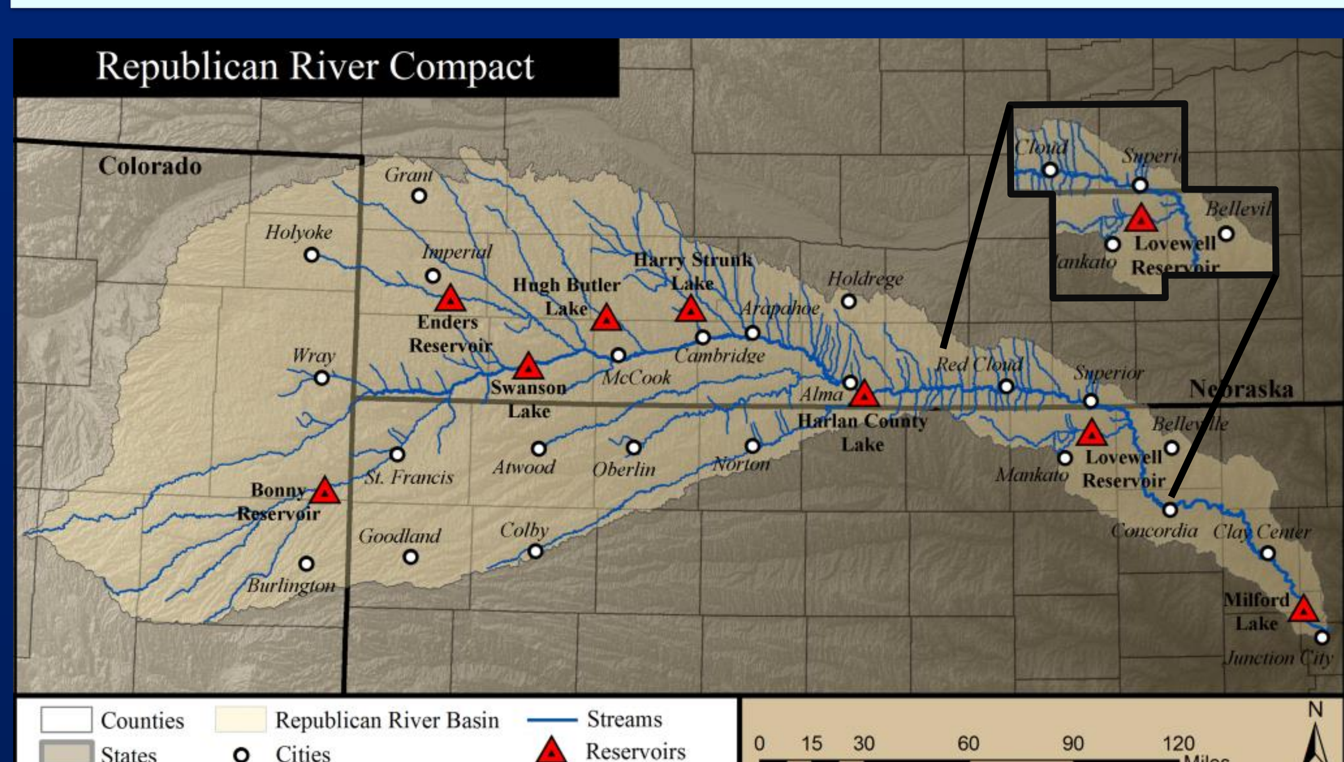
(a) University of Connecticut Agriculture and Resource Economics Department, (b) University of Pennsylvania Management Department

Introduction

Agriculture relying on Republican River Basin withdrawal is challenged by climate change. Predicting the region's water demand provides a tool for resource management.

Withdrawal from the basin is restricted by federal regulations on minimum river flows, an inter-regional compact, and surface water rights. As groundwater and surface water are connected, upstream groundwater overdraft may result in downstream river flow reduction. Compact restrictions have been disputed, with SCOTUS judgement placing liability on the upstream state(s).[1]

Prior economic analysis constructs steady-state constrained optimization models for simulating allocations between the two states withdrawing the most water, Nebraska and Kansas.[2] Such simulations incorporate the above flow restrictions, steady state hydrology, compact restrictions, and surface water rights. Our research extends this work to examine net benefit of withdrawing water under projected climate change. (See Map[3])



Objectives

Estimate marginal benefit of each state's water withdrawal dependent on amount withdrawn and climate variables.

Obtain optimal allocation for individual states and social planner.

Predict change in net benefits from climate change projections and discuss policy implications.

Data

Data spans 1997-2017, sources include:

- USDA Agricultural Census
- PRISM temperature data by way of Schlenker and Roberts.[4]
- NOAA precipitation data
- NEMAC CMIP5 climate simulations projections.
- Kansas Geological Survey and Nebraska Department of Natural Resources water well depth

Methodology

$$WCP_{i,y,c} = \frac{\sum_{crop=1}^{4} P_{crop,i,y} * A_{crop,i,y,c}}{\sum_{crop=1}^{4} A_{crop,i,y,c}}$$

$$PC_{i,y,c} = 3.14 * 12 + 0.007 * 12 * WD_{i,y,c}$$

$$NPW_{i,y,c} = \frac{PC_{i,y,c}}{WCP_{i,y,c}}$$

$$NPW_{y,c} = \beta_0 + \beta_1 Pr_{y,c} + \beta_2 Pr_{y,c}^2 + \beta_3 T_{y,c} + \beta_4 T_{y,c}^2 + \beta_5 TIA_y + \alpha_c$$

$$NB_i = \int NPW_i(Pr_i, T_i, TIA_i)\, dTIA_i - PC_i GW_i$$

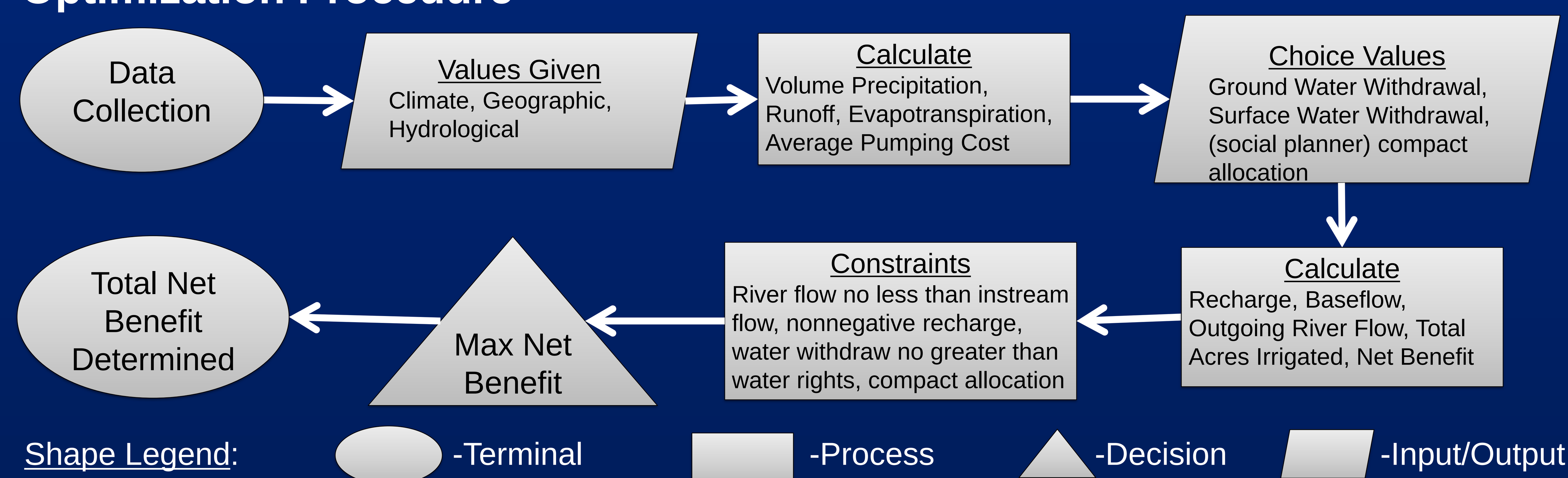
Calculations are on a region (i), year (y), county (c) basis. Crop prices per bushel (P) make up a weighted crop price (WCP) when averaged with harvested area (A) as weights. Pumping cost (PC) is found by a linear relationship with well depth (WD).[5] Normalized price of water (NPW) is water's marginal benefit.

NPW for each region represents a demand for water when regressed on average precipitation (Pr), average temperature (T), volume of irrigated water for region varied by total irrigated area (TIA), and county fixed effects. The net benefit (NB) of each region is the area under their water demand dependent on TIA, deducting cost of groundwater withdrawal (GW).

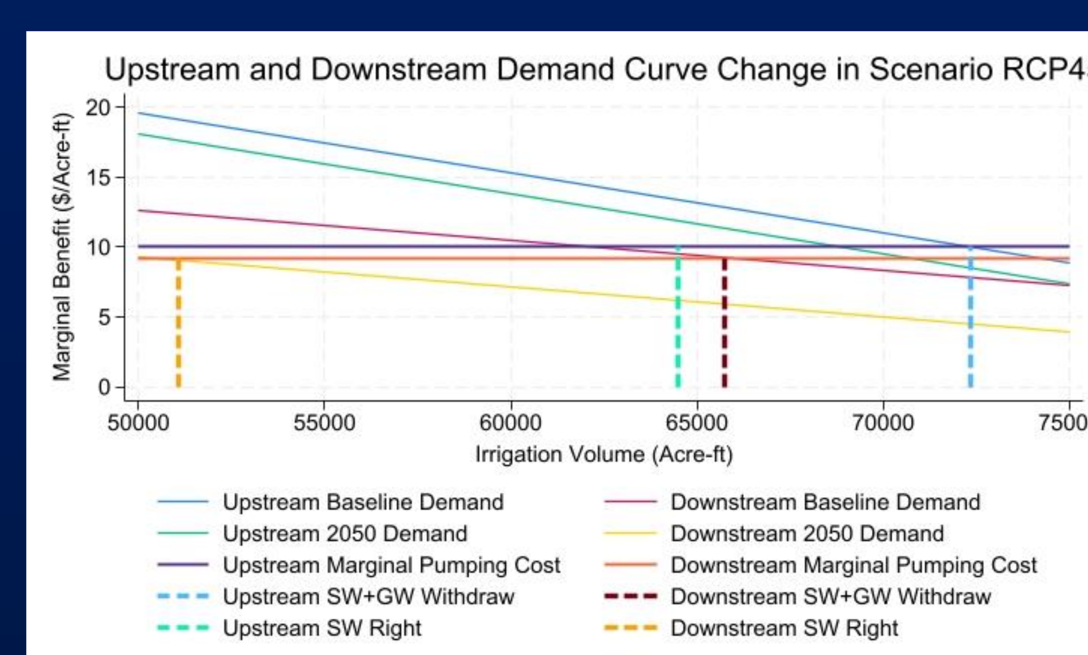
Simulations of compacts with and without groundwater accounting include two scenarios:

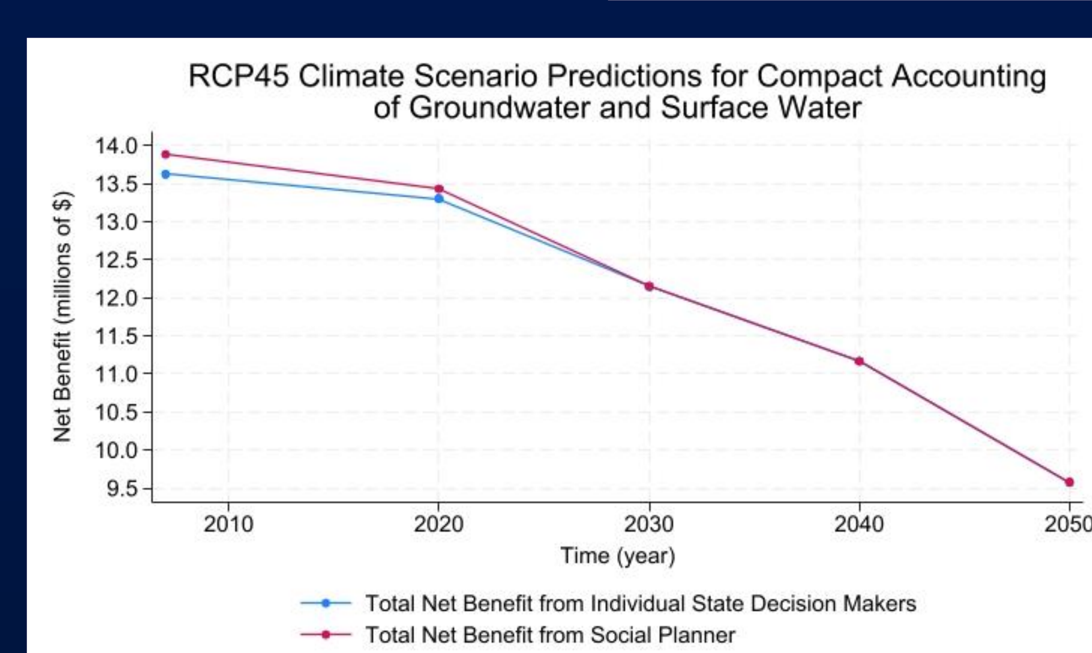
Both states act independently $Max\ NB_1$ & $Max\ NB_2$ **versus** a social planner $\text{Max} \sum_{i=1}^{2} NB_i$

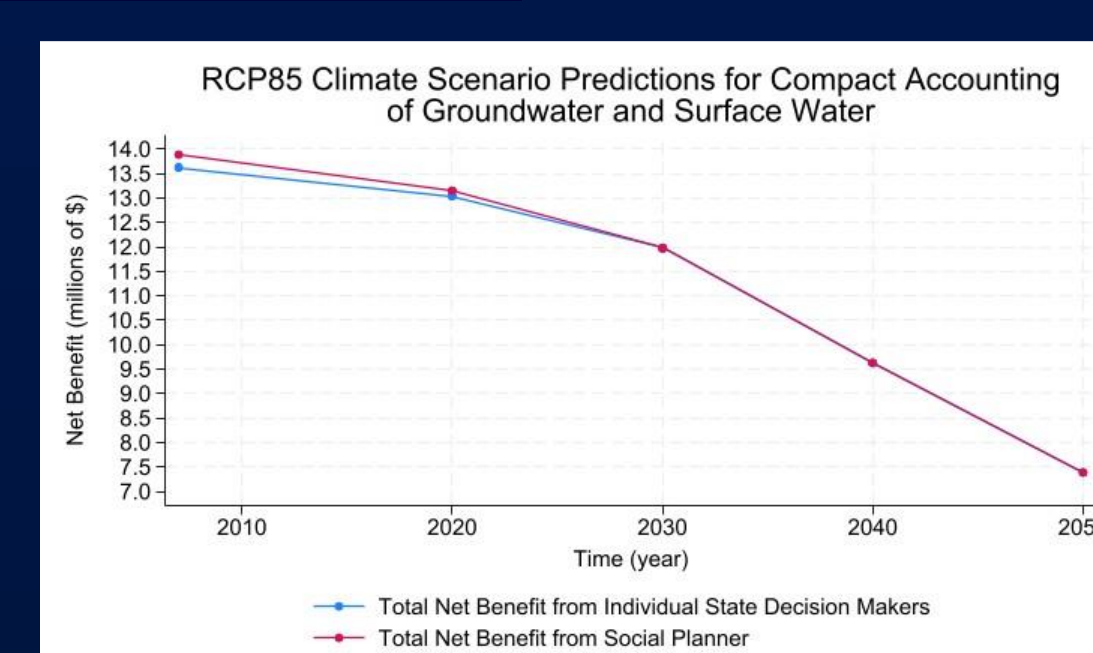
Optimization Procedure



Results







Result and Policy Discussion

Irrigation water demand decreases with climate change's increasing temperature, especially downstream. Downstream groundwater use is predicted to go to zero as temperature increases.

Total net benefit for both decision-making solutions in each climate scenario (RCP 4.5 and 8.5) converge with increasing temperature.

Response to these results include incentivizing adaptation by improving production, not limited by water availability. For example, switching crops to breeds that are resilient to increasing temperatures.

In addition, state policymakers may want to facilitate alternative employment and training opportunities given the likely decrease in agricultural production.

Future Work

Expand dataset to include majority of counties from each state that encompass Republican River Basin.

Provide a dynamic analysis beyond steady-state, allowing for changes in groundwater stock and featuring pumping cost dependence on water depth.

Incorporate predicted effects of climate change on water availability and groundwater hydrology.

Research changes in water demand that may result from adoption of alternative crop breeds.

Generalize model for water systems beyond the Republican River basin.

Citations

1. Kansas v. Nebraska, 574 U.S. 445 (2015)

2. Bruno, C. (2020). *Economics of Inter-Regional Water Compacts with Consideration of Groundwater and Surface Water Interaction: A Case Study from the Republican River Basin*. MS Thesis, Department of Agricultural and Resource Economics, University of Connecticut.

3. State of Nebraska. Department of Natural Resources. (n.d.) *Republican River Compact*, https://dnr.nebraska.gov/water-planning/republican-river-compact

4. Schlenker, W., & Roberts, M. J. (2009). *Nonlinear temperature effects indicate severe damages to U.S. crop yields under climate change*. Proceedings of the National Academy of Sciences of the United States of America, 106(37), 15594–15598.

5. Williams, R. B., Al-Hmoud, R., Segarra, E., & Mitchell, D. (2017). *An estimate of the shadow price of water in the southern Ogallala Aquifer*. Journal of Water Resource and Protection, *9*(3), 289–304.