Center for Agricultural and Rural Sustainability

Spatial irrigation management to sustain groundwater and economic returns

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Introduction

What is the opportunity cost of groundwater conservation to achieve greater economic returns for an agricultural landscape with and without “water-saving” irrigation technologies?

Irrigation storage reservoir

Tail-water recovery structure

Surge irrigation

Center pivot irrigation

Computerized pipe-hole selection

Multiple-inlet rice irrigation

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Introduction

What is the opportunity cost of groundwater conservation to achieve greater economic returns for an agricultural landscape with and without "water-saving" irrigation technologies?

Optimization determines:

- acreage of crops (rice, soybeans, corn, etc.)
- adoption of irrigation technologies subject to water and land availability.
- economic returns and depletion of the aquifer

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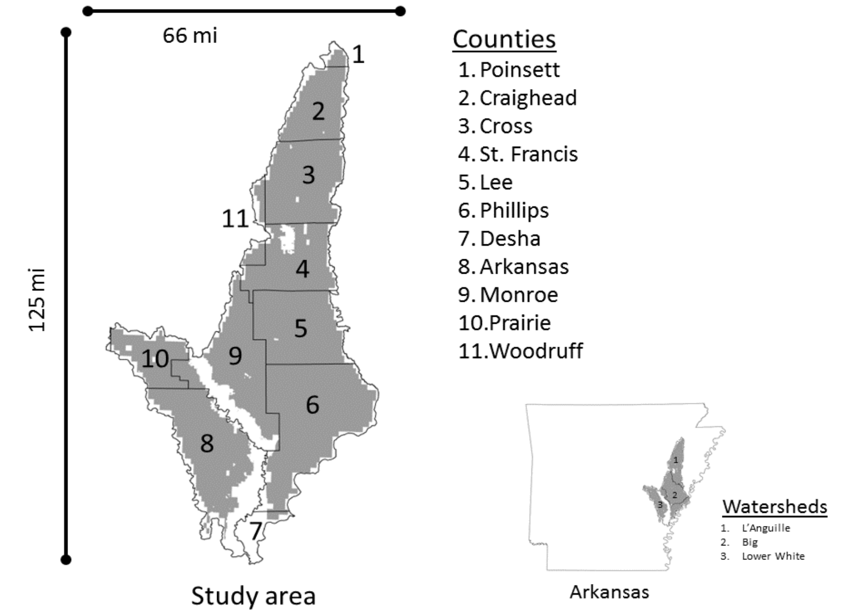

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Land balance equation

$$\sum_j \sum_k L_{ijk}(t) = \sum_j \sum_k L_{ijk}(0)$$

Land demand — Land availability

$L_{ijk}(t)$ = amount of land in cell i in state j using irrigation technology k

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Water balance equation

$$\sum_j \sum_k wd_{jk} L_{ijk}(t) \leq GW_i(t) + RW_i(t)$$

Water demand   Water availability

$GW_i(t)$ = water pumped from the ground
$RW_i(t)$ = water pumped from the reservoir

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Aquifer stock equation

$$AQ_i(t) = AQ_i(t-1) - \sum_{k=1}^{m} p_{ik} GW_k(t) + nr_i$$

$AQ_i(t)$ = groundwater in the aqufier
p_{ik} = groundwater flowing out of site i and into site k
nr_i = natural recharge

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Farm Net Benefits Objective

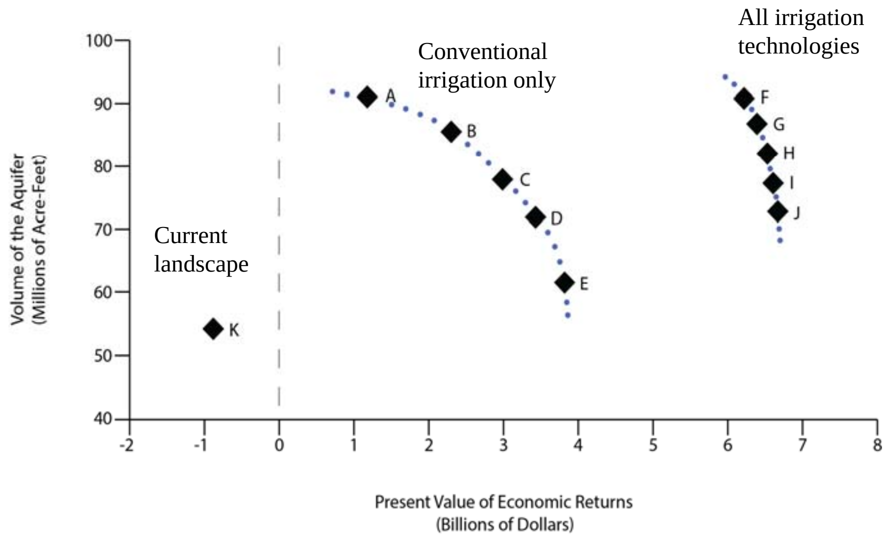
Profit w/o water costs — Reservoir construction cost — Reservoir water pumping cost — Ground water pumping cost

$$\max : \sum_{t=1}^{T} \delta_t \left(\sum_{i=1}^{m} \sum_{j=1}^{n} \underbrace{\left(pr_j y_{ij} - ca_j \right) L_{ij}(t)}_{\text{Profit w/o water costs}} - \underbrace{c^r FR_{ij}(t)}_{\text{Reservoir construction cost}} - \underbrace{c^{rw} RW_i(t)}_{\text{Reservoir water pumping cost}} - \underbrace{GC_i(t) GW_i(t)}_{\text{Ground water pumping cost}} \right)$$

Subject to: constraints of land and water availability.

Results

Efficiency frontiers



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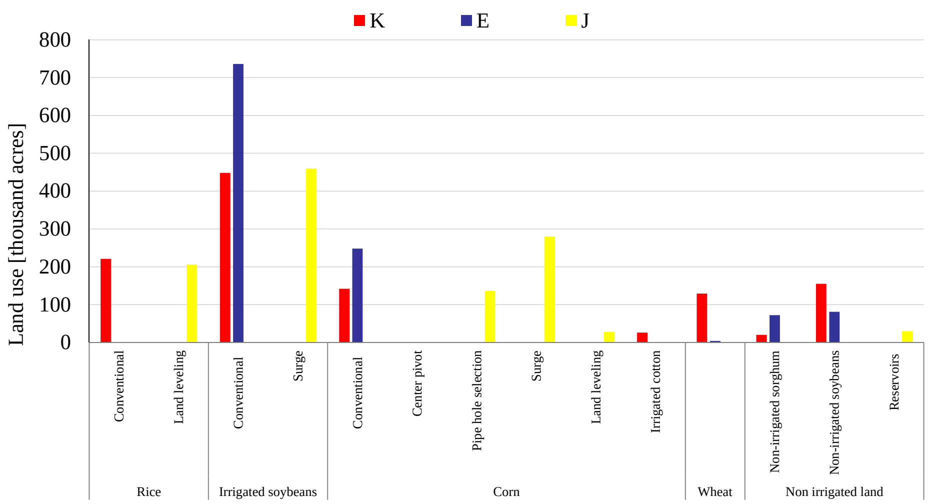
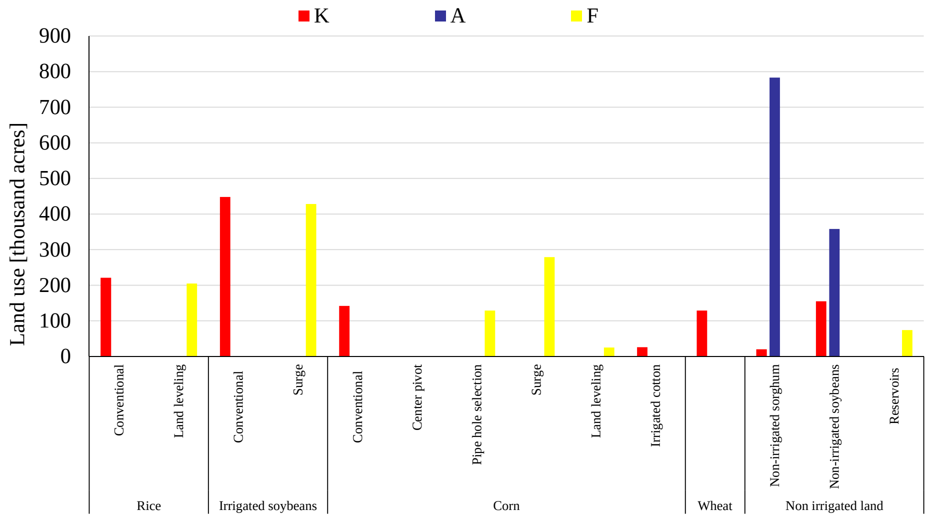
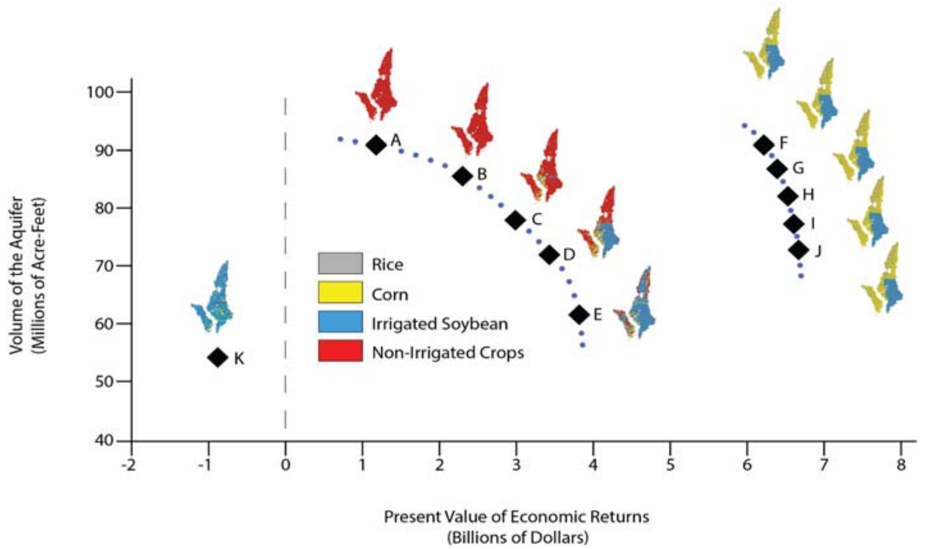
Land use for max profits points on the efficiency frontier



Land use for max aquifer points on the efficiency frontier



Crop mix patterns



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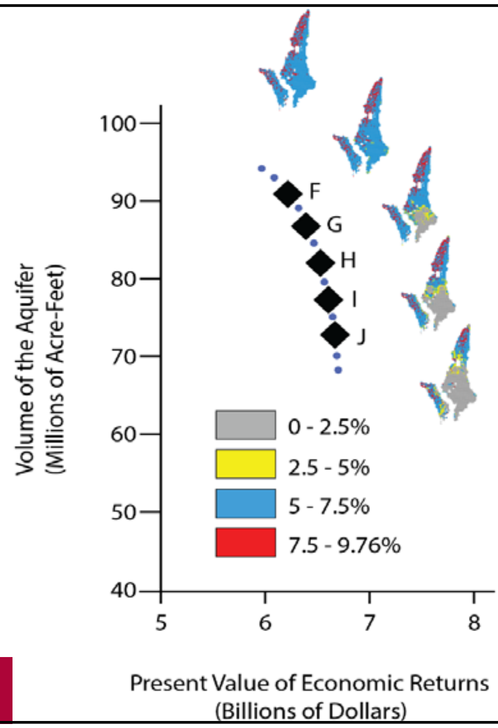
Percentage of land in reservoirs



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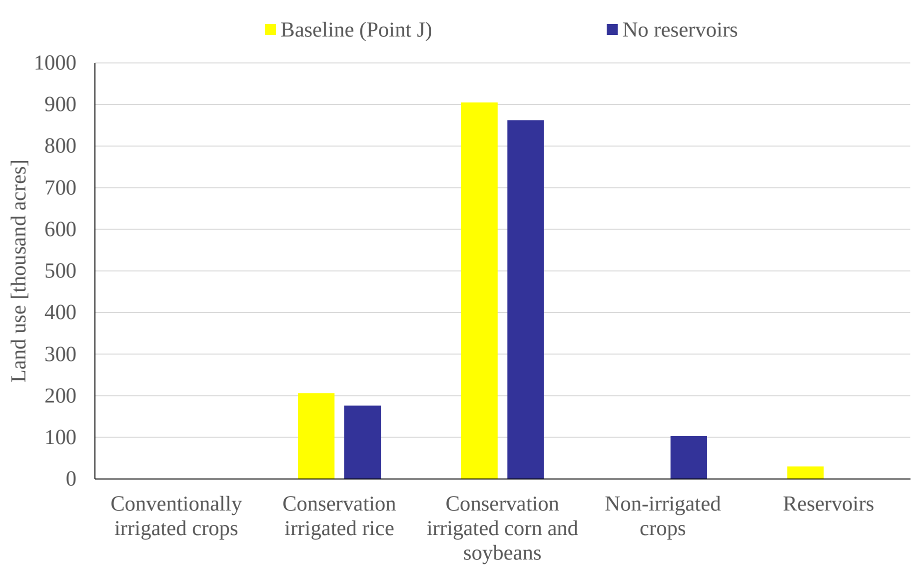
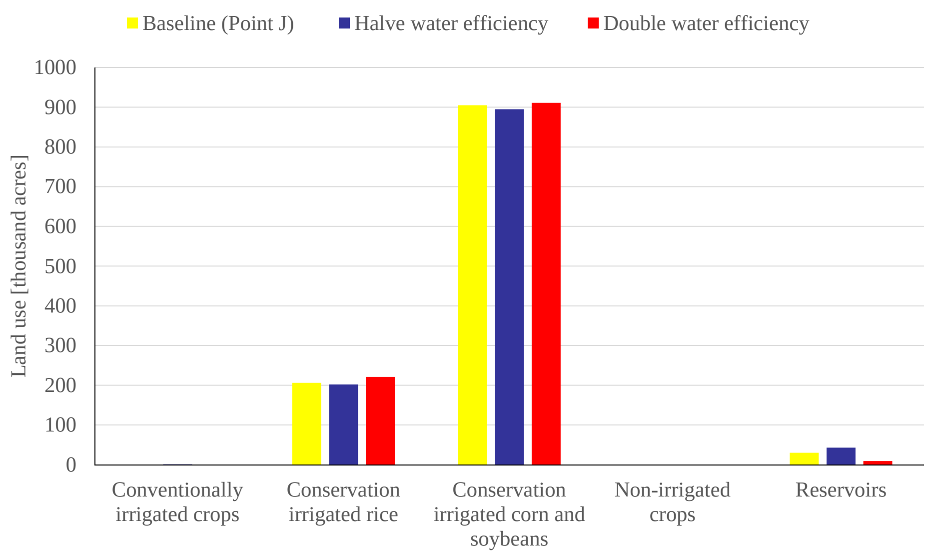
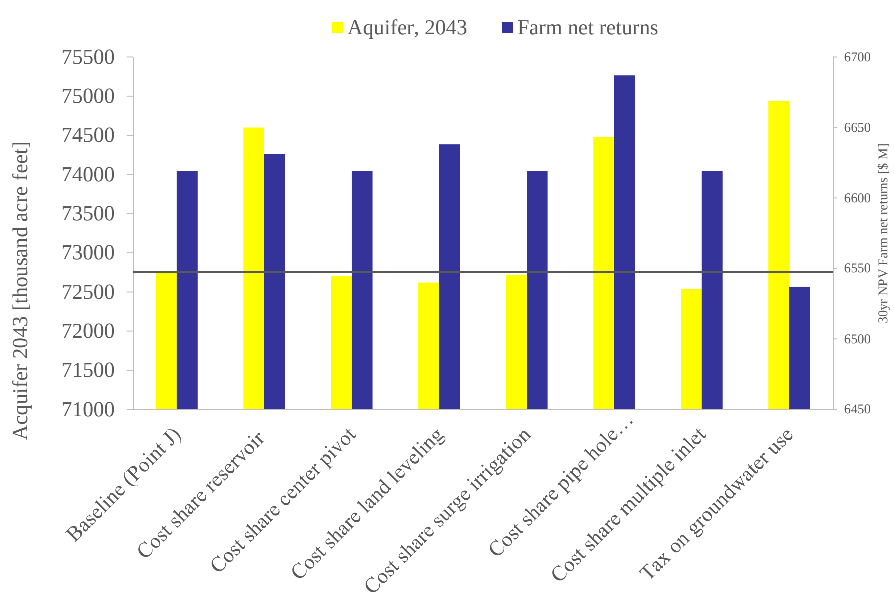
Sensitivity analysis: No reservoirs



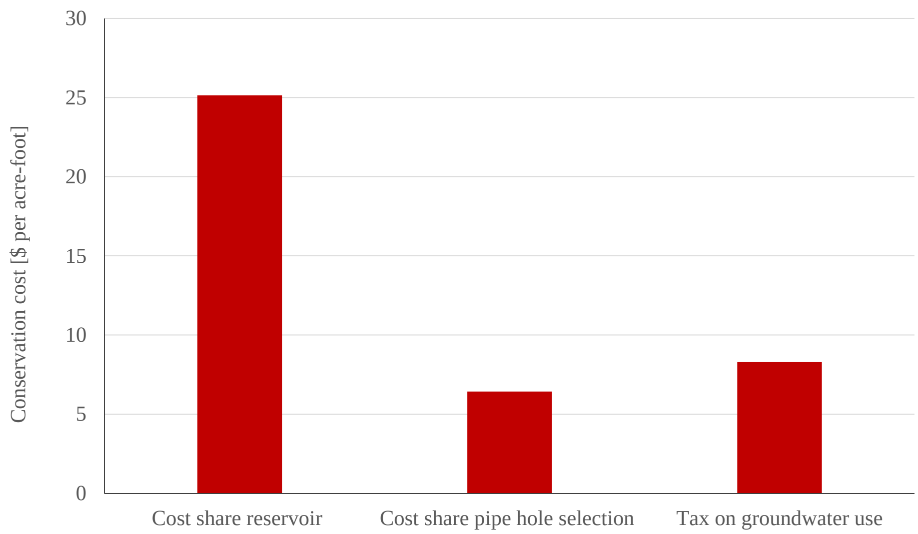
Sensitivity analysis: Irrigation efficiency



Conservation policies



Groundwater conservation cost



Conclusions

- Opportunity cost of groundwater with max profits
  - 71% of max aquifer if conventional irrigation only
  - 79% of max aquifer if all irrigation technologies
- Max profits increase 74% if use all irrigation technologies
- Policies to cost-effectively achieve conservation goal
  - Cost-share pipe hole selection implementation
  - Tax on groundwater

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