Bioenergy as a Bridge: Smart Irrigation Transitions to Conserve the U.S. High Plains Aquifer

Karthik Ramaswamy[1], Nazli Uludere Aragon[1], and Tyler Lark[1,2]

[1]Nelson Institute-SAGE, University of Wisconsin–Madison; [2]Dept. of PSM, Michigan State University

I. Problem & Motivation

i. Groundwater declines in the U.S. High Plains Aquifer (Ogallala) threaten irrigation viability

ii. Depletion raises energy costs, reduces well capacity, and declines farm value

iii. Question: Where does irrigation remain viable vs. could bioenergy & other alternative cropping systems dominate?

II. Objectives

i. Quantify county-level hydro-economic viability of irrigated corn vs. alternatives

ii. Map timing of potential transitions and opportunities, and costs for bioenergy adoption

iii. Identify policy levers to smooth transitions and conserve aquifer life

III. Study Area & Data

i. 180 High Plains Aquifer counties (CO, KS, NE, NM, OK, SD, TX, WY

ii. Representative field: 48.6-ha (120-ac) center pivot on quarter section; well capacities 6.3-31.5 L s^{-1} (100–500 GPM

iii. Inputs: aquifer storage & decline, yields & prices, enterprise budgets, and irrigated land mask

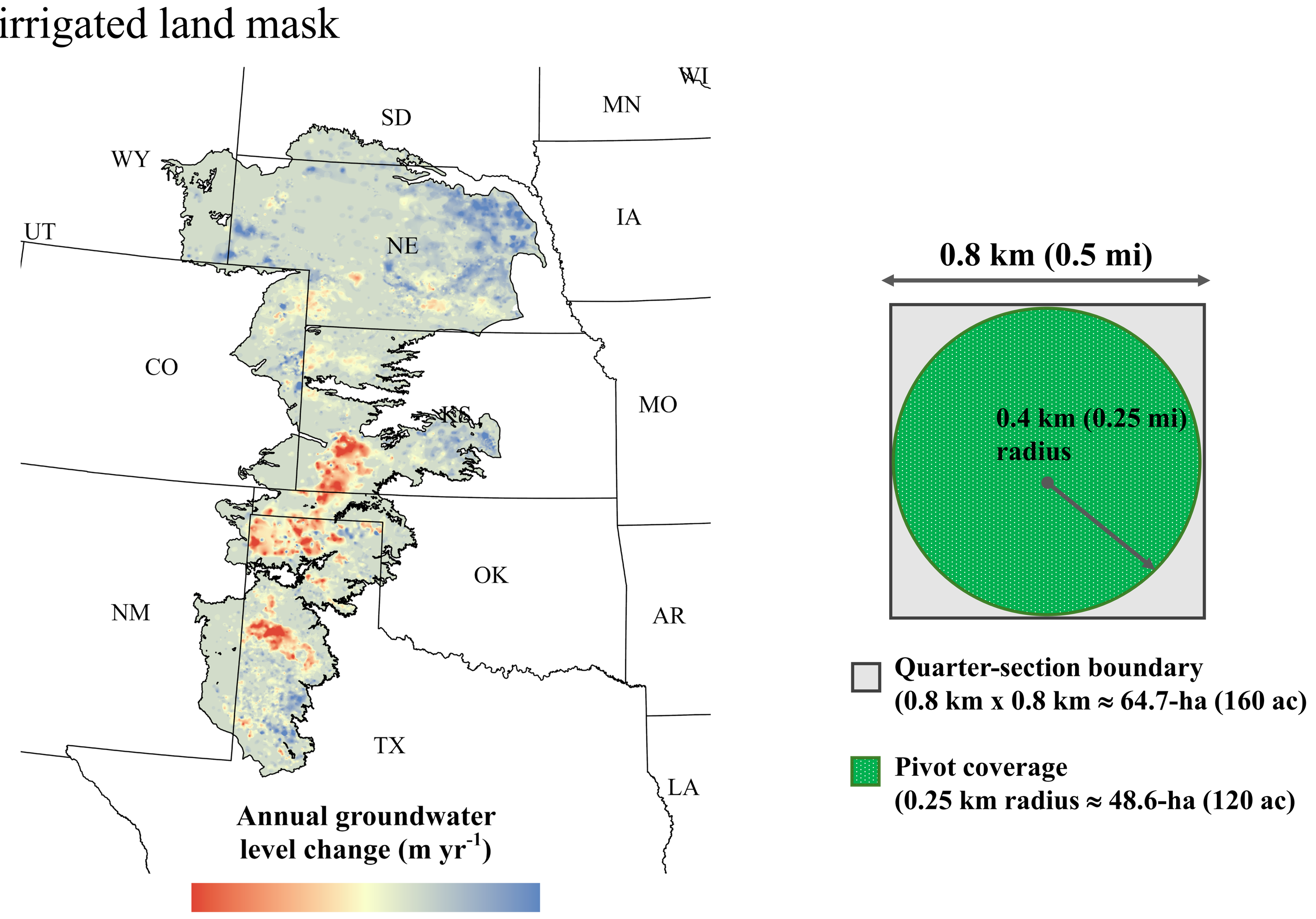

Fig. 1. Spatial variation in groundwater conditions across the U.S. High Plains Aquifer. *Representative farm field is shown on the right.*

IV. Methods

i. Mixed integer programming model (MIP) with center pivot investment (pivot life 15 yrs; optional replacement at year 16; ~$75k; 7% discount)

ii. System choices: irrigated corn or sorghum, dryland corn or sorghum, and switchgrass

iii. Net returns linked to well capacity, and constraints – water & land

iv. Outputs: optimal crop path, aquifer drawdown, biomass supply, and net present value (NPV)

IV. Methods (cont.)

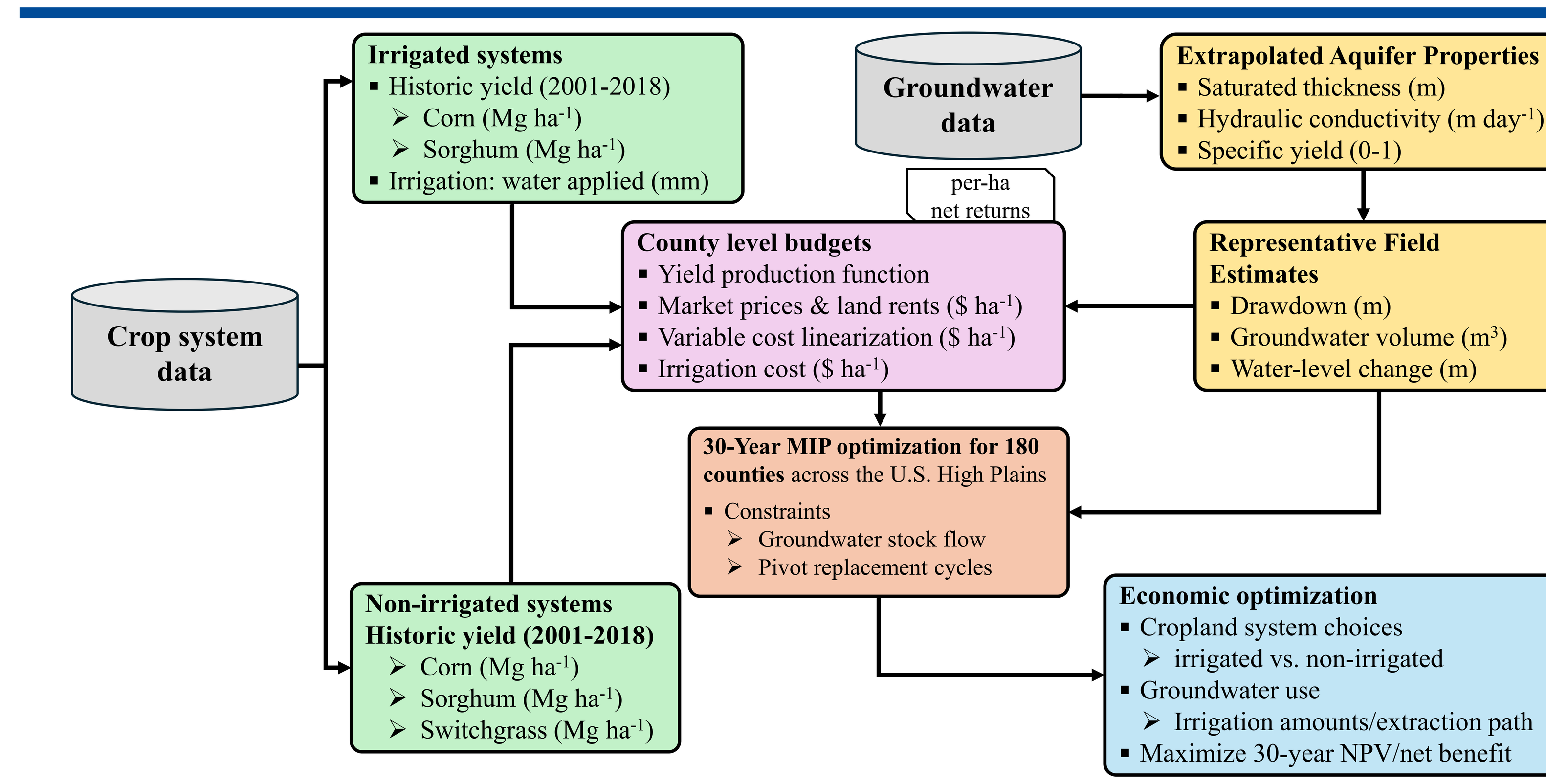

Fig. 2. Modeling approach and data integration. *Multi-source data integration for optimizing agricultural systems, crop budgets, and aquifer dynamics.*

V. Results

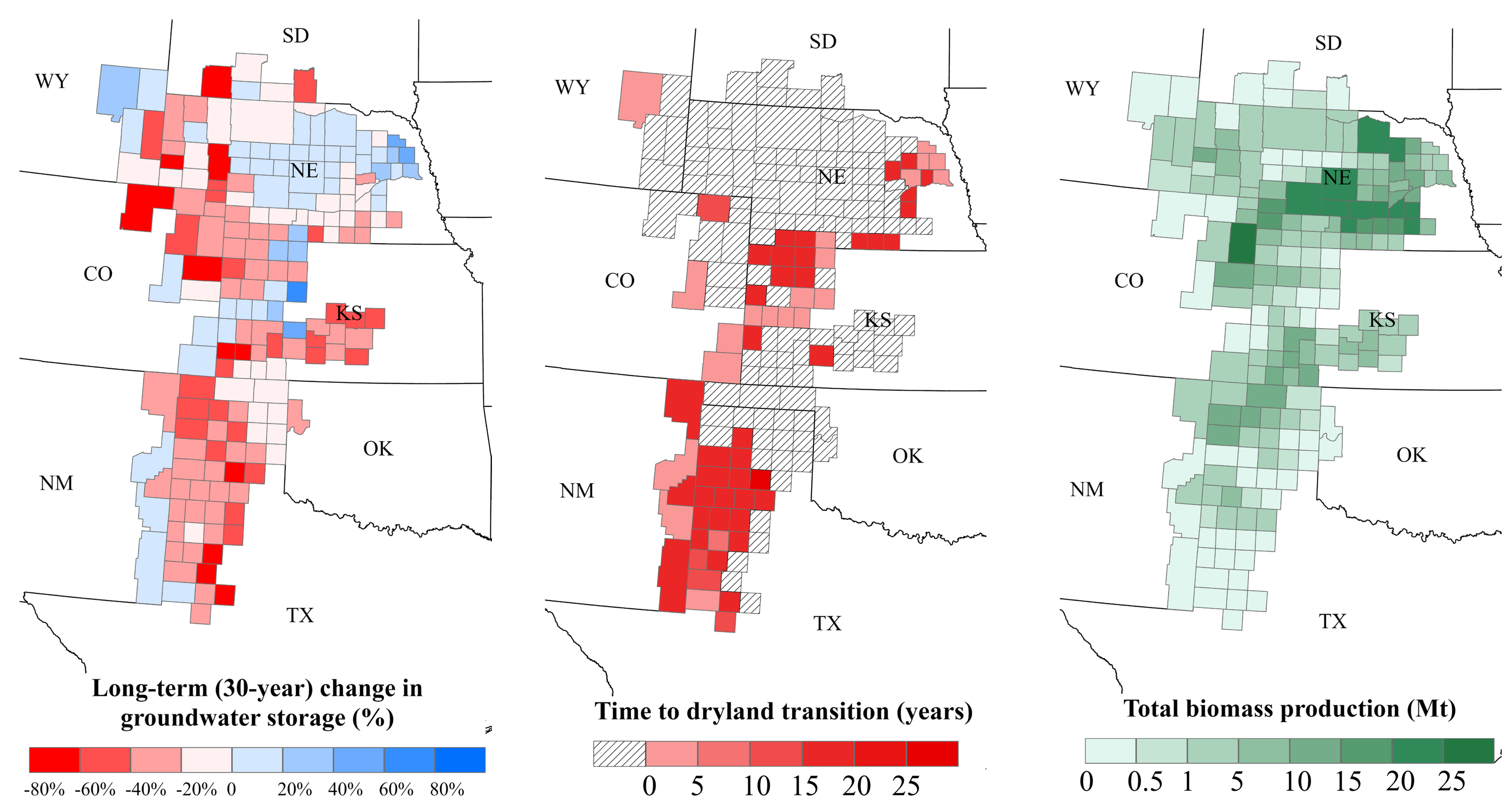

Fig. 3. Dynamics of groundwater storage, dryland transitions time, and biomass production across the U.S. High Plains Aquifer during the 30-year simulation period. *Cross-hatched counties denote no transition.*

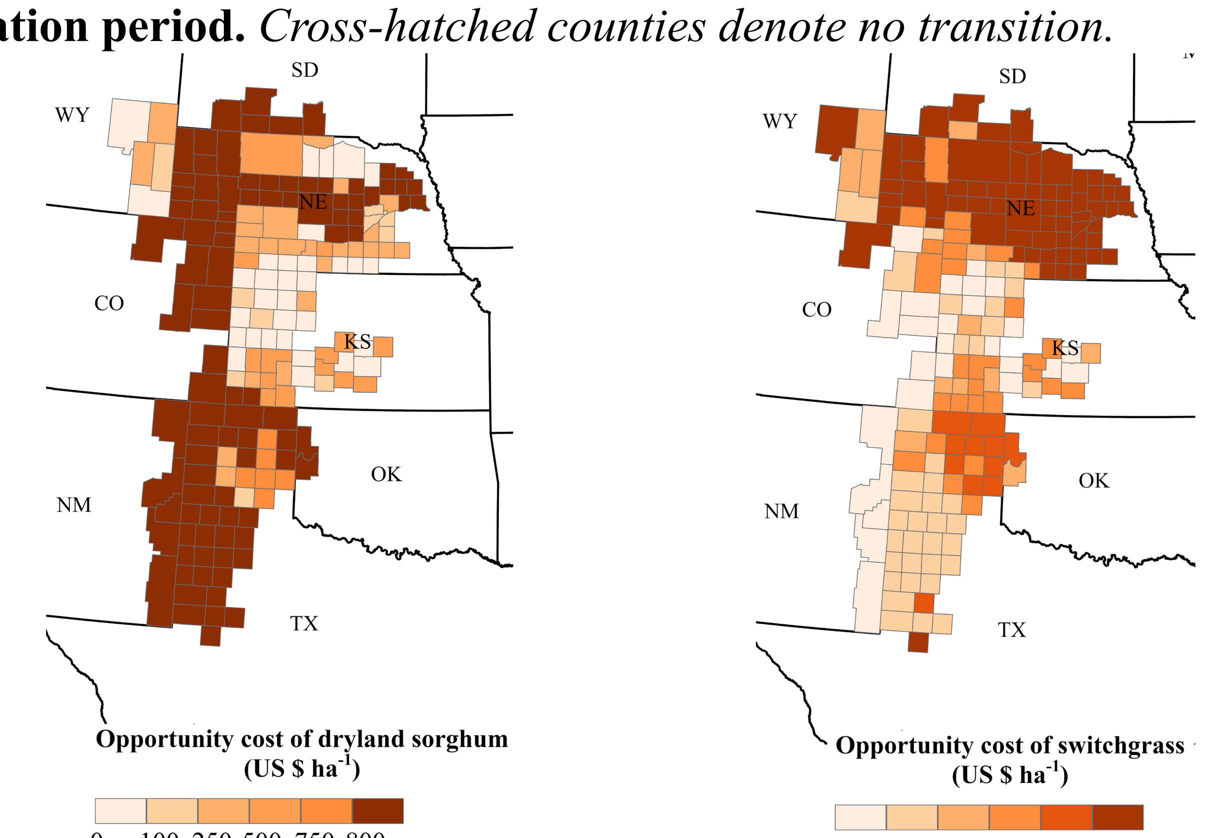

Fig. 4. Spatial variation in opportunity costs for non-irrigated bioenergy crops across the U.S. High Plains Aquifer.

V. Results (cont.)

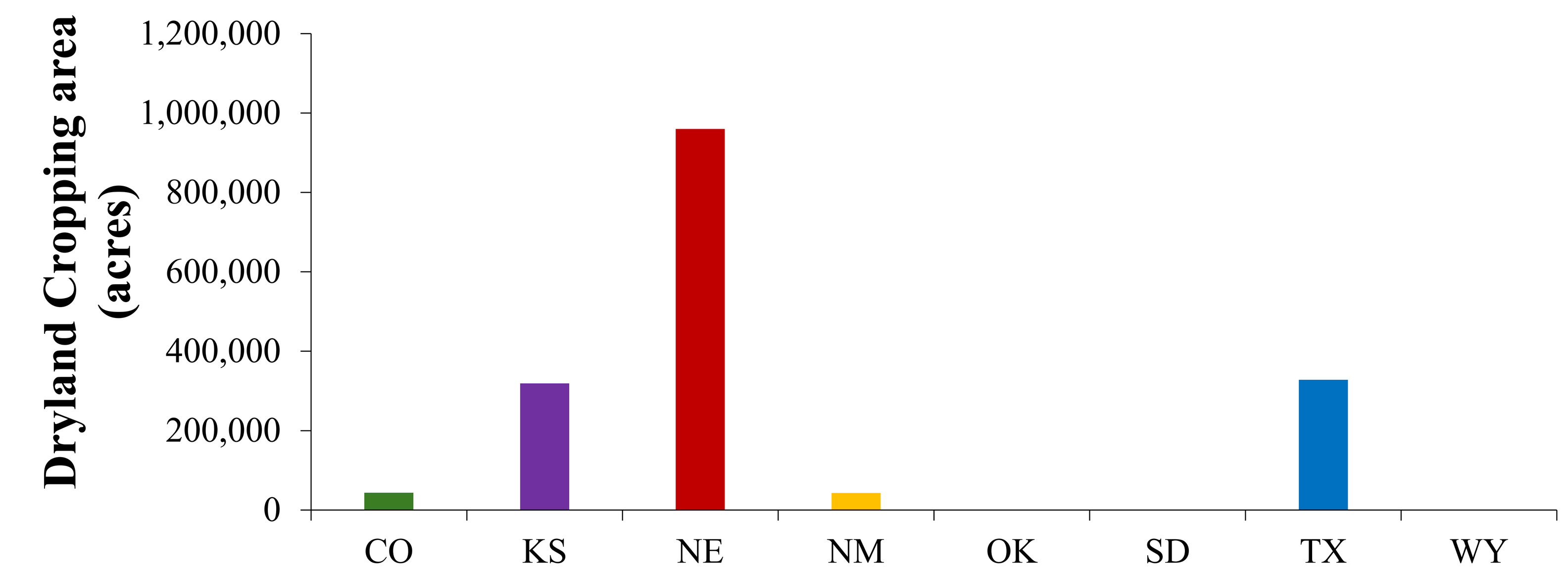

Fig. 5. Shifts from irrigated crop area to dryland production across the U. S. High Plains Aquifer States.

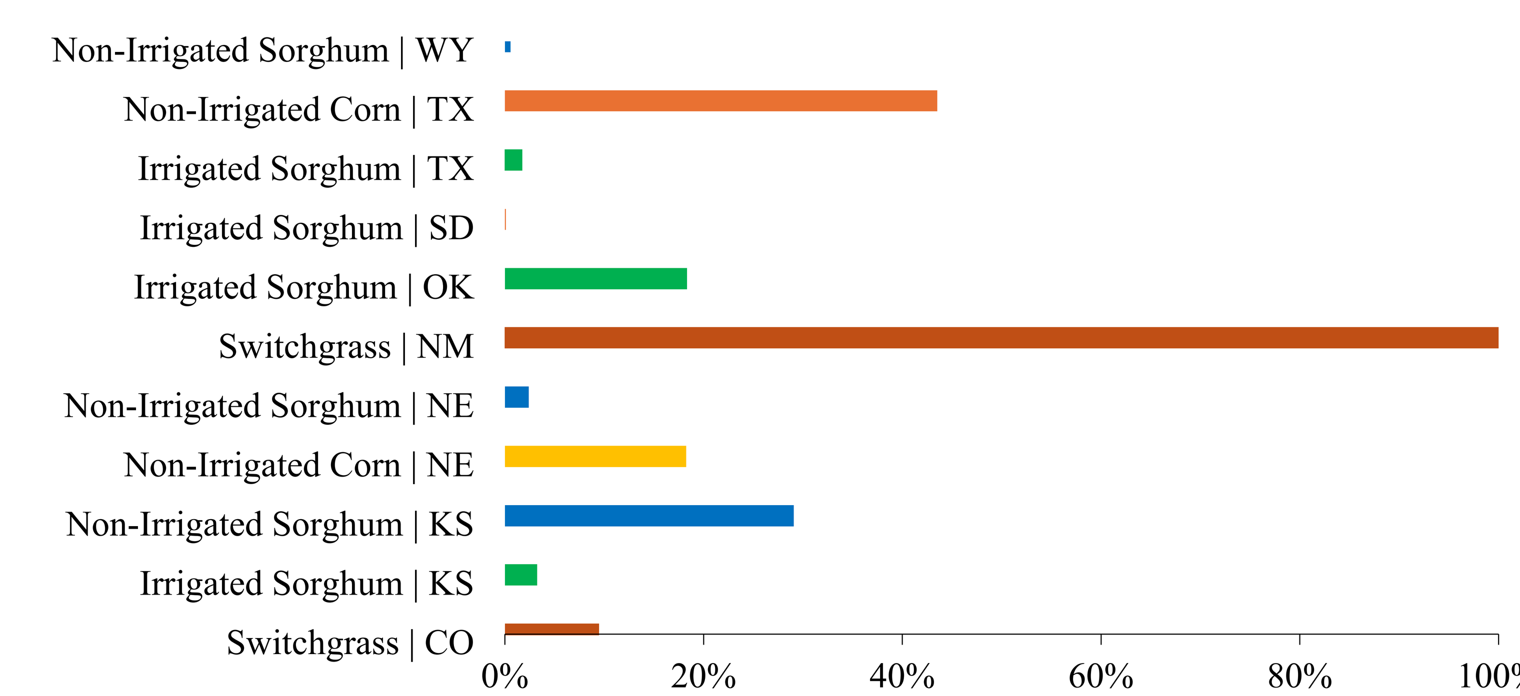

Fig. 6. Crop share by state under optimal transition outcomes across the U.S. High Plain Aquifer.

VI. Key Findings

i. Ogallala aquifer depletion could reduce irrigated corn area by 23% over 30 years

ii. 31% of transitioned lands shift to dryland sorghum and switchgrass

iii. Nebraska still supports irrigation on 78% of its initial groundwater volumes, while Texas retains only 41%

iv. Switchgrass adoption expands arid southern subregions showing resilient bioenergy feedstock

v. Transition corridor found where sorghum and switchgrass could be competitively adopted under policy

VII. Limitations

i. Single-cell aquifer per county (no lateral flow) and masked heterogeneity

ii. Uniform yield-response functions, stationary climate, and average prices

iii. No new groundwater regulations or stochastic shocks modeled

Acknowledgements

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