A Hydro-Econometric Analysis of Producer Water Use and Aquifer Hydrology in the Texas High Plains

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CIRE
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• Groundwater in the Ogallala Aquifer - the only reliable water source for irrigated agriculture in the Texas High Plains

• Irrigation efficiency improvements - promising groundwater conservation measures.

• Water conservation measures - slow down aquifer depletion? irrigated acreage, irrigation technology and crop choice, and return flow.

• The producer's water use decisions and the hydrologic conditions of the aquifer - interlinked and examined in a unified framework.

• Groundwater Management Area (GMA) - “desired future conditions (DFC)” for the groundwater resources.
Goal: A policy assessment model/tool to evaluate the impacts of water conservation policies and assess strategies for management of the groundwater resources.

Objectives:

• Develop and estimate a hydro-econometric model, accounting producers’ economic behavior and the aquifer’s behavior.

• Simulate the short- and long-term impacts on the aquifer of a set of policy measures identified by stakeholders.

• Disseminate policy findings through targeted publications and

• Make publicly accessible the dataset used in the hydro-econometric analysis.
Study Area
Concept of Linked Model

Hydro-Economic System

Economic Subsystem

Irrigation Response

Hydrologic Subsystem

Aquifer Response

Well Yield
Well Lift

Pumping Stress
Return Flow

Policy
Groundwater Availability
Hydrological Model
Hydrological Model

- Groundwater Availability Model (GAM) (Blandford et al., 2008).
- MODFLOW – 2000
- 270 rows, 290 columns
- 4 layers (hydrogeologic units)
- Stress periods (1930 – 2060)
Hydrological Model (2)

- Modify well configuration (current wells and to allocate the artificial wells in the center of the cells)
- The GAM model was modified by replacing the well package with MNW package
- Estimate head values on the node cell using the GAM
- Integrate the wells and analytical solution in ArcGIS environment, well heads values were estimated using the analytical solution

\[
h_{well} = h_n - \frac{Q_n}{2 \pi T} \ln \left( \frac{r_e}{r_w} \right)
\]

\[
h_{well} = \frac{Q_{net} + \sum_{n=1}^{m} CWC_n h_n}{\sum_{n=1}^{m} CWC_n}
\]

\[
CWC_n = \left[ \frac{\ln \left( \frac{r_e}{r_w} \right)}{2 \pi b_n k_n} \right]^{-1}
\]
Change in Groundwater Levels

1970

2000
Groundwater levels and Sat. Thickness in 2040
Simulated Results at a Well

Well Castro2: Simulated and forecasted conditions

- DTW (ft)
- Sat. Thickness (ft)
- Pump Lift (ft)-Conf
Saturated Thickness at Well Castro2 (1038401)

Current trend vs. DFC

Saturated Thickness (ft)

0 50 100 150 200 250 300 350


Current trend

Desired future condition
Groundwater demand prediction
Econometric Model
Study Region and Period

**Study Region**

Our study region include 21 counties.

- Groundwater is very important for agriculture in the region, and its resources are facing depletion.
- Cover most of south Ogallala aquifer
- Cover most of Groundwater Management Area 2 (TWDB)
- Located at Texas AgriLife Extension Districts 2 (Crop budget)
- Plenty of historical data.
- GAM model can be linked to econometric model.

**Study Period**

Our study period cover 36 years, 1972-2007.
• Use historic data to fit a decision model explaining the producer’s choice over various crops and irrigation technologies.

• The producer decision model will be used to predict cell-level irrigation water demand.

• The producer decision model will be integrated with the GAMS to simulate future conditions of the aquifer.
• Explained Variable: County-Level Acreage Shares of Crop-Irrigation Technology Combinations

• Explanatory Variables: Crop Price, Fertilizer Price, Seed Price, Irrigation Capital Costs, Lagged Crop Shares, Pumping Lift, Well Yield
Irrigation Acreage & Crop

The bar chart illustrates the irrigation acreage and crop distribution over a period from 1975 to 2005. The x-axis represents the years, while the y-axis indicates the acreage in millions. Each bar is color-coded to represent different crops:

- **Green**: Other
- **Pink**: Wheat
- **Greenish**: Sorghum
- **Blue**: Peanut
- **Red**: Corn
- **Black**: Cotton

The chart shows fluctuations in acreage for each crop category over the years.
External Validation of the Model’s Predicting Power

Cotton (true and predicted) in Parmer county
## Price Elasticity of Crop Acreage Shares

To predict farmer's response to market or policy change

<table>
<thead>
<tr>
<th></th>
<th>Cotton</th>
<th>Corn</th>
<th>Sorghum</th>
<th>Wheat</th>
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<td>-0.0003</td>
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</tbody>
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• Project Year 1 (9/2009-8/2010): Data Assembly and Modeling
• Project Year 2 (9/2010-8/2011): Model Estimation and Calibration
• Project Year 3 (9/2011-8/2012): Integration of Economic and Hydrologic Models
• Project Year 4 (9/2012-8/2013): Policy Simulations