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OPTIMAL NITROGEN/WATER USE IN THE SOUTHERN SUB-REGION OF THE SOUTHERN OGALLALA AQUIFER

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General Problem– Texas High Plains (THP)

- **Sustainability in agriculture**
  - 7.4 billion people
  - Increase to 10.9 billion by 2050
  - Strains natural resources needed to support a growing population

- **Why the Texas High Plains?**
  - 25% of U.S. cattle (Johnson et al., 2013)
    - West Texas supports 85% of the state’s fed beef (Almas, 2004)
  - 30% of U.S. Cotton (Johnson et al., 2013)
    - 61% of the state’s cotton
  - Irrigated agriculture directly accounts for $6.6 billion of industry output (Guerrero and Amosson, 2013)

- **Texas High Plains**
  - Semi-arid
  - Low annual precipitation
  - Relies heavily on Ogallala Aquifer to meet irrigation needs
Ogallala Aquifer Important Facts

- Covers 174,000 miles across eight states
  - 35,000 square miles in Texas
  - 11% of total land in Texas

- Contains 3.3 billion acres of fresh water
  - Saturated thickness range
    - 1,300 ft in Nebraska
    - <1 ft in Texas
    - Average of 200 ft

- 170,000+ pumping wells
  - 50,000+ in Texas alone

- 90%+ used to irrigate crops
  - $20 billion in food and fiber production each year
Objective

- Determine the economically optimal nitrogen and water use for corn production in the southern sub-region of the Southern Ogallala Aquifer using producer-level data.
Rationale

- Improved nitrogen and water use efficiency can reduce water use and increase profit.

- Agronomic studies on optimal nitrogen application amounts and timing largely overlook economic impacts (Al Kaisi and Yin, 2003; Bullock and Bullock, 1993).

- This analysis will provide producers with best management practices for nitrogen application for center pivot irrigation systems with varying amounts of water availability.
Corn Requirements

- **Water**
  - Average 22 inches
  - Range 20-25 inches

  *More vulnerable to water stress*

  - Limited resource in Texas High Plains
    - Producers must become more water efficient
      - Genetic improvements
      - Better irrigation scheduling
      - Adoption of conservation tillage
      - Adoption of more efficient irrigation systems

- **Nitrogen (N)**
  - The most commonly applied nutrient
  - Costliest
  - Benefit to Cost Ratio exceeds that of other nutrients
  - Increases strength of individual plants and yield of the crop
  - Requires good management (best management practices) to reduce environmental consequences
    - Oxygen depletion aquatic ecosystems
    - Biodiversity losses
    - Water and air pollution
Corn Production in Texas

Average Annual Precipitation

Texas

Legend (in inches):
- Under 14
- 14 to 18
- 18 to 21
- 22 to 26
- 26 to 30
- 30 to 34
- Above 34

Planted Acres

- 600 - 11,500
- 11,501 - 24,100
- 24,101 - 43,800
- 43,801 - 85,500
- 85,501 - 127,000
- Not published

For information on the P3ISIM modeling system, visit the SCAW website at http://www.scaw.net/index.html.

The latest P3ISIM digital data set created by the SCAW can be obtained from the Climate Source at http://www.climatesource.com.
Data

Texas High Plains Counties

- 7 counties (Dallam, Deaf Smith, Hartley, Moore, Ochiltree, Sherman, Stanton)
  - data ranging over the years 1998-2016
  - 42 - 762 observations per county

- Data includes:
  - Yield (bu/ac)
  - Water Applied
  - Nitrogen Applied
Methodology

  - Quadratic Production Functions by County by Year
    - OLS
      - Yield = $\beta_0 + \beta_1 W + \beta_2 W^2 + \beta_3 N + \beta_4 N^2 + \beta_5 W \times N + \epsilon$
    - Use estimated coefficients to determine optimal Water/Nitrogen given a range of prices for Corn, Water, and Nitrogen
Results

- Expected Signs for Quadratic Production Functions

<table>
<thead>
<tr>
<th>Intercept</th>
<th>Water</th>
<th>Water²</th>
<th>Nitrogen</th>
<th>Nitrogen²</th>
<th>Water*Nitrogen</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
</table>

- 2 Counties with correct signs
  - Dallam (‘07, ‘09, ‘10)
  - Sherman (‘00)
## Results

<table>
<thead>
<tr>
<th>Price of corn, $/bushel</th>
<th>Price of Water, ac-in</th>
<th>Price of N-Fertilizer, 30 cents lb/acre</th>
<th>40 cents lb/acre</th>
<th>50 cents lb/acre</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Water, N, Net Return</td>
<td>Water, N, Net Return</td>
<td>Water, N, Net Return</td>
</tr>
<tr>
<td></td>
<td></td>
<td>52.0094, 76.61997, 676.4583</td>
<td>22.47112, 76.801, 669.2743</td>
<td>18.942, 76.9814, 661.5852</td>
</tr>
</tbody>
</table>
Next Step

- A different functional form will need to be used to evaluate the optimal level of Water/Nitrogen for Corn production in the Southern Sub-Region of the Ogallala Aquifer.

- The following authors support the use of Stochastic Linear Response Plateau as the correct functional form for modeling crop response to Nitrogen input.
  - Grimm, Paris, and Williams (1987)
  - Tumusiime, Brorsen, Mosali, Johnson, Locke, Biermacher (2011)
  - Boyer, Larson, Roberts, McClure, Tyler, and Zhou (2013)
  - Ouedraogo and Brorsen (2014)
  - Rodriguez and Bullock (2015)