SIMULATING THE FEASIBILITY AND PERFORMANCE OF A REAL-TIME WATER MARKET BY COUPLING AN AGENT-BASED MODEL AND RAPID MODEL - A CASE STUDY IN GUADALUPE RIVER BASIN

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Research Question:

• What would be the potential impacts of a real-time water market in Guadalupe River Basin (GRB)?
  – Assess impacts on:
    • Profits and losses
    • River flows
    • Resilience to drought

Coupled agent-based modeling and RAPID river flow modeling approach
Irrigation Water Use

Number of water right holders

Water consumption in 2011

<table>
<thead>
<tr>
<th>Water Use Type in GBR</th>
<th>DOM</th>
<th>Domestic</th>
<th>MUL</th>
<th>Multiuse</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOM</td>
<td>0.13</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HYD/P</td>
<td>0.04</td>
<td>Hydroelectricity</td>
<td>MUN</td>
<td>Municipal use</td>
</tr>
<tr>
<td>IRR</td>
<td>0.06</td>
<td>Irrigation</td>
<td>NON</td>
<td>Non-consumptive</td>
</tr>
<tr>
<td>IND</td>
<td>0.04</td>
<td>Industry</td>
<td>REC</td>
<td>Recreation</td>
</tr>
<tr>
<td>INS</td>
<td>0.02</td>
<td>In stream</td>
<td>OTH</td>
<td>Other use</td>
</tr>
</tbody>
</table>

Irrigation users are major water right holders and water consumers: initial study focus.
simulate the actions and interactions of autonomous agents (each agent follow individual behavior rule and can learn to update the rule) with a view to assessing their effects on the system as a whole.
Agent-based Modeling Components

**Agents & Attributes**

- Entity = Customer
- Customer ID
- First Name
- Surname
- Date of birth
- Address
- Phone no.

**Behavior & Learning Rules**

- These are the ‘attributes’ for the entity ‘customer’

**Interaction Topology**

- Diagram showing network connections

**Environment**

- Background showing grid pattern
Initial Study: Agricultural Water Rights Trading

Assess impacts of water rights trading on:

- Crop yield
- Irrigation technology diffusion rate
- Resilience to drought

Define Agriculture Agents

- Assumption: farmers are utility maximizers -- their objective is to maximize profit from crop yield

\[
\text{max: } Y = Y_d + (Y_m - Y_d)[1 - (1 - I_r/I_m)^\beta], \text{ (Hu, 2013)}
\]

- \(Y\): crop yield (bushel/acre)
- \(Y_d\): rain-fed yield without artificial irrigation (bushel/acre)
- \(Y_m\): maximum yield without water shortage (bushel/acre)
- \(I_m\): maximum irrigation amount (inch/acre)
- \(I_r\): Irrigation amount (inch/acre)
- \(\beta\): Irrigation efficiency index, \(0 < \beta < 1\)
Agriculture Agent Attributes

1) Soil types

2) Water rights priority order

3) Irrigation technology diffusion index

### Agent Attribute 1: Soil Type

<table>
<thead>
<tr>
<th>Type</th>
<th>$Y_m$ (bushel/acre)</th>
<th>$Y_d$ (bushel/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 #</td>
<td>152.57</td>
<td>67.74</td>
</tr>
<tr>
<td>2 #</td>
<td>181.75</td>
<td>159.21</td>
</tr>
<tr>
<td>3 #</td>
<td>257.29</td>
<td>63.04</td>
</tr>
</tbody>
</table>

### Agent Attribute 2: Water Right Priority Order

<table>
<thead>
<tr>
<th>Order</th>
<th>1 #</th>
<th>2 #</th>
<th>3 #</th>
</tr>
</thead>
</table>

### Agent Attribute 3: Irrigation Technology Diffusion Index

<table>
<thead>
<tr>
<th>Type</th>
<th>Index ($\theta$)</th>
<th>Investment Payback Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 #</td>
<td>0.2</td>
<td>5 years</td>
</tr>
<tr>
<td>2 #</td>
<td>0.5</td>
<td>2 years</td>
</tr>
</tbody>
</table>
Agent Interacting Environment
Agent-based Modeling Setup

- Historical Water Availabilities
- Water Right Priority Order
- Soil Type & Irrigation Technology

Monte-Carlo Simulation

Crop Production

- Optimization
- Actual Profit (by current technology)
- Ideal Profit (by new technology)
- Water Trading Profit

Production Plan

Water Trading Plan

Water Price

Optimization

Willingness to Adopt New Tech Index (r(i,t))

Is r(i,t) > threshold value? 

Technology Choice for t+1
Results for Kendall County: Crop Yield
Results for Kendall County: Crop Yield & System Resilience

Crop Yield Comparison

Agriculture System Resilience to Drought

Both crop yield and agriculture system resilience improve about 10% by using a water market when conditions are dry.
Results for Kendall County: Irrigation Technology Diffusion

Irrigation technology adoption rate is faster if farmers are allowed to trade their water rights.
Conclusions

- Allowing agriculture water right trading could increase crop yield and resilience to drought

- Irrigation technology could diffuse faster with a water market
Future Work

• Couple RAPID model with agent-based model to evaluate water market’s impacts on river flow

• Include other water users

• Consider transaction costs of water trading and effects of incomplete information on agents’ decision-making processes

• Evaluate different auction mechanisms for water trading