Balancing global water supplies and demands: initial experiments in an integrated assessment model

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JGCRI Technical Workshop and GCAM Community Modeling Meeting 2014
1. Methodology - representing water in GCAM
   - Water supplies and demands
   - Mapping water supplies and demands
   - Balancing supplies and demands

2. Impact of water pricing and closing water markets

3. Sensitivity studies
   - renewable runoff water supply
   - non-renewable ground water
   - alternative water pricing

4. Climate mitigation and water pricing interactions
GCAM Global Water Supplies: Renewable Water

- GCAM has a macroscale global hydrologic model
- Modified River Transport Model scheme
- Simulates runoff and streamflow (1901-2100)
- Requires climate information from GCMs as inputs
- 233 basins globally
- 18 basins in the US consistent with the USGS WRRs
- Monthly temporal scale
- 0.5x0.5 degree spatial resolution

Toward understanding the implications of climate change impacts on water availability and on energy and land decisions in GCAM
GCAM Global Water Supplies: Non-renewable Water Resources

- Non-renewable (fossil) groundwater
  - Depletable resources
  - No constraint on maximum volume due to lack of information and the large amounts that are available
  - Cost of groundwater pumping increases with depth following the work of Zhu et al., (2007)

- Desalinated water
  - Assumed a constant per unit cost

<table>
<thead>
<tr>
<th>Desalination water source</th>
<th>Global Share (%)</th>
<th>Global Cost ($/m^3)</th>
<th>US Share (%)</th>
<th>US Cost ($/m^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea</td>
<td>56</td>
<td>1</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Brackish</td>
<td>24</td>
<td>0.6</td>
<td>51</td>
<td>0.6</td>
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<tr>
<td>River</td>
<td>9</td>
<td>0.6</td>
<td>26</td>
<td>0.6</td>
</tr>
<tr>
<td>Waste water</td>
<td>6</td>
<td>0.6</td>
<td>9</td>
<td>0.6</td>
</tr>
<tr>
<td>Pure</td>
<td>5</td>
<td>0.6</td>
<td>7</td>
<td>0.6</td>
</tr>
<tr>
<td>Brine</td>
<td>0</td>
<td></td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>SUM</td>
<td>100</td>
<td>0.824</td>
<td>100</td>
<td>0.628</td>
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</tbody>
</table>

Water Flow Schematic

Basin Runoff, Ground Water & Desalination

Total Basin Supply

Water Distribution & Mapping

Consumer
Closure of the Water System in GCAM
2. IMPACT OF WATER PRICING AND CLOSING WATER MARKETS
Comparison of scenario with and without water pricing

1. No Water Constraint (No Water Price)
2. “Accessible” Water Constraint with Water Price (53% avg. of total runoff)
   - “Accessible” Water accounts for renewable inflow, reservoir capacity and storage, and environmental requirements
Which regions are affected by water pricing?
Which sectors are affected by water pricing?

![Graph showing water withdrawal with and without pricing](image-url)
How does water scarcity affect global agriculture production?

1. Total global agriculture production
2. Regional shifts in agriculture production
3. Changes to the price of agricultural goods
4. Share of irrigated and non-irrigated agriculture
Changes to Global Agriculture Production With & Without Water Pricing
Changes to Regional Agriculture Production With & Without Water Pricing

- Changes in Global Corn Production
- Changes in Global Rice Production
- Changes in Global Wheat Production
- Changes in Global Sugar Crop Production
Agriculture commodity prices do not change significantly due to global trade.

Constraining global trade of agricultural goods is likely to result in higher prices (not explored).
Changes in Irrigated and Rain-fed Agriculture Production with Water Pricing
Water Scarcity with and without Water Pricing 2050 and 2100 by Basin

No Water Price

With Water Price

2050

2100
3. SENSITIVITY STUDIES
Renewable Runoff Sensitivity Cases

- “Accessible” Water (53% avg. of total runoff)
- “Accessible” Water + 20%
  - 20% greater accessible for each basin (62% avg. of total runoff)
- “Accessible” Water – 20%
  - 20% less accessible for each basin (42% avg. of total runoff)

Why is global water withdrawal insensitive to alternative assumptions of “Accessible” water?

Water stressed regions are already at near max or exceed renewable runoff.
Changes to Regional Agriculture Production with 20% Greater Accessible Water

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**Changes in Global Corn Production**
- Africa
- Australia_NZ
- Canada
- China
- Eastern Europe
- Former Soviet Union
- India
- Japan
- Korea
- Latin America
- Middle East
- Southeast Asia
- USA
- Western Europe

**Changes in Global Rice Production**
- Africa
- Australia_NZ
- Canada
- China
- Eastern Europe
- Former Soviet Union
- India
- Japan
- Korea
- Latin America
- Middle East
- Southeast Asia
- USA
- Western Europe

**Changes in Global Wheat Production**
- Africa
- Australia_NZ
- Canada
- China
- Eastern Europe
- Former Soviet Union
- India
- Japan
- Korea
- Latin America
- Middle East
- Southeast Asia
- USA
- Western Europe

**Changes in Global Sugar Production**
- Africa
- Australia_NZ
- Canada
- China
- Eastern Europe
- Former Soviet Union
- India
- Japan
- Korea
- Latin America
- Middle East
- Southeast Asia
- USA
- Western Europe

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Proudly Operated by Battelle Since 1965
Ground water is not a significant share of global withdrawal.

- It’s a depletable resource with rising cost of production.

Non-renewable ground water has important local and regional impact.

- More research needed on ground water cost and availability.
# Relative Cost of Water

- Why did water pricing affect agriculture more?
- Why did water pricing not affect energy generation?

<table>
<thead>
<tr>
<th>Agriculture</th>
<th>Water Coefficient (m$^3$/kg)</th>
<th>Water Price ($/m^3$)</th>
<th>Water Cost ($/kg)</th>
<th>Crop Price ($/kg)</th>
<th>Water Cost Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>corn</td>
<td>0.42</td>
<td>0.10</td>
<td>0.042</td>
<td>0.10</td>
<td>43%</td>
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<tr>
<td>rice</td>
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<td>0.10</td>
<td>0.080</td>
<td>0.66</td>
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<tr>
<td>wheat</td>
<td>0.58</td>
<td>0.10</td>
<td>0.058</td>
<td>0.13</td>
<td>45%</td>
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</table>

<table>
<thead>
<tr>
<th>Electricity</th>
<th>Water Coefficient (m$^3$/GJ)</th>
<th>Water Price ($/m^3$)</th>
<th>Water Cost ($/GJ)</th>
<th>Elect Price ($/GJ)</th>
<th>Water Cost Share</th>
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<tbody>
<tr>
<td>coal conv</td>
<td>2.24</td>
<td>0.10</td>
<td>0.22</td>
<td>15.26</td>
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</tr>
<tr>
<td>gas cc</td>
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<td>0.10</td>
<td>0.02</td>
<td>13.71</td>
<td>0.1%</td>
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<tr>
<td>nuclear</td>
<td>1.65</td>
<td>0.10</td>
<td>0.17</td>
<td>15.89</td>
<td>1%</td>
</tr>
</tbody>
</table>
4. CLIMATE MITIGATION AND WATER PRICING INTERACTIONS
Climate Mitigation Scenarios

- Ref Scenario with Water Pricing
- 450 ppm Scenario with Water Pricing (same runoff constraint)

- Global water withdrawal increases under climate mitigation policy.
- Irrigation and electricity withdrawals are responsible.
Increased use of biomass for energy contributes to greater irrigated water use.

Additionally, higher agricultural prices from increased biomass use and valuing carbon on land raise irrigated water use for other crops.

Greater investigation of land-water-energy-carbon interactions required.
Climate Mitigation Scenarios
Which technologies are responsible for increased electricity water withdrawal?

Ref

Electricity Generation - Ref (w/ water price)

450

Electricity Generation - 450 ppm (w/ water price)

Water Withdrawal for Electricity - Ref (w/ water price)

Water Withdrawal for Electricity - 450 (w/ water price)
Questions

Thank you:

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