Achieving Sustainable Irrigation Water Withdrawals: Global Impacts on Land Use

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Increasing reliance on unsustainable water withdrawal

- **Unsustainable**: permanent decrease in the volume of water stored in aquifers (Aeschbach-Hertig and Gleeson, 2012)
- **Sustainable**: withdrawal less than 20% of available (Alcamo et al., 2000)
Increasing reliance on unsustainable water withdrawal

- **Unsustainable**: permanent decrease in the volume of water stored in aquifers (Aeschbach-Hertig and Gleeson, 2012)
- **Sustainable**: withdrawal less than 20% of available (Alcamo et al., 2000)
- **Irrigation scarcity index**:

\[
\text{Irrigation scarcity index} = \frac{\text{Irrigation Withdrawal}}{\text{Water Available for Irrigation}}
\]
Vulnerable irrigation hotspots in 2006

Source: author’s calculation based on 10-yr (2000-2010) average of simulated irrigation demand and irrigation availability for 958 sub-basins.
Where to target for sustainable irrigation in the future?

Evolving irrigation scarcity index, 2050 relative to 2006

Source: author’s calculation.
Achieving sustainable irrigation water use can be costly

Less irrigation may

- reduce food supply
- have side effects on other environment and development metrics
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Outcome depends on
- climate
- population and income growth
- investment in infrastructure and technology, policies, etc.
Method: Integrated hydro-economic modeling

- **Hydro-model**: Irrigation availability
- **Econ-model**: Food price, Crop output, Land use change
- **Sustainability Policies**

Diagram illustrating the interconnectedness of hydro-economic models with sustainability policies.
Method: Integrated hydro-economic modeling (cont.)

Global Hydro-model (water supply):

- 30 arc-min, aggregated to 958 sub-basins
- Water is sourced from surface, reservoir, and soil-stored water
- Water available for irrigation is the residual after subtracting residential, industrial and livestock uses

Global Econ-model (water demand):

- Partial equilibrium model with sub-national detail on water and land
- Irrigated and rainfed crop production at the 30 arc-min level
Experiments:
Reduce sub-basin irrigation scarcity index to 0.2 in 2050

- No adaptation
- With adaptation
  - inter-basin water transfer
  - improved water productivity (TFP growth)
  - integrated market
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Results

Cropland area change, 2050 relative to 2006
NO adaptation
Sustainability constraint suppresses global cropland expansion in 2050 (Mha)

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<th>Region</th>
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<tr>
<td>Total</td>
<td><strong>156</strong></td>
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Sustainability constraint suppresses global cropland expansion in 2050. However, it encourages expansion into the carbon-rich rainfed area.

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<td>Total</td>
<td>-67</td>
<td>223</td>
<td>156</td>
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- Global cultivated cropland area in 2006: 1,486 Mha
≈ 1.5 US

- With sustainability constraint, global cropland area in 2050
≈ 1.5 US + Alaska

- Without sustainability constraint, global cropland area in 2050
≈ 1.5 US + Alaska + Texas
Grid-level irrigated cropland change ($10^3$ ha/grid)

Global sum = -67 Mha
Results

Cropland area change, 2050 relative to 2006
*WITH* adaptations
- Inter-basin transfer: keep China from losing 10 Mha cropland
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- R&D: reduce global cropland expansion by 50% (156 → 98)
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- R&D: reduce global cropland expansion by 50% (156 → 98)
- Trade: alter the spatial distribution of cropland expansion
Summary

- The interaction between physical and socio-economic drivers makes possible different future scenarios. Under each, the targeting and consequences of sustainable irrigation also differ.

- Adaptations affect food supply in a similar manner, but have different implications for land use change.

- Integrated grid-resolving modeling has the potential to identify sub-national variations and assist decision-making at the local level.
Thank you!
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Current model features:

- 16 regions, 2 sectors, 4 commodities
- globally 58447 grids (30 arc-min)
- constant elasticity of substitution production function
- split irrigated and rainfed cropland area and crop output, grid-specific irrigation intensity ($m^3/ha$)
- Armington substitution between domestic and imported commodities

Additional grid-specific characteristics under development

- land supply elasticity
- yield function
- nitrogen leaching function
- groundwater mining
References
