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)

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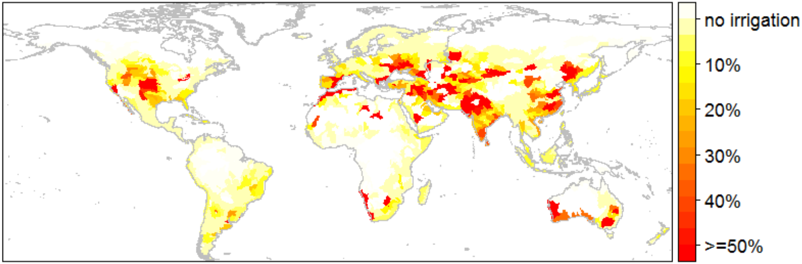
- Irrigation scarcity index:

$$= \frac{Irrigation\ \ Withdrawal}{Water\ \ Available\ \ for\ \ Irrigation}$$

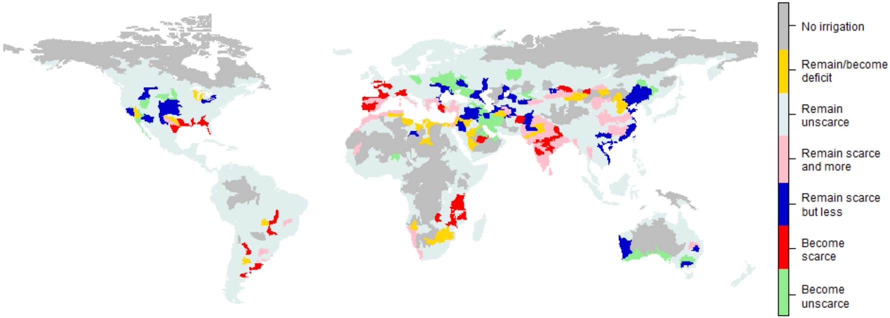
Vulnerable irrigation hotspots in 2006



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
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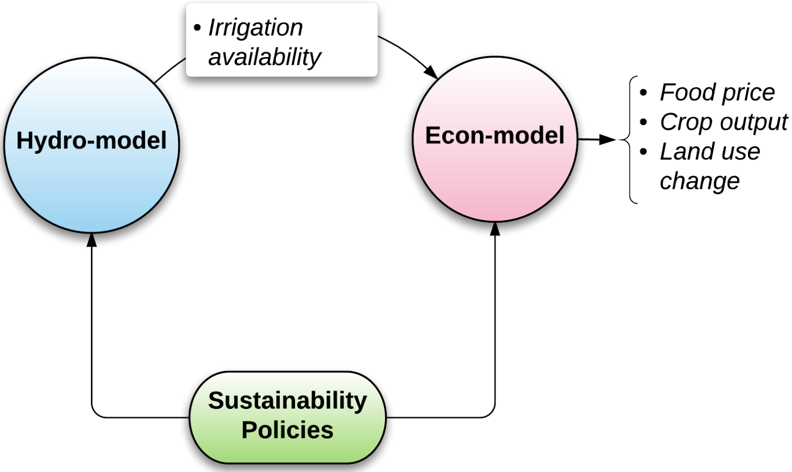
Outcome depends on

- climate
- population and income growth
- investment in infrastructure and technology, policies, etc.

Method: Integrated hydro-economic modeling



Method: Integrated hydro-economic modeling (cont.)

Global Hydro-model (water supply):

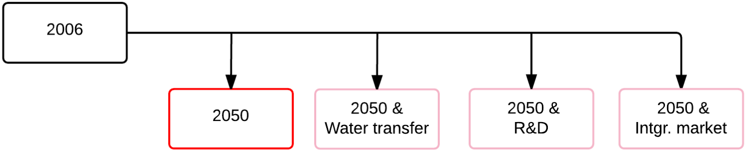
- 30 arc-min, aggregated to 958 sub-basins ‣ sub-basin1 ‣ sub-basin2
- Water is sourced from surface, reservoir, and soil-stored water
- Water available for irrigation is the residual after subtracting residential, industrial and livestock uses

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 ‣ detail

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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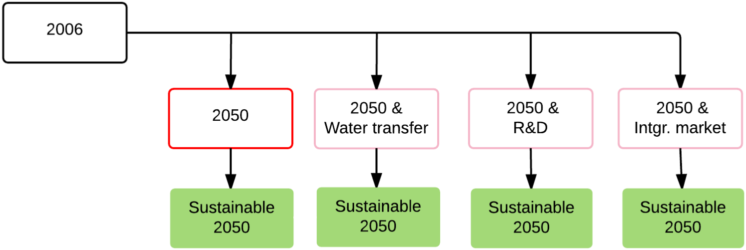


Results

Cropland area change, 2050 relative to 2006
NO adaptation

Sustainability constraint suppresses global cropland expansion in 2050 (Mha)

Region	Sustainable			Unsustainable		
	Irrigated	Rainfed	Total	Irrigated	Rainfed	Total
S_Asia			-18			31
CHN_MNG			-20			3
US			9			12
S_Amer			29			29
SSA			121			120
Rest of world			35			45
Total			156			240

Sustainability constraint suppresses global cropland expansion in 2050. However, it encourages expansion into the carbon-rich rainfed area.

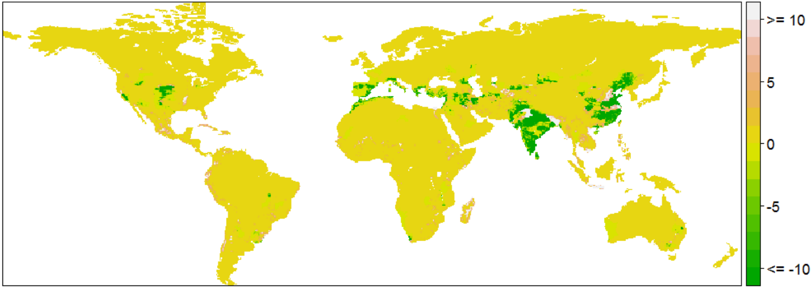
Region	Sustainable			Unsustainable		
	Irrigated	Rainfed	Total	Irrigated	Rainfed	Total
S_Asia	-40	22	-18	14	17	31
CHN_MNG	-23	3	-20	2	1	3
US	-3	12	9	2	10	12
S_Amer	2	28	29	2	27	29
SSA	3	118	121	3	117	120
Rest of world	-4	39	35	9	36	45
Total	-67	223	156	32	208	240

- Global cultivated cropland area in 2006: 1,486 Mha
$\approx$ 1.5 US

- With sustainability constraint, global cropland area in 2050
$\approx$ 1.5 US + Alaska

- Without sustainability constraint, global cropland area in 2050
$\approx$ 1.5 US + Alaska + Texas

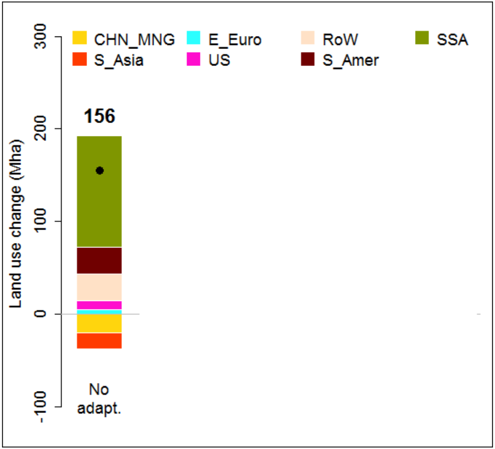
Grid-level irrigated cropland change (10^3 ha/grid)



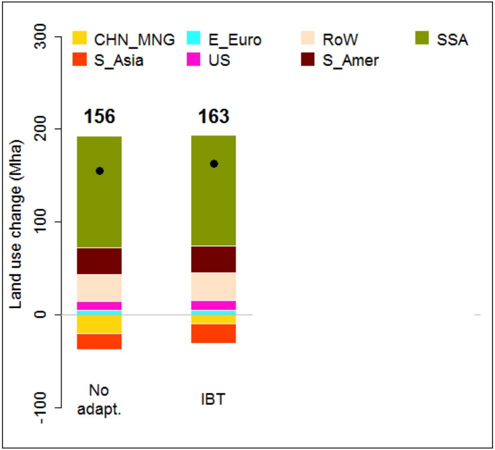
Global sum = -67 Mha

Results

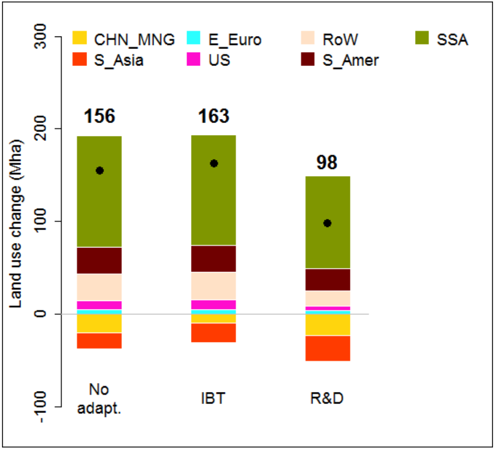
Cropland area change, 2050 relative to 2006
WITH adaptations


CHN_MNG
E_Euro
RoW
SSA
S_Asia
US
S_Amer
Land use change (Mha)
300
200
100
0
-100
156
No adapt.

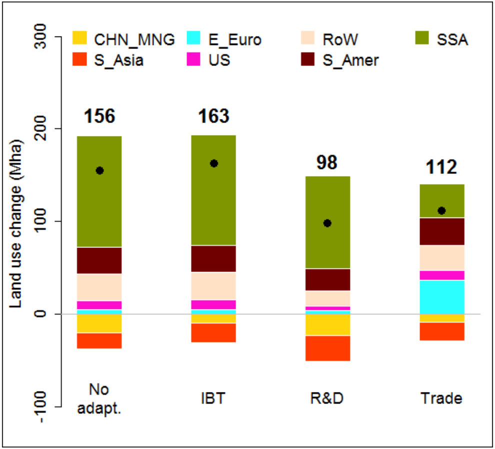
- Inter-basin transfer: keep China from losing 10 Mha cropland



- Inter-basin transfer: keep China from losing 10 Mha cropland
- R&D: reduce global cropland expansion by 50% (156 $\rightarrow$ 98)



- Inter-basin transfer: keep China from losing 10 Mha cropland
- R&D: reduce global cropland expansion by 50% (156 $\rightarrow$ 98)
- Trade: alter the spatial distribution of cropland expansion



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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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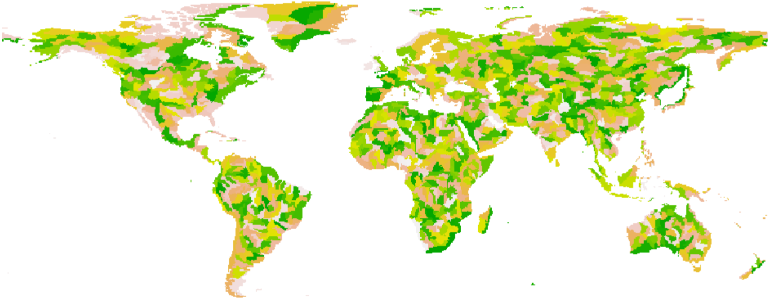
Current model features:

- 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

return



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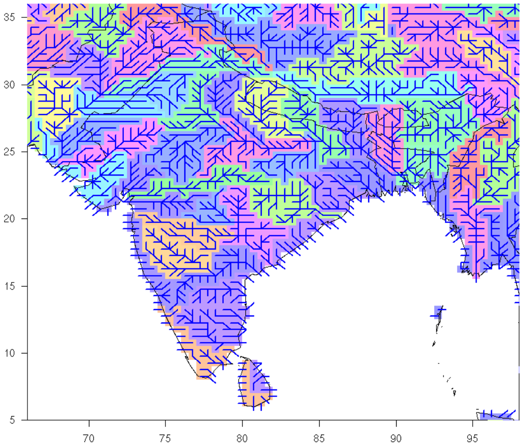

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References

Aeschbach-Hertig, W. and T. Gleeson (2012). Regional strategies for the accelerating global problem of groundwater depletion. *Nature Geoscience 5*(12), 853–861.

Alcamo, J., T. Henrichs, and T. Rosch (2000). World water in 2025: Global modeling and scenario analysis. *World water scenarios analyses*.