Sustainable irrigation in the global food system

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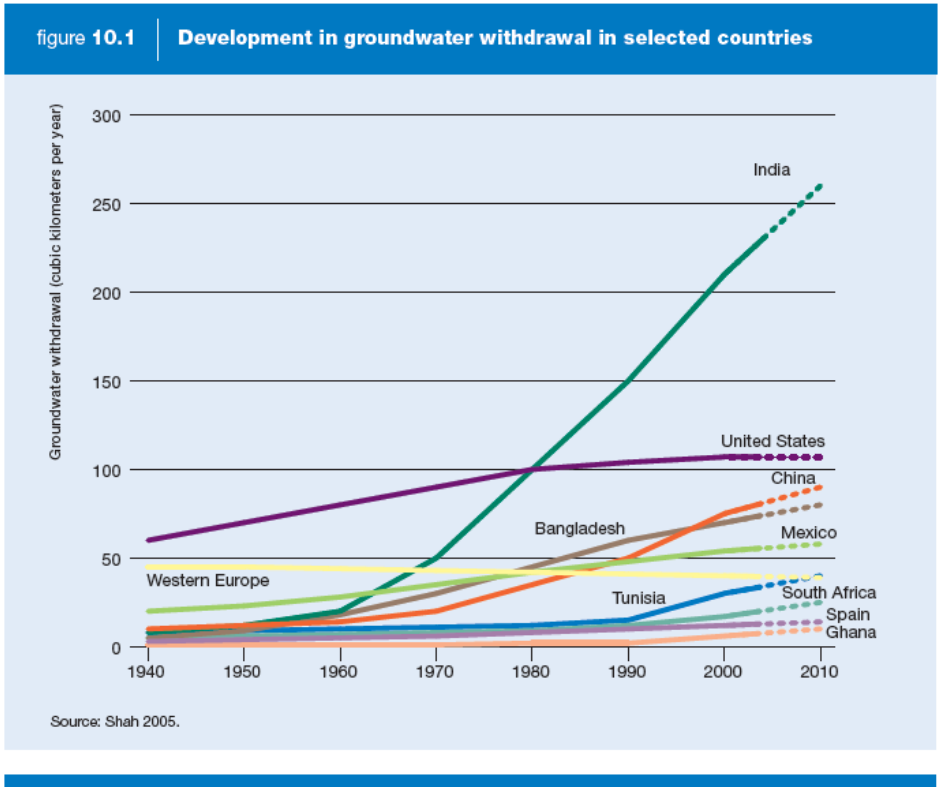
Outline of the talk

- Agricultural irrigation -- a threat to sustainability
- A Hydro-economic model of global irrigation
- Irrigation sustainability in 2050:
  - As affected by irrigation productivity growth
  - In face of climate mitigation
- Consequences for food security and carbon in the presence of:
  - Inter-basin water transfers
  - Integrated commodity markets and trade
- Conclusions

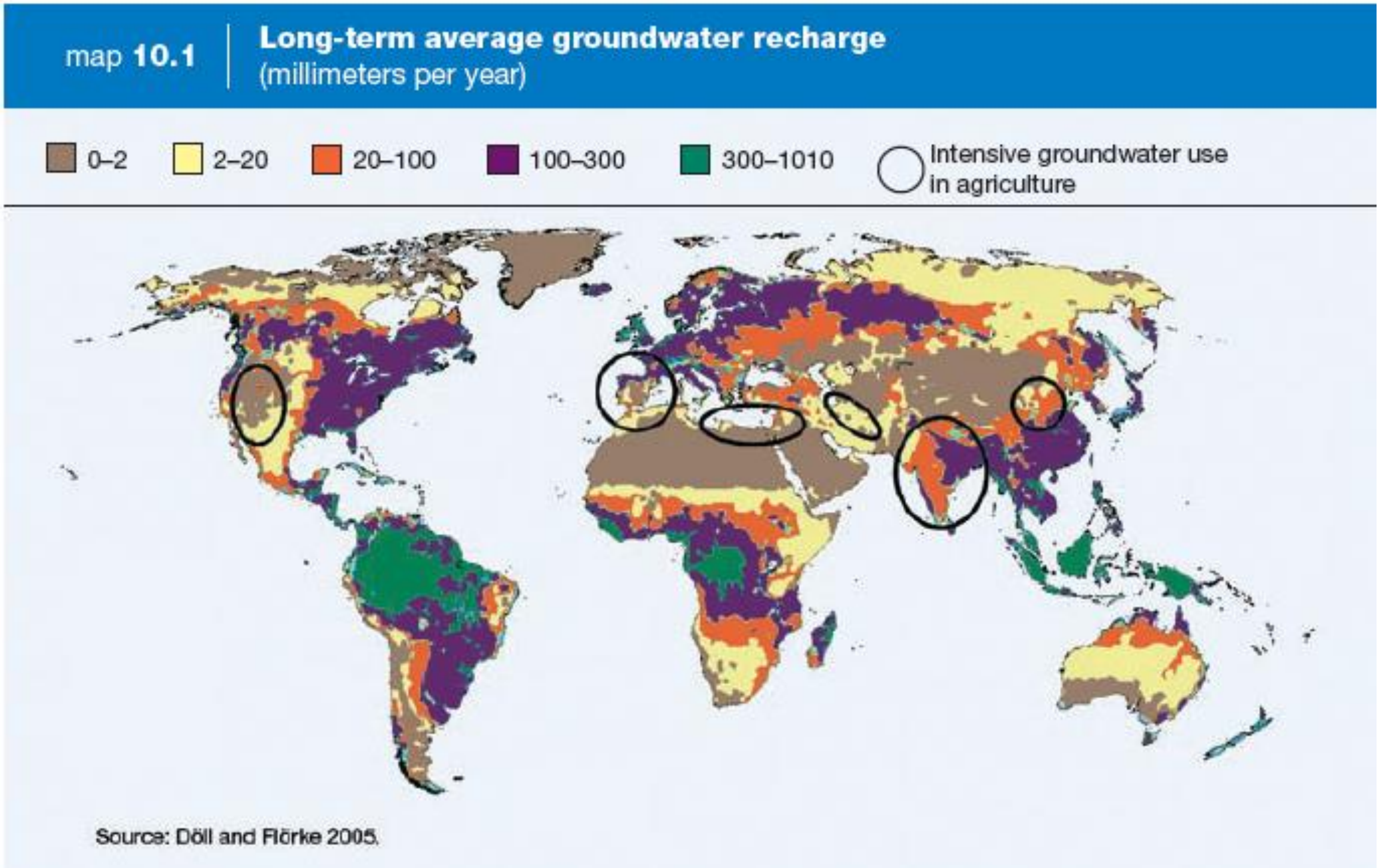
Groundwater irrigation has become increasingly important

- Partly in response to surface water scarcity
- Groundwater is ubiquitous and accessible without large scale government initiatives
- Greater drought resilience, as surface water often not available during drought years
- Reliability in time and space: low transmission and storage losses
- If undertaken in areas with high recharge rates, then it is also sustainable



Source: Burke and Villholth, 2007

But strongest growth has been in arid areas with low recharge rates



Source: Burke and Villholth, 2007

As a result, nonrenewable groundwater abstraction for irrigation is widespread

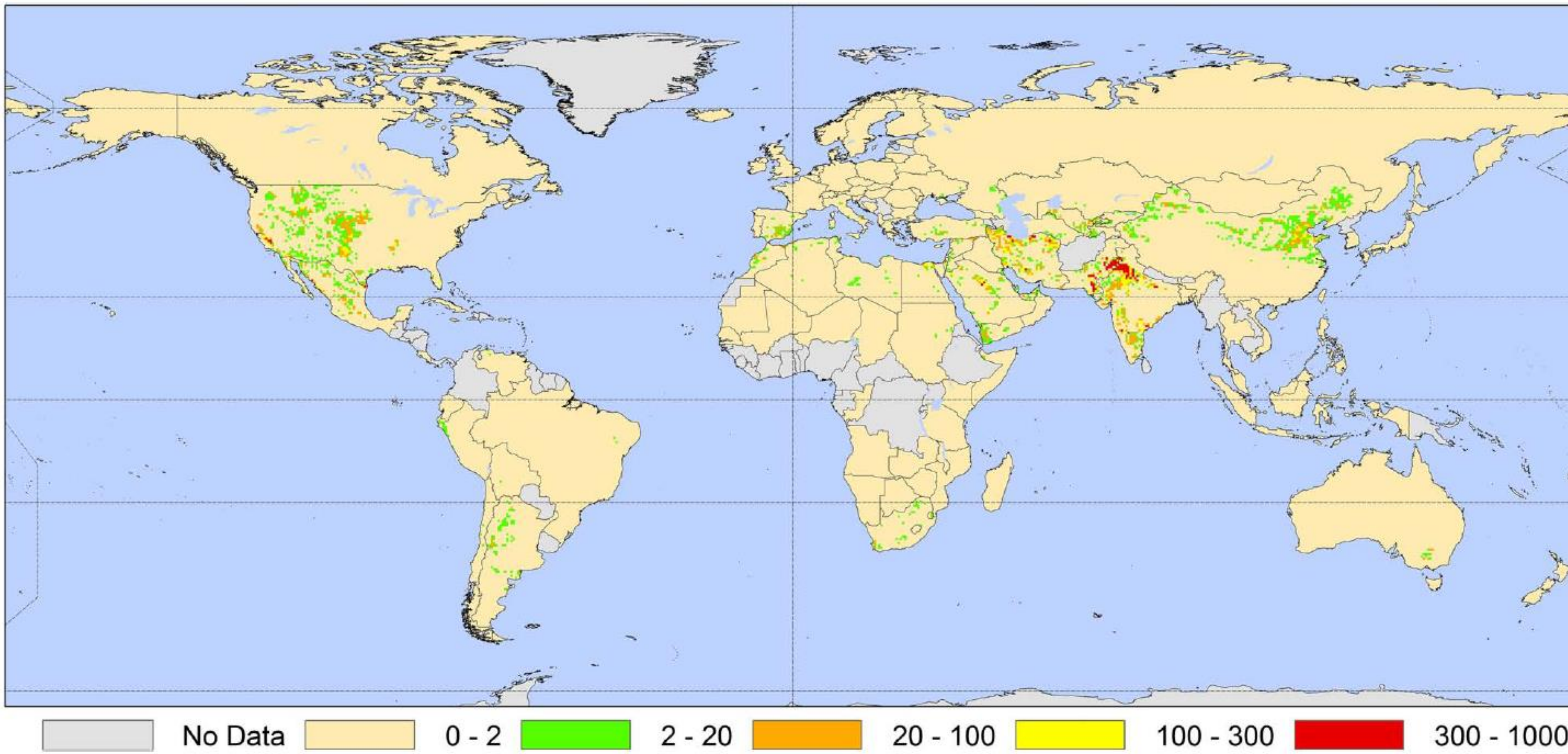


Figure 5. Nonrenewable groundwater abstraction for irrigation for the year 2000 (10^6 m^3 yr^{-1}).

Wada et al. (WRR, 2012): Estimated ***nonrenewable groundwater abstraction for irrigation*** for the year 2000 (10^6 m^3/yr)

We focus on sustainable irrigation threshold: Withdrawals less than 20% of available water (Alcamo et al., 2000)

- Irrigation vulnerability index:

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

$$\begin{aligned} Available\ water = &(discharge + storage + soil\text{-}stored\ water) \\ &- (residential + industrial + livestock\ demands) \end{aligned}$$

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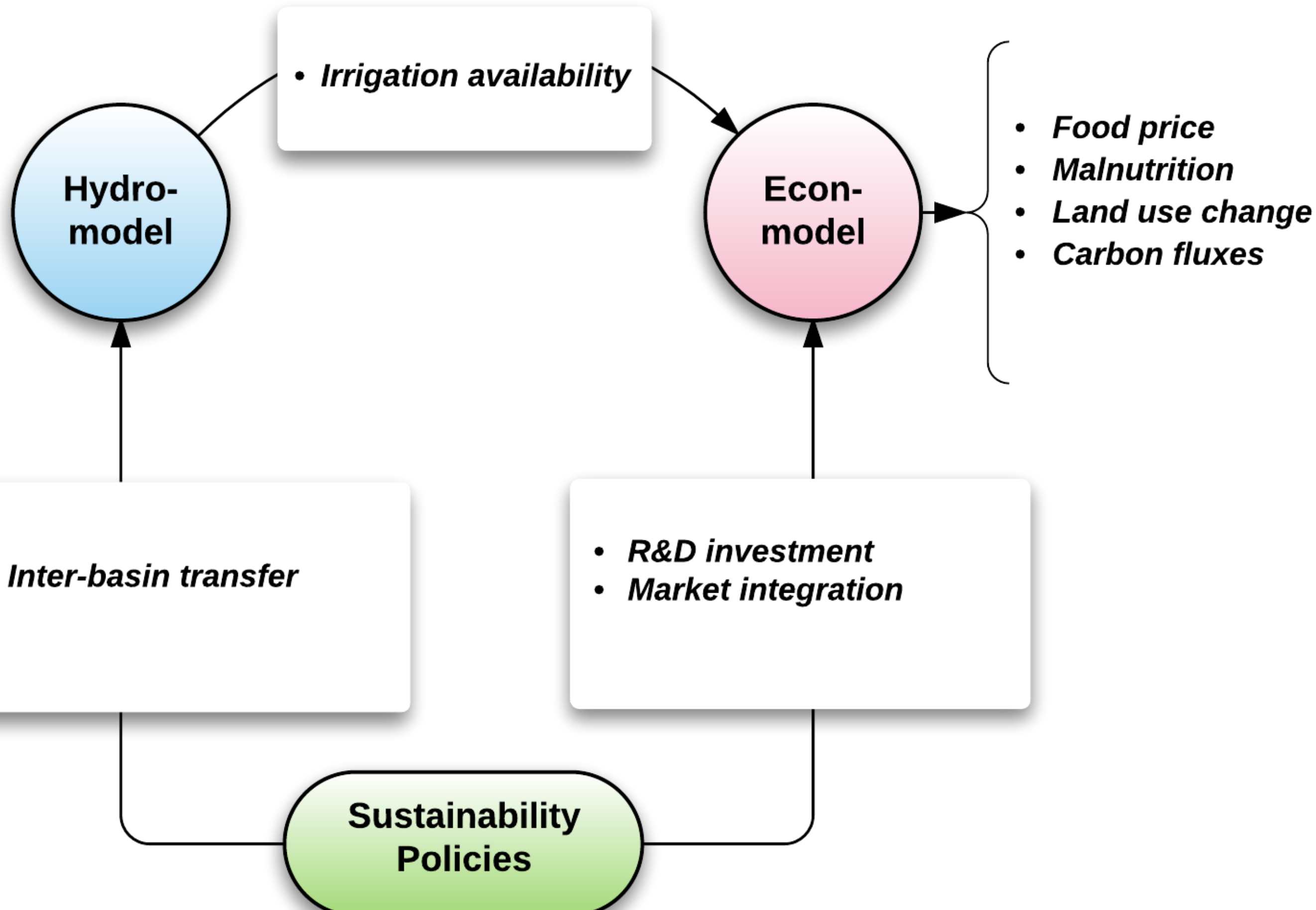
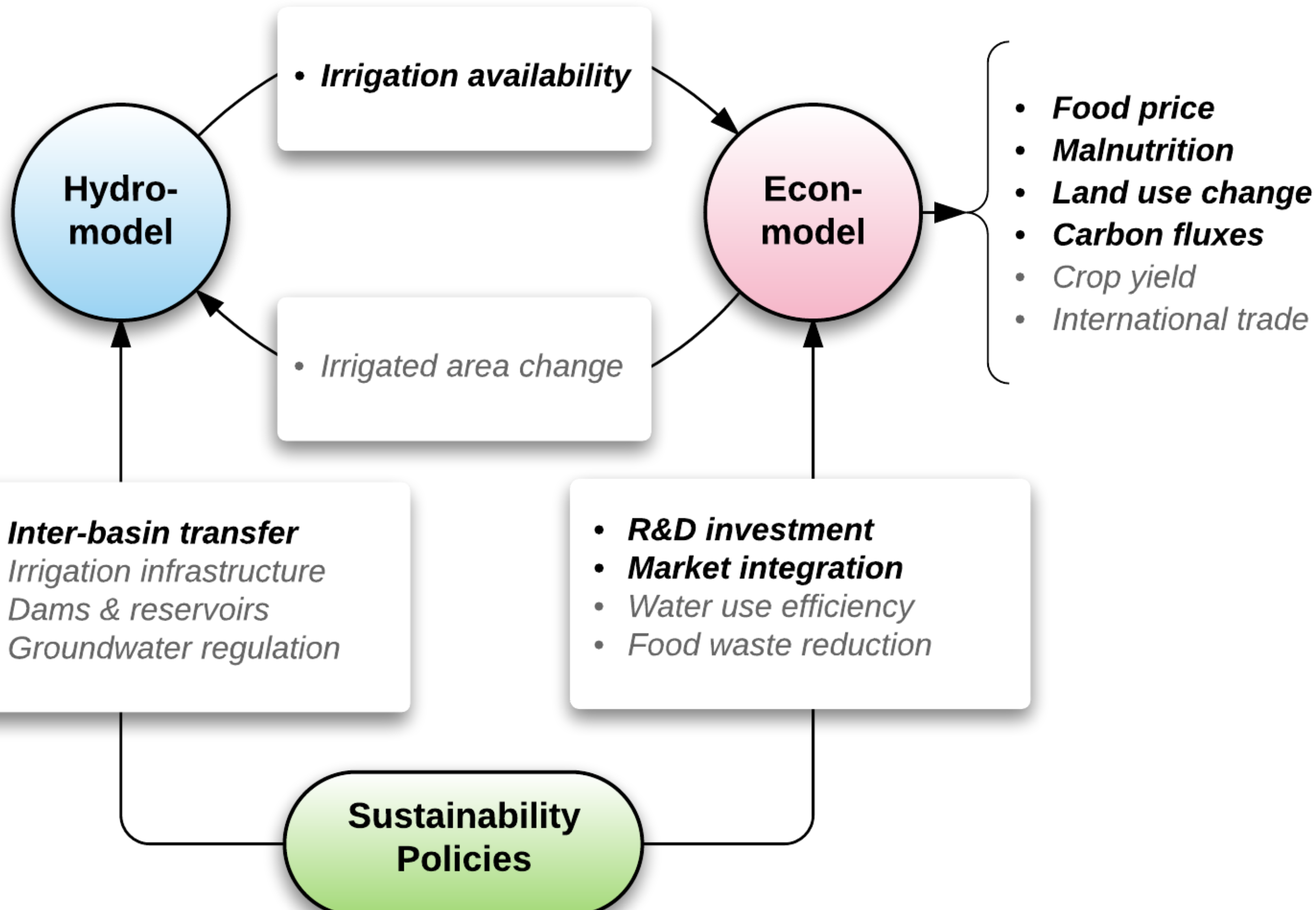
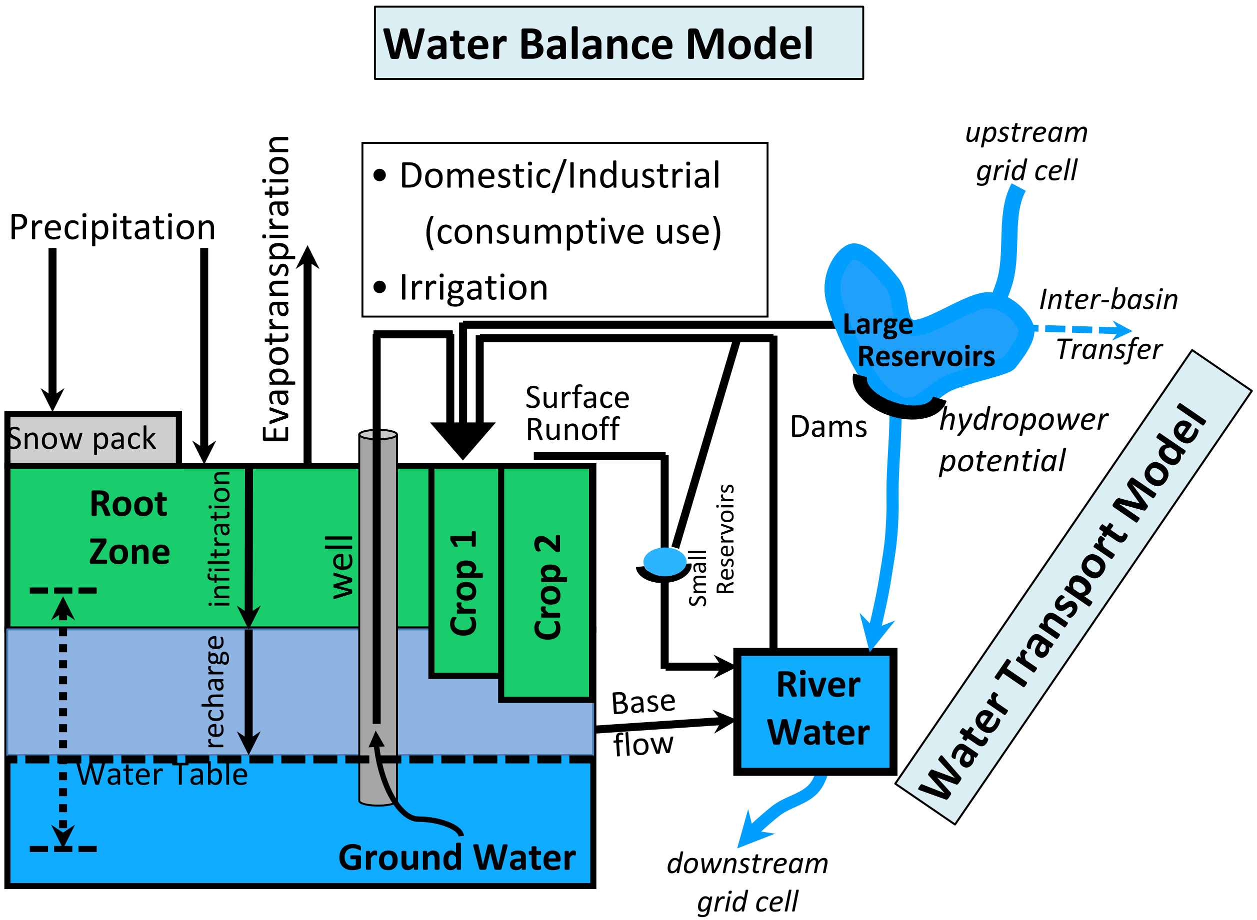
Method: Integrated hydro-economic modelling



Method: Integrated hydro-economic modelling

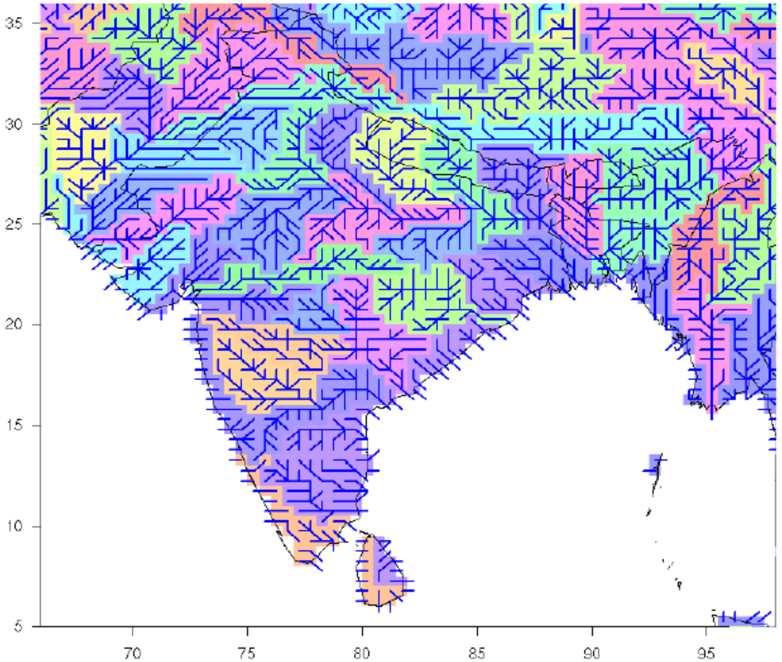


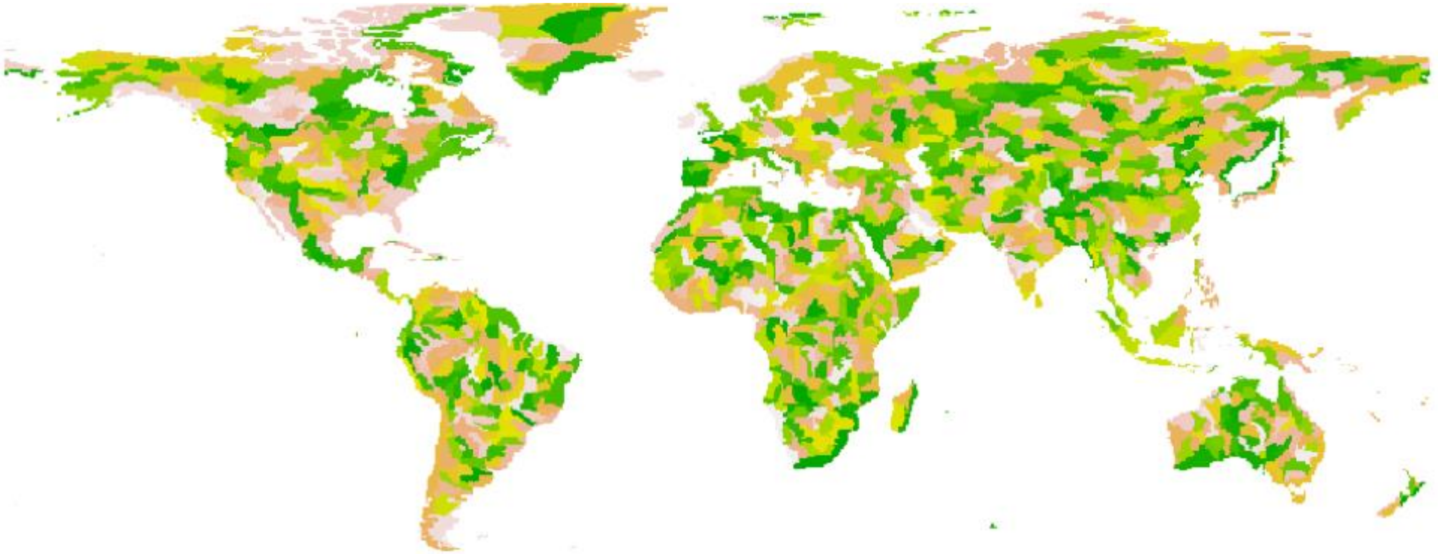
UNH: Hydrological Model



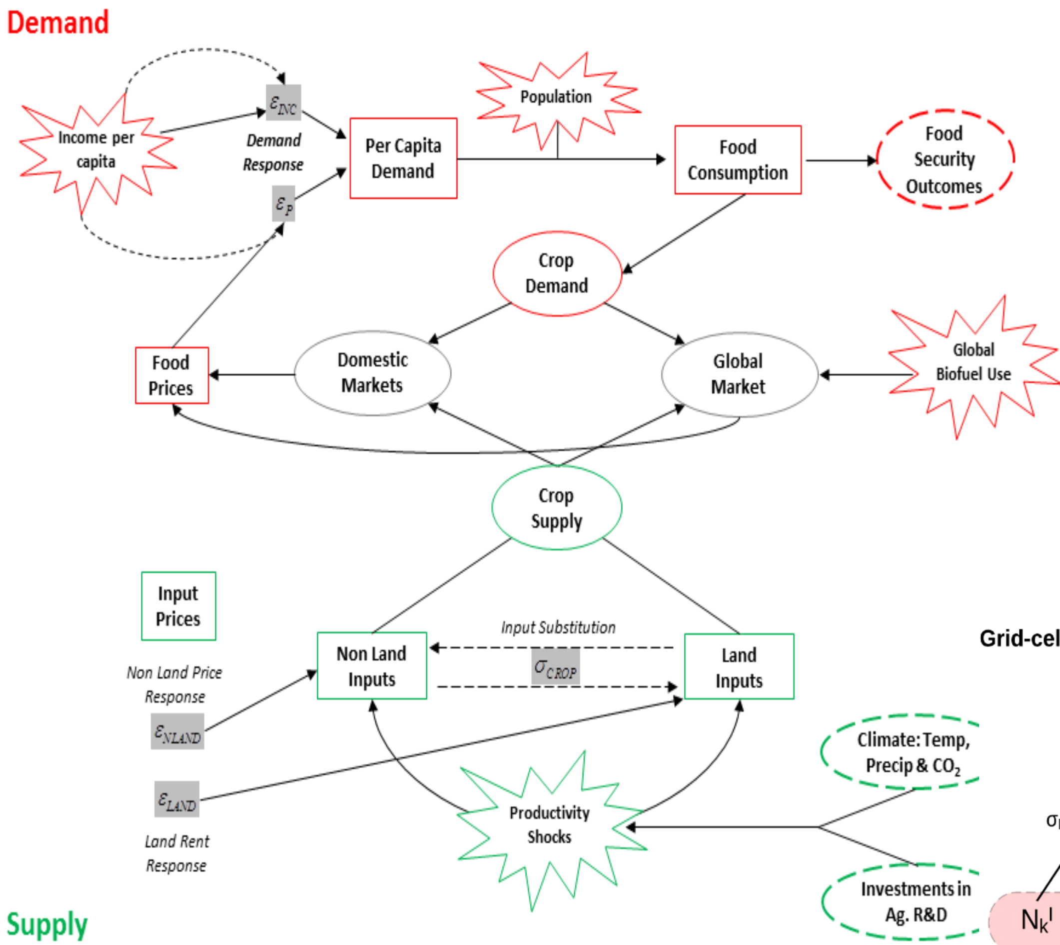
Flexible grid size, daily time step, water source/use tracking
Driven by: gridded daily weather, gridded crop & water use maps, reservoirs, IBTs, …

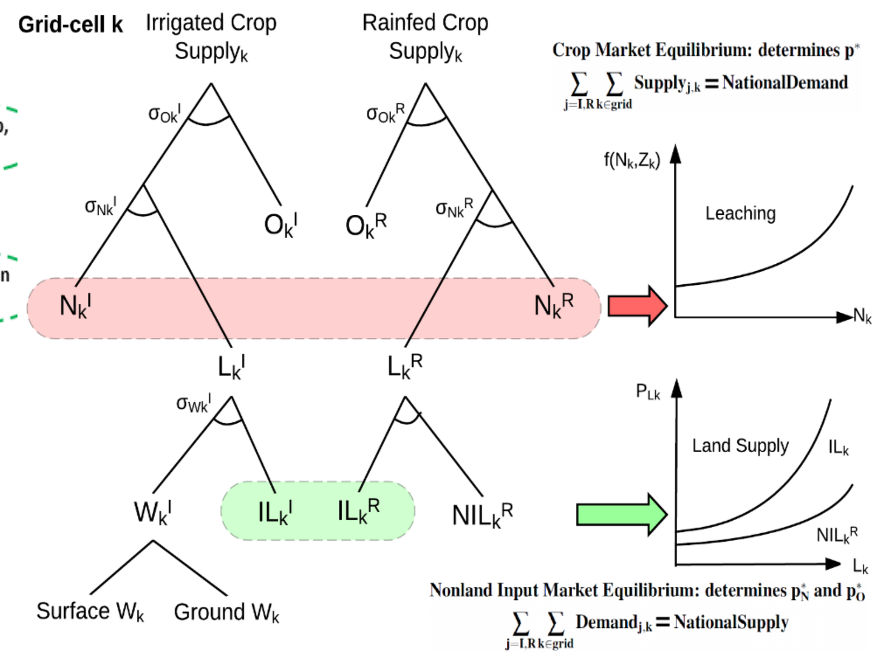
Water Balance Model Communicates results to economic model at sub-basin level





SIMPLE-on-a-Grid: Economic Model

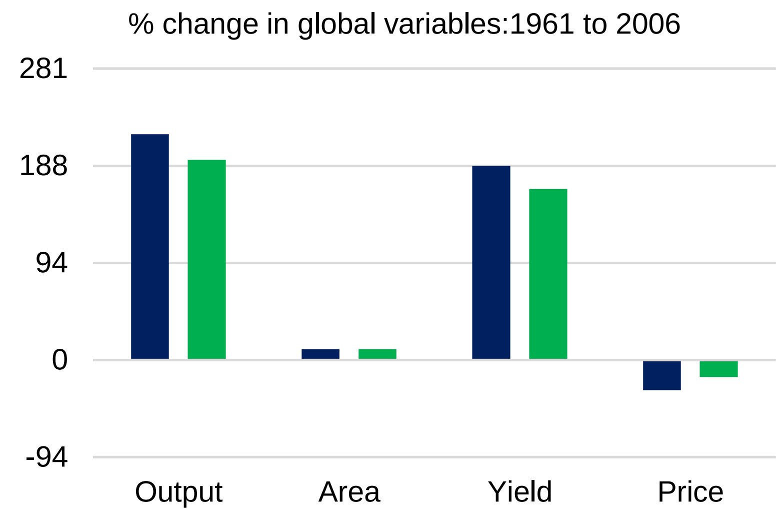


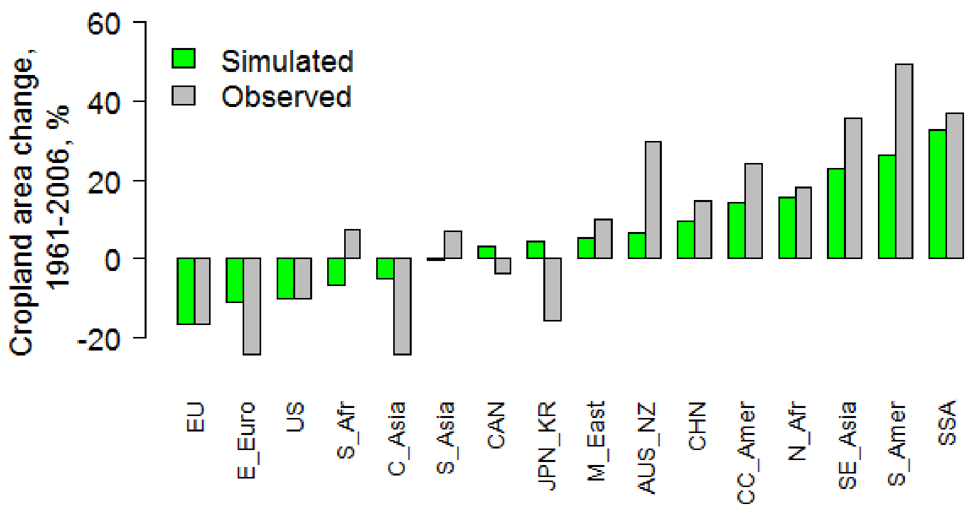


Sub-basins are aggregations of grid cells

SIMPLE Validation: Hindcasting 1961-2006

- Exogenous drivers are **pop, income, estimated TFP growth**, by region and sector

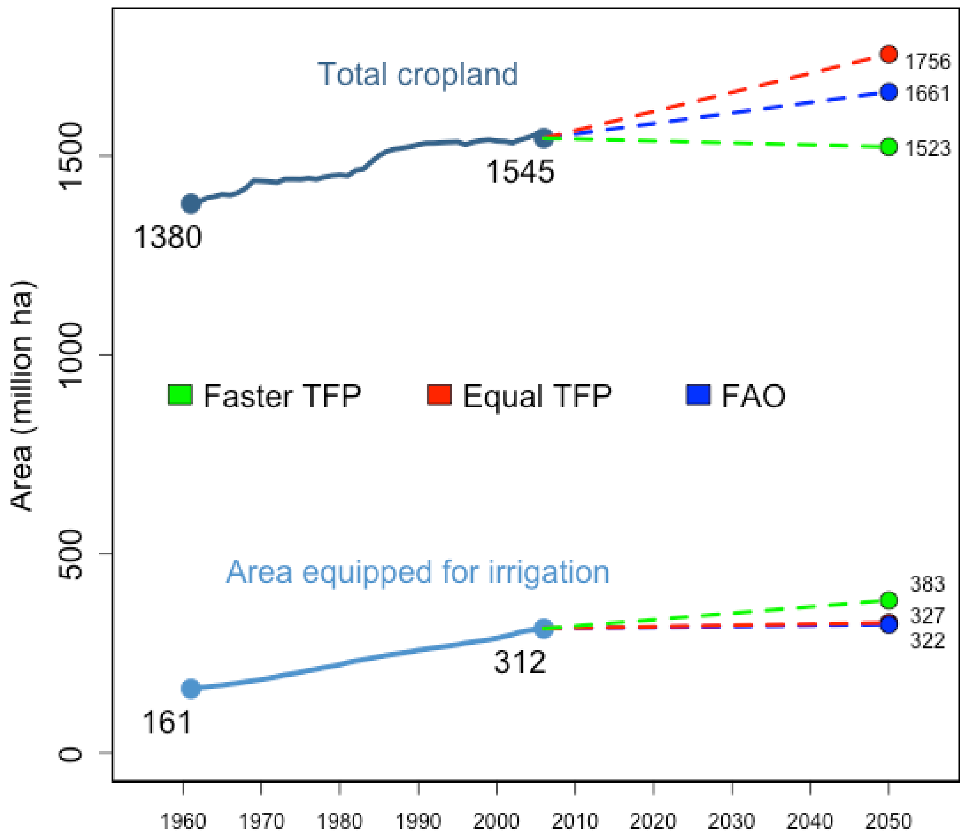




- Productivity growth was **more rapid for irrigated croplands**: 8.9% over 1961-2006 period

Sources: Baldos and Hertel, ERL (2013); Liu et al., in prep.

Future projections depend critically on the relative rates of Total Factor Productivity (TFP) growth for rainfed and irrigated croplands



Sources: Alexandratos and Bruinsma, 2012 and authors calculations.

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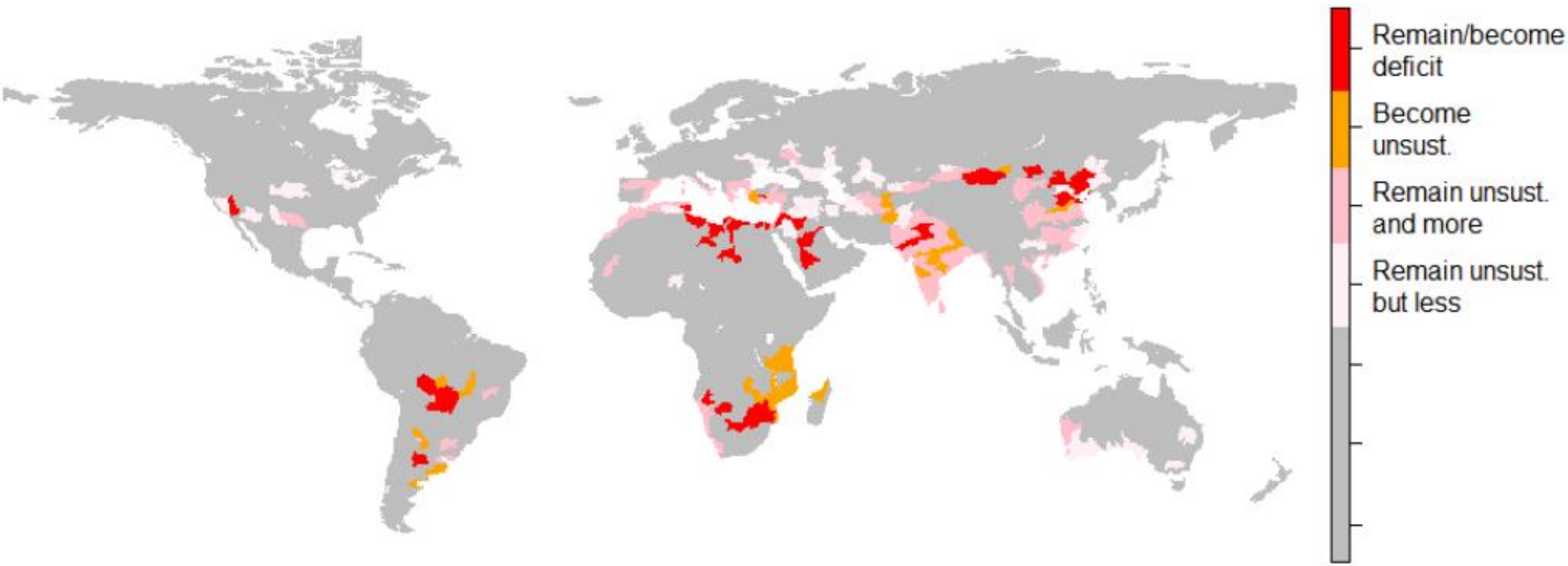
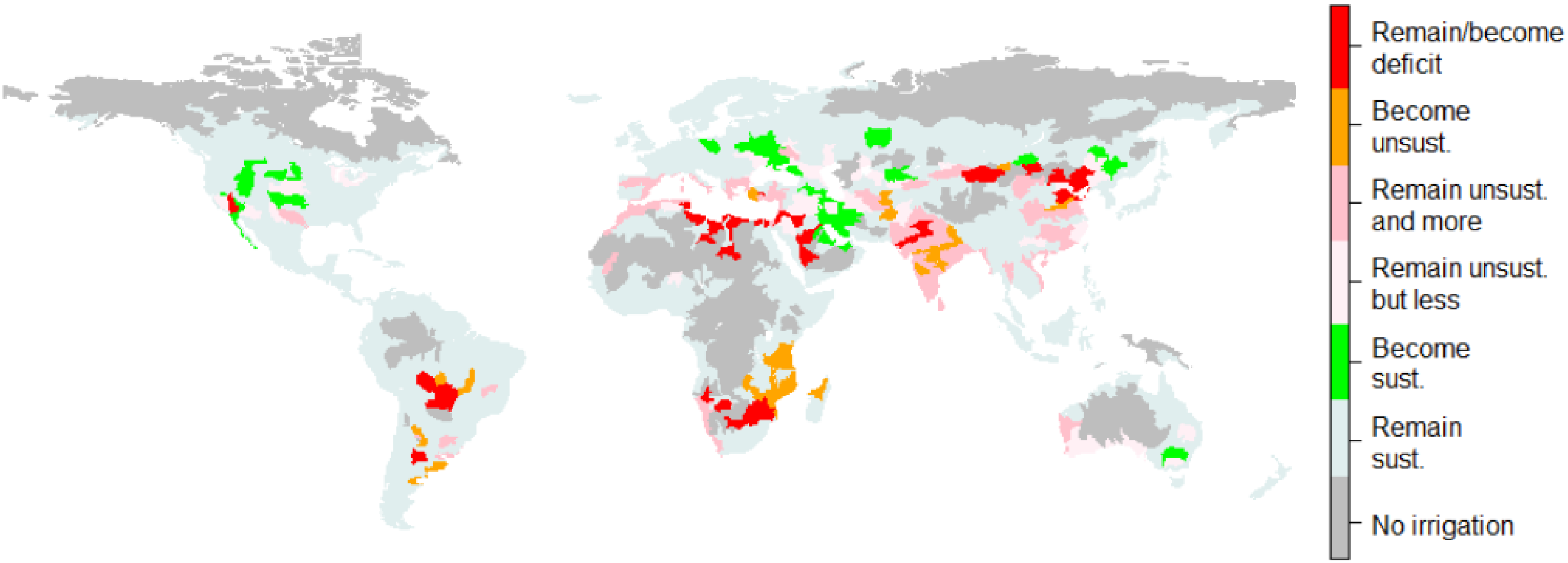
Projections to 2050: Unsustainable irrigation (RCP 8.5, equal rates of productivity growth)



Source: author's calculation.

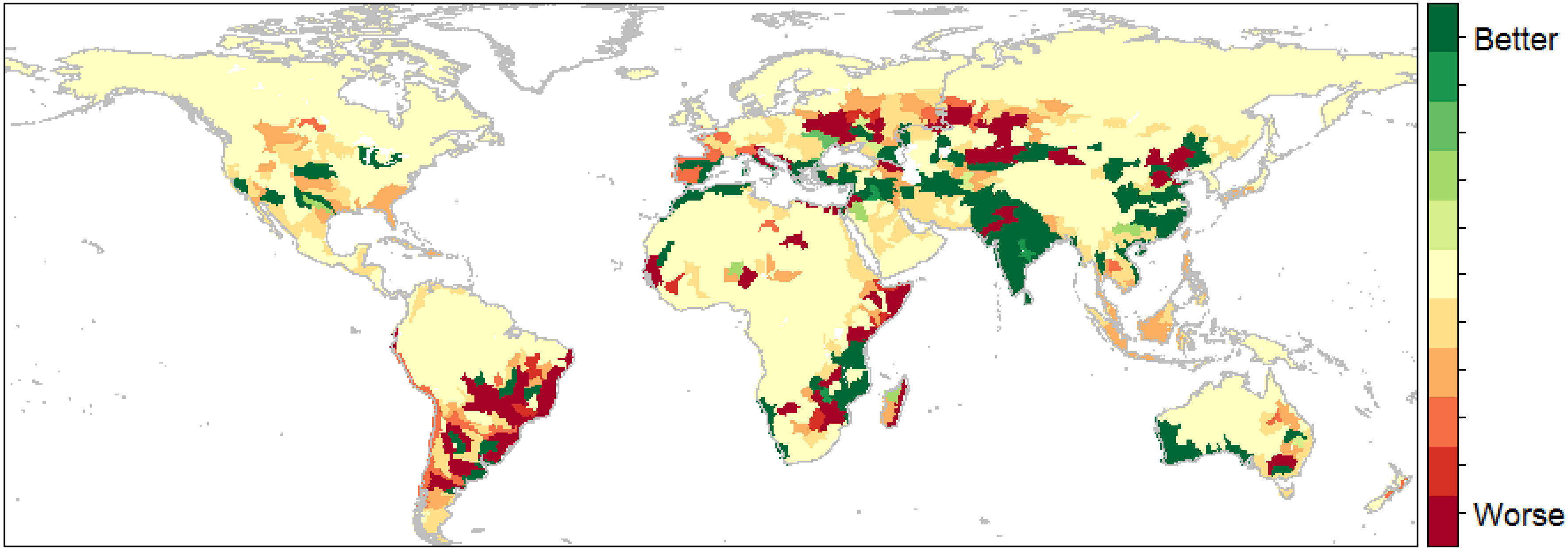
Irrigation in some regions becomes more sustainable (2006-2050: RCP 8.5, equal TFP)



Source: author's calculation.

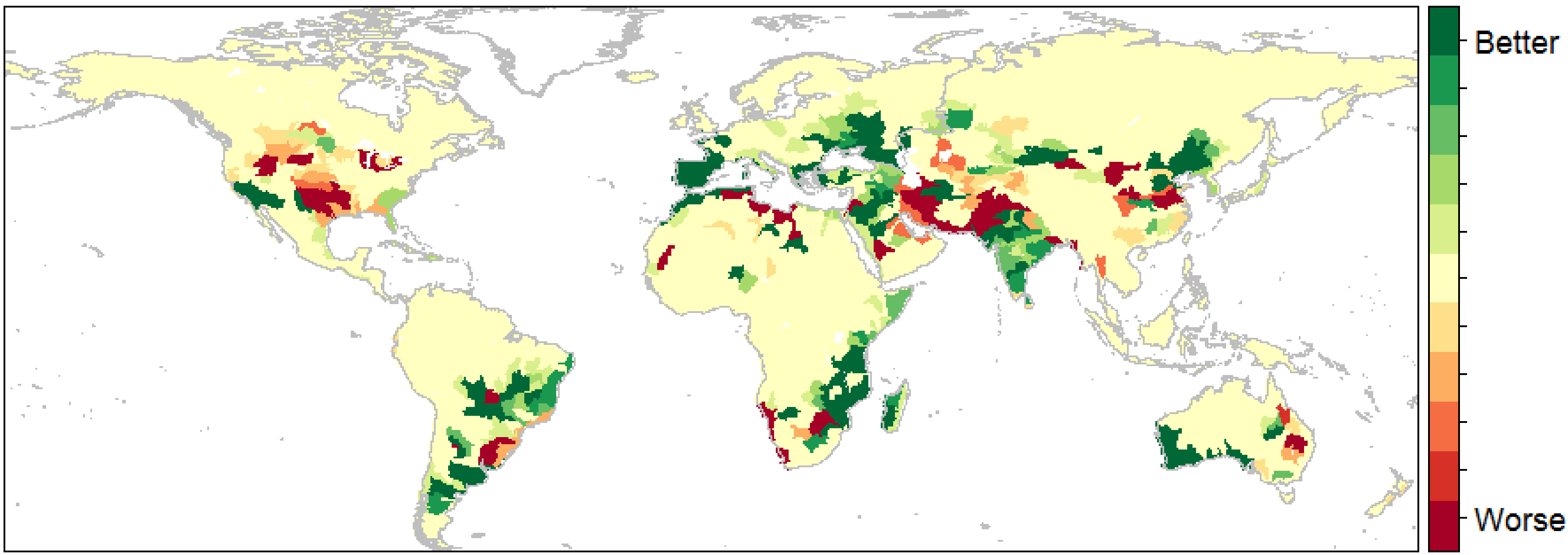
Impact on sustainability index of *faster productivity growth on irrigated lands*

'Better' means index value is smaller (more sustainable) with faster irrigation productivity growth



Impact of *climate change mitigation* on sustainability index (RCP 2.6 – 8.5)

‘Better’ means index value is smaller (more sustainable



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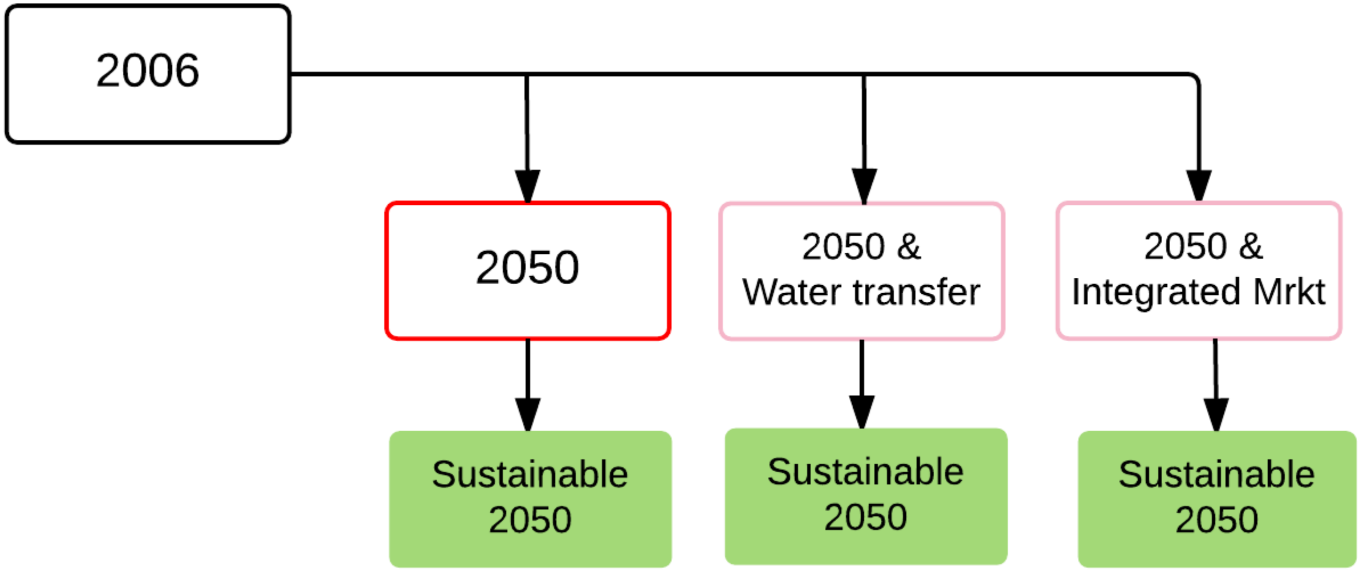
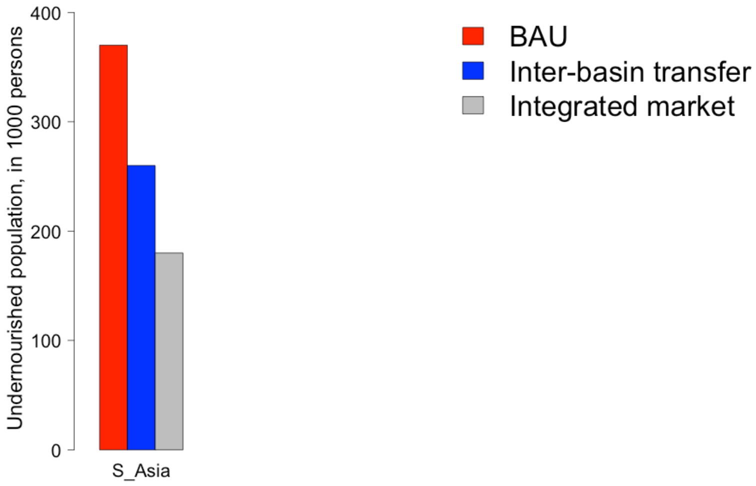
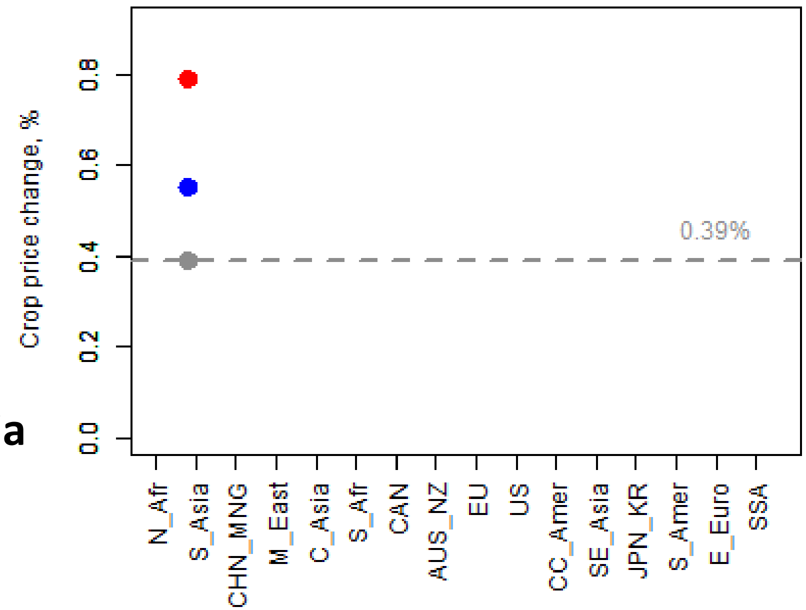
- Agriculture and the threat to global sustainability
- A Hydro-economic model of global irrigation
- Irrigation sustainability in 2050
- **Consequences of irrigation sustainability policies for food security and carbon:**
  - **BAU**
  - **In presence of inter-basin water transfers**
  - **In presence of integrated commodity markets**
- Conclusions

Impacts of imposing sustainability in 2050:



Imposing sustainable irrigation has adverse impact on food security
Impact on undernourished population in 2050 (1,000's of people) and on crop prices (% change relative to baseline)





Inter-basin transfers moderate these effects
Integrated markets moderate impact in South Asia

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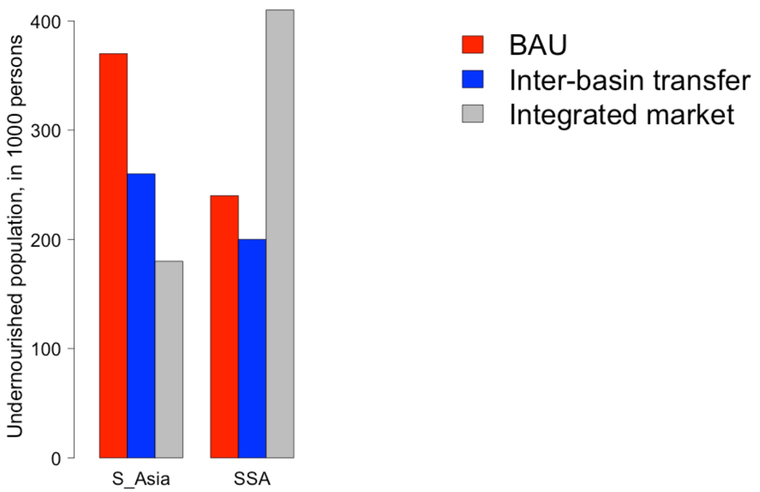

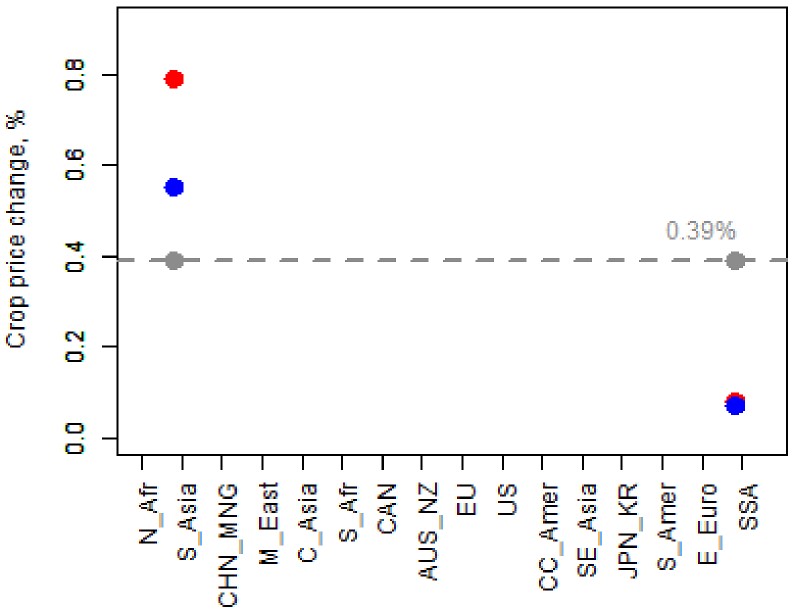

Inter-basin transfers moderate these effects

Integrated markets exacerbate impacts in SSA

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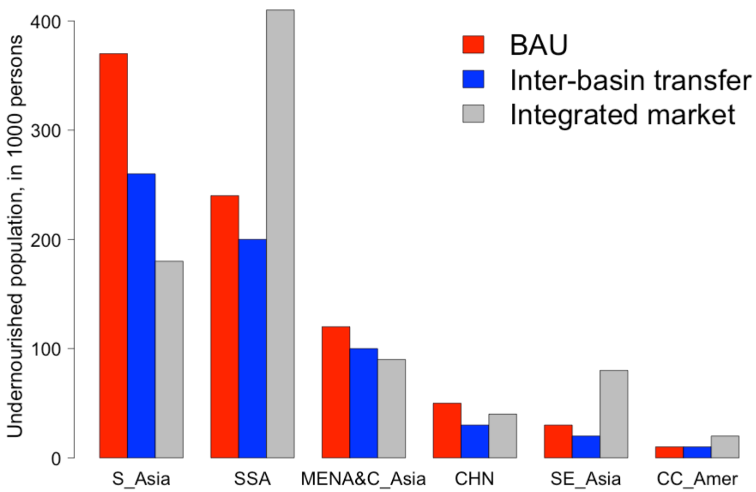
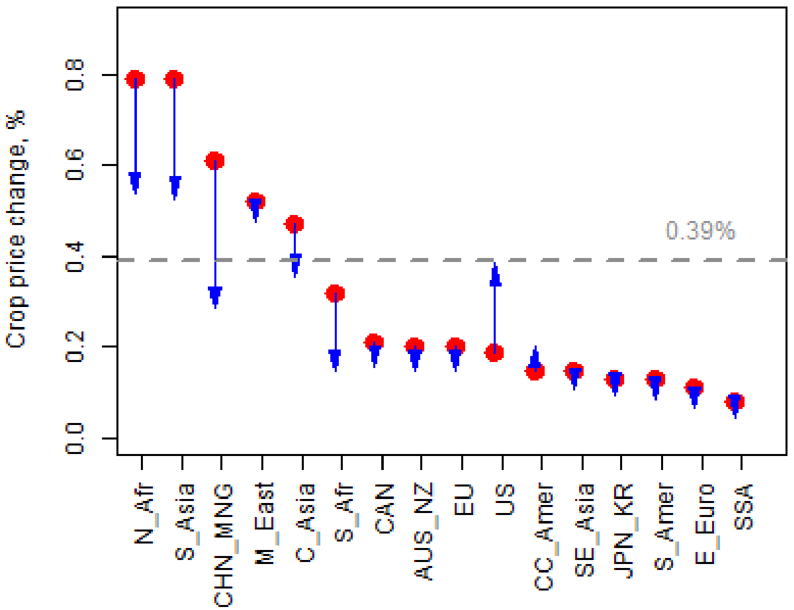
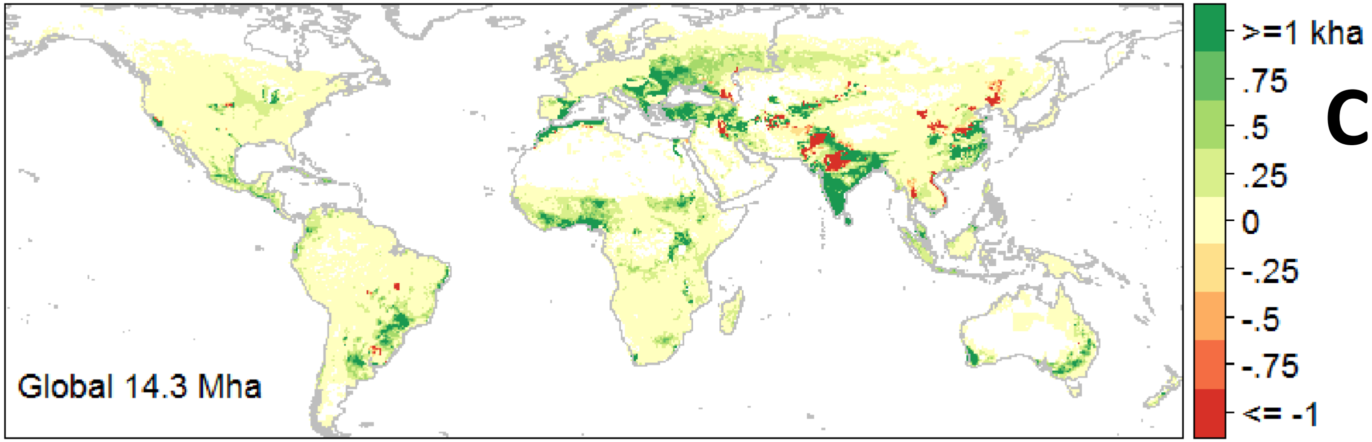




Inter-basin transfers moderate these effects

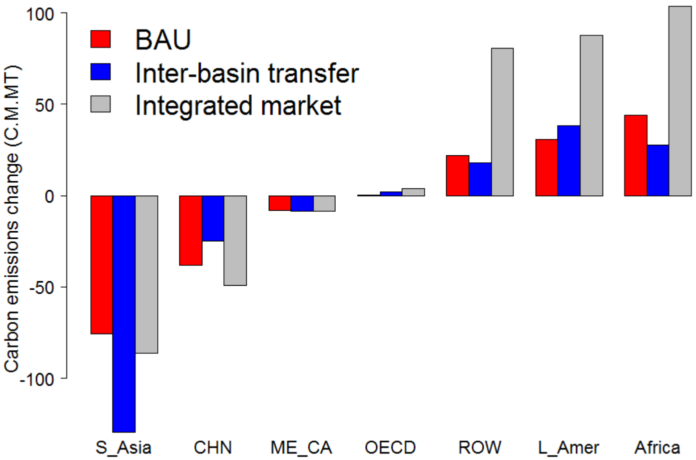
Imposing sustainable Irrigation has mixed effect on cropland cover and terrestrial carbon – (equal TFPs, BAU RCP 8.5)

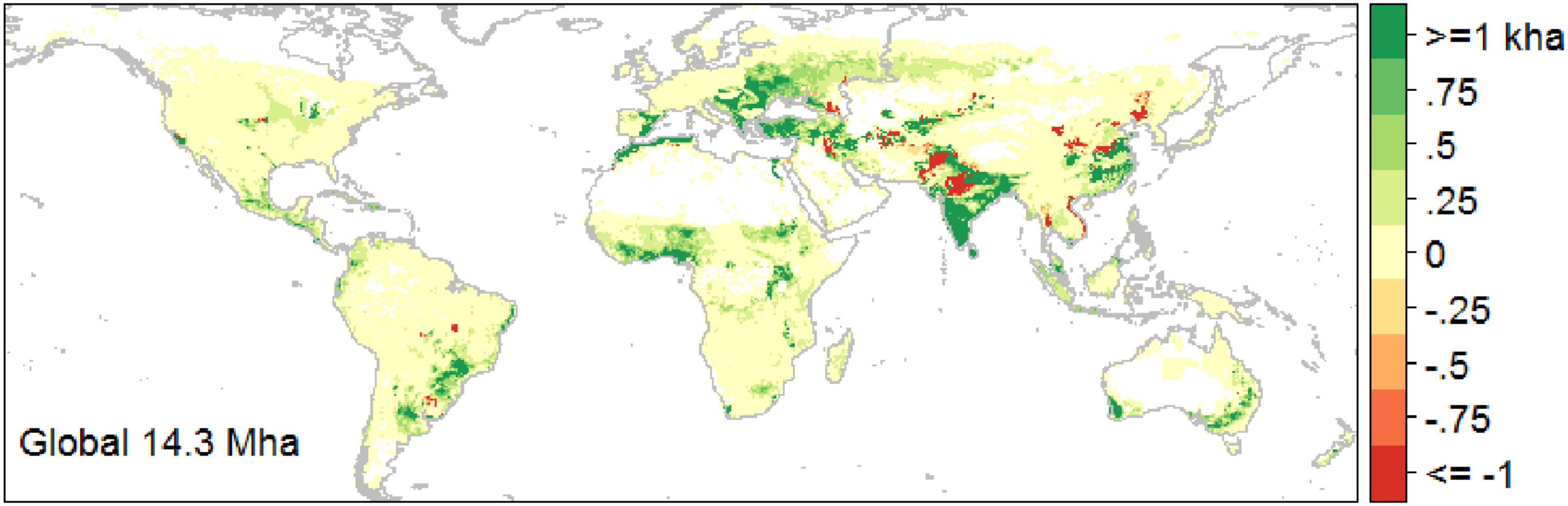
Map bottom shows net cropland area change under integrated markets



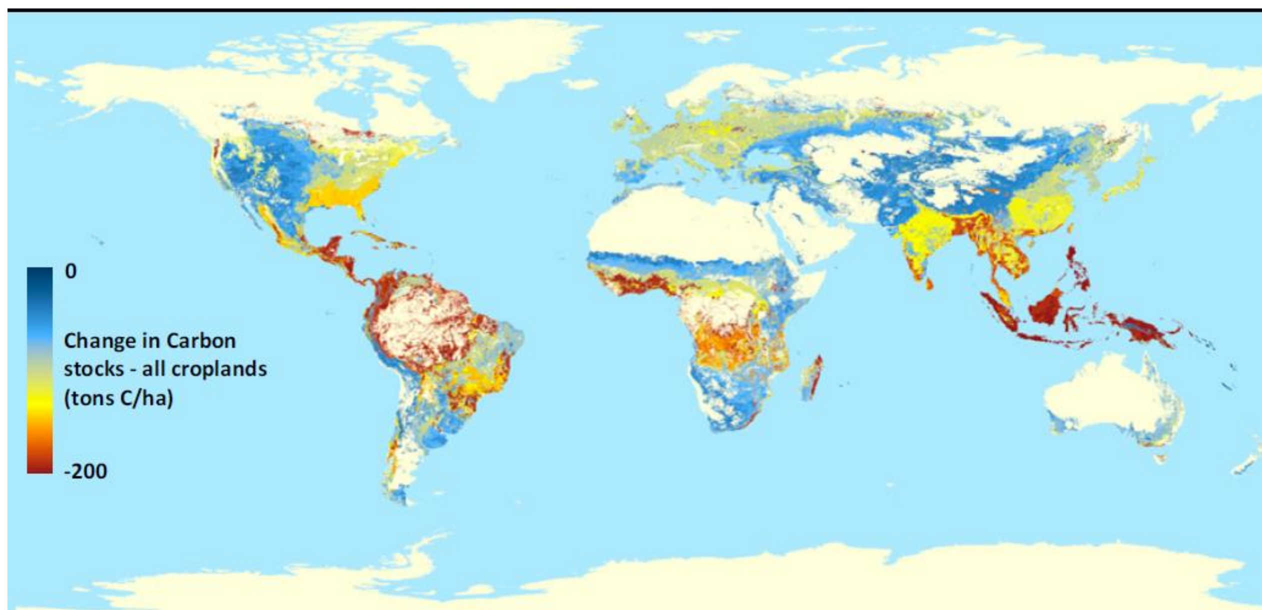
Cropland cover change

Terrestrial carbon fluxes, by region, due to sustainable irrigation policy





Varied impacts are driven by interaction between cropland change and terrestrial carbon stocks



Conclusions

- **Under BAU scenario, unsustainable irrigation increases in many, but not all, regions**
- **Evolving irrigation vulnerability index depends on:**
  - Relative rate of productivity growth: irrigation vs. rainfed crops, and
  - Climate change scenario
  - However, effects vary by sub-basin
- **Impact of sustainability policy also depends on structure of water and commodity trade:**
  - Presence of inter-basin water transfers
  - Extent of commodity market integration

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