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Modeling of water resources: applications of the models *KLUM-W* and *GTAP-W*

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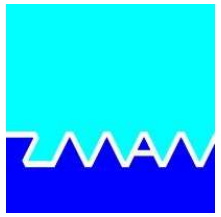


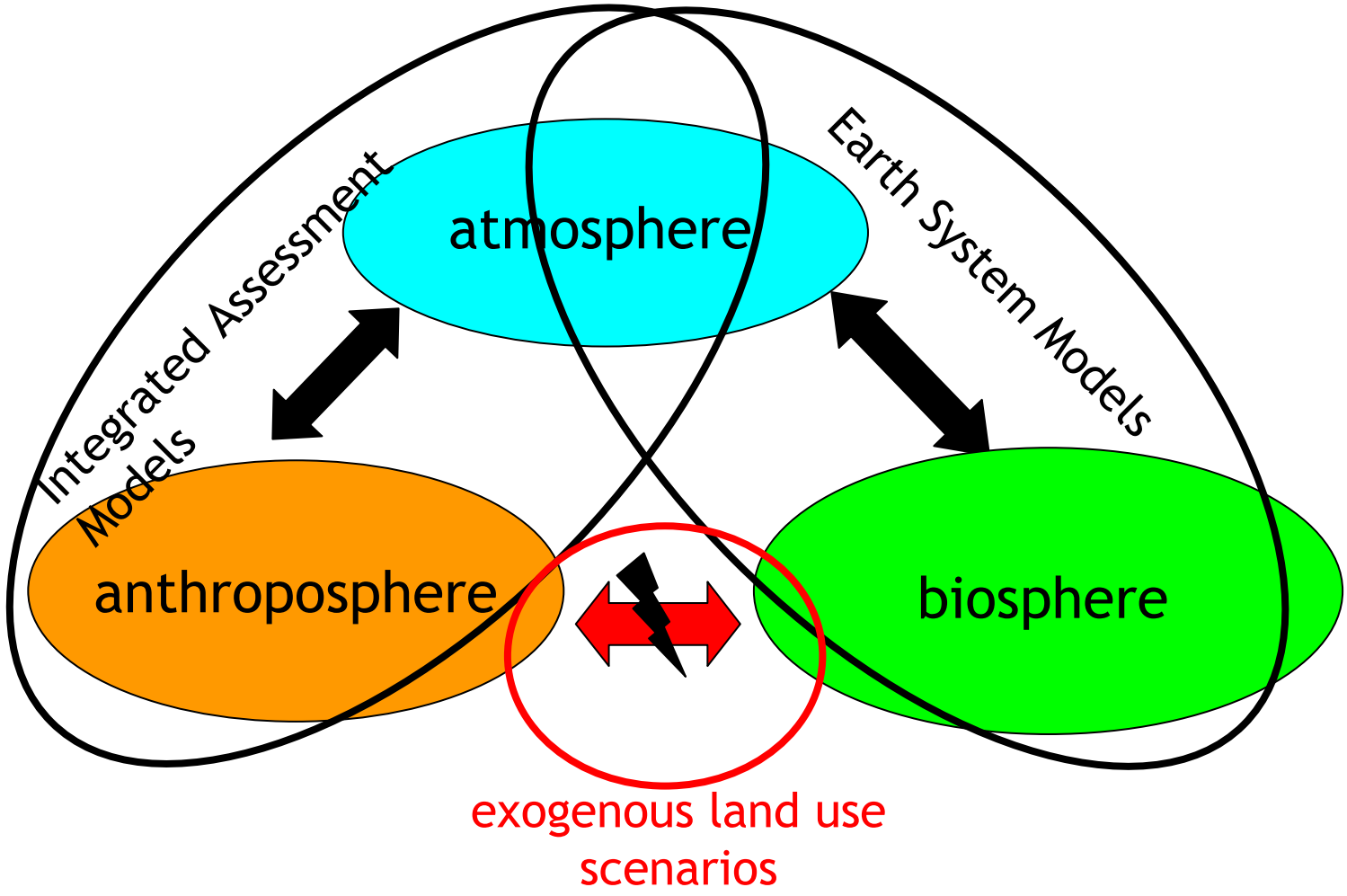
Outline

- **Part I: Introduction**
  - the importance of water resources
  - concepts of land use modeling
- **Part II: *KLUM-W***
  - concepts of *KLUM* / *KLUM-W*
  - evaluation of the stand-alone version of *KLUM*
  - initial analyses with *KLUM-W @ Global-FASOM*
- **Part III: *GTAP-W***
  - description of GTAP-W
  - scenarios of water efficiency assessments
  - application and results
- **Part IV: Conclusions**
  - summary and first insights

Water availability and use

- The main users are agriculture, industry and domestic water use
- About 70% of water resources are used in agriculture
- Unfortunately, water resources are unevenly spread over the globe
- In some regions water resources are seriously under pressure
- This tendency is likely to worsen
- Increase the import of water-intensive products to arid areas to relieve water stress
- Seek improvements in the efficiency of irrigation systems and water consumption

Climate change assessment



Global land use modeling

- Global models tend to be disciplinary:
  - emphasis on geography (based on land suitability, interested in spatial patterns)
  - emphasis on economy (based on profit maximization, interested in effect on economy)
- Some integrated approaches
  - comprehensive: Not appropriate for coupling purposes
  - empirical / rule-based: Neglecting economic motivation and dynamic market feedbacks
  - rarely consider irrigation cost and water scarcity

KLUM → KLUM–W

Initial objective of KLUM:

- design a land use model that is complex enough to describe essential economic and geographic aspects of land use decisions

  and simple enough to enable online coupling and global long-term projections

Need for an extension of KLUM:

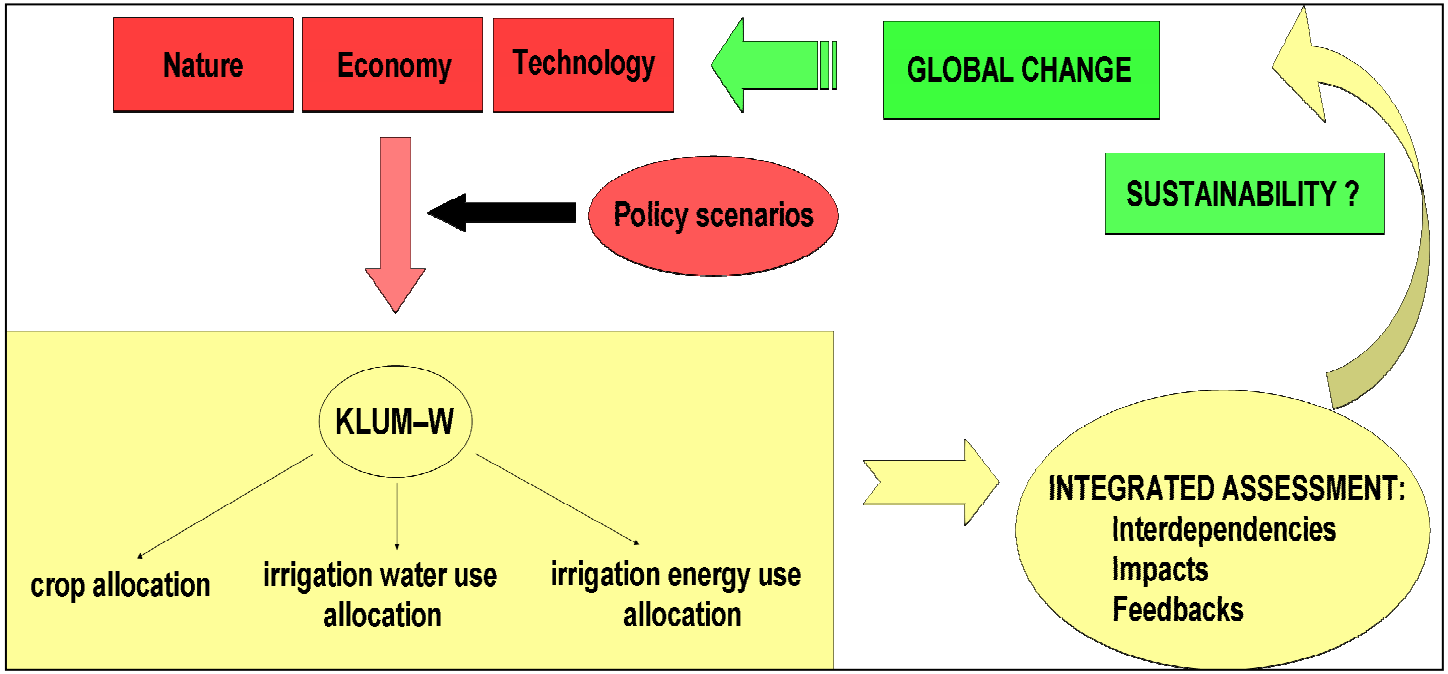
- no distinction between rainfed and irrigated yields
- no consideration of management options and related cost
- unconstrained water availability

Research aims

- effects of changing water availability and irrigation cost on global crop distribution
- role of energy use in irrigation
- possible implications for water balance and sustainability

→ integration of irrigation water use to improve the projection of actual cropping decisions and research in the context of global change

KLUM-W approach



Realization

- **derive the crop allocation from a profit function**
- **data used for validation:**
  crop prices, yields, harvested areas of 35 years (1966-2000)*
  crop irrigation water demands, rainfed/irrigated yield ratios**
  energy prices***
  labor cost****
- **model characteristics:**

  temporal resolution: years

  spatial resolution: countries (regions)
  - 182 countries, 16 world regions

  agricultural commodities: food crops
  - 20 crop aggregates (about 120 individual crops)

  four irrigation methods; choice between four energy sources

* (FAOSTAT 2004 & World Development Indicators 2003)
** (Observed data yet unpublished)
*** (EIA 2006 & GTZ 2005)
**** (World Development Indicators 2006 & IMF 2007)

Mathematical formulation

$$\pi_A = \sum_{k,mg,im}^{n} p_k \alpha_{k,mg} \rho_{k,mg,im} - C_{k,mg,im} - \gamma \sum_{k,mg,im}^{n} \mathrm{Var}[\, p_k \alpha_{k,mg} \rho_{k,mg,im} - C_{k,mg,im}\,]$$

expected profit

risk adjustment (variance of expected profit)

with

$$C_{k,mg,im} = f\,(\,\rho_{k,mg,im}\,,\ \text{capital cost}_{mg,im}\,,\ \text{O\&M cost}_{k,mg,im}\,,\ \text{further cost}_{k,mg}\,)$$

Maximize profit s.t. use no more land than available
s.t. use no more water than available

π_A : profit from crop production per country

p_k : price of crop k

$\alpha_{k,mg}$: productivity [yield in tons/1000 ha] by management of crop k

$\rho_{k,mg,im}$: share of land by management and irrigation method allocated to crop k

γ : risk adjustment factor

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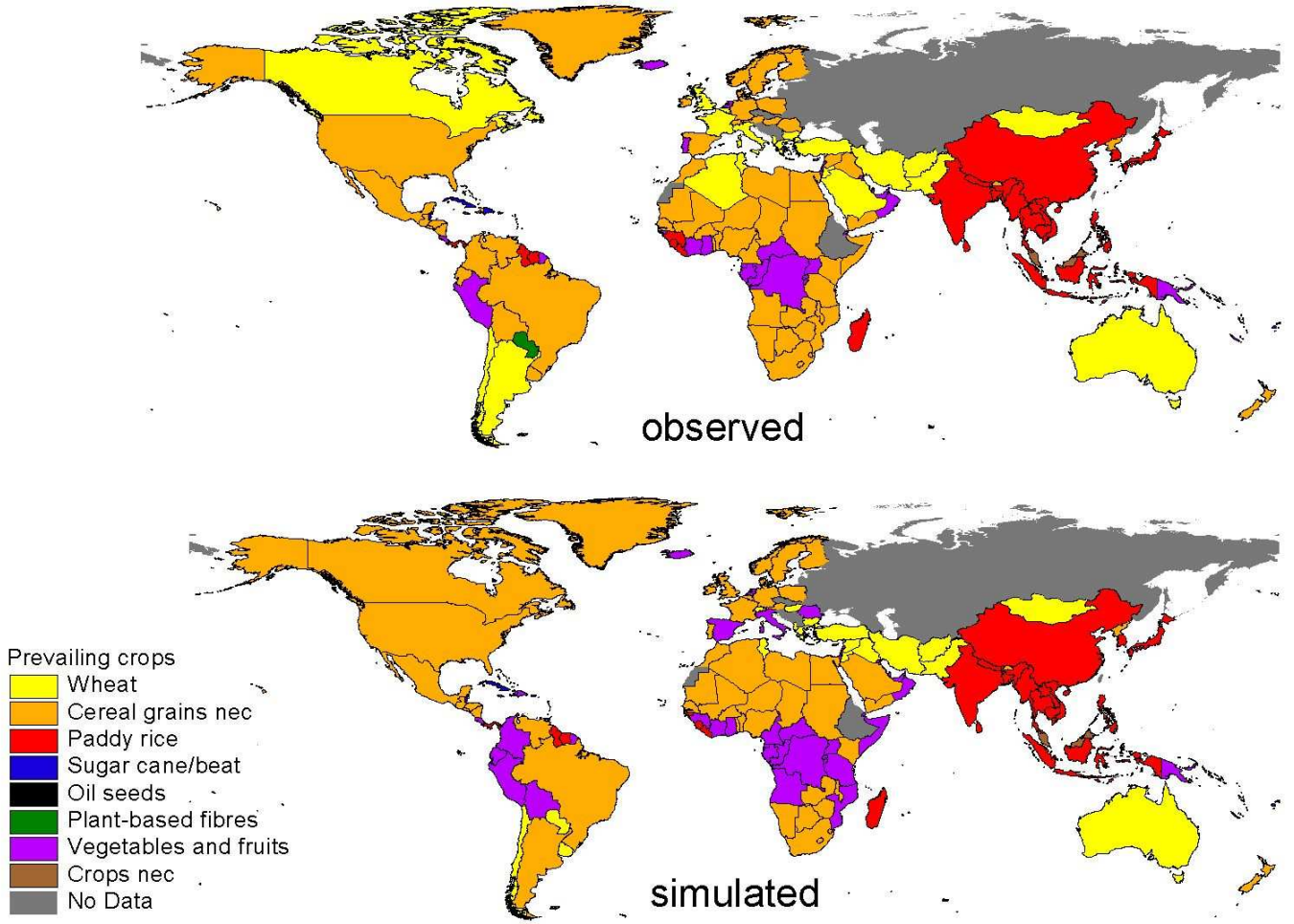
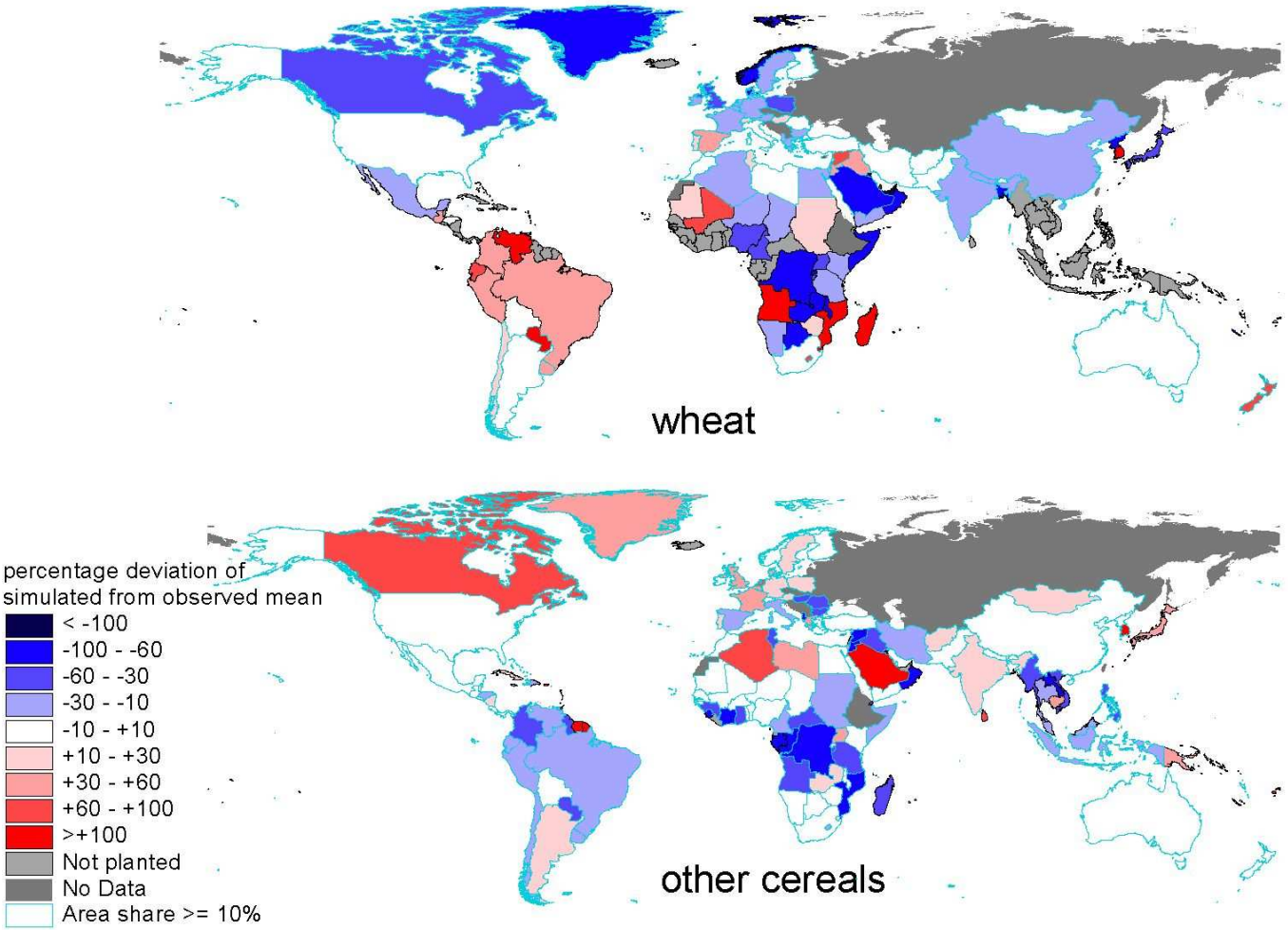
Implementation

- testing and validation of the *KLUM*/*KLUM-W* stand-alone version
- integration into the *Global-FASOM* modeling framework
- coupling with *GTAP* for application in scenario assessments

Crop patterns

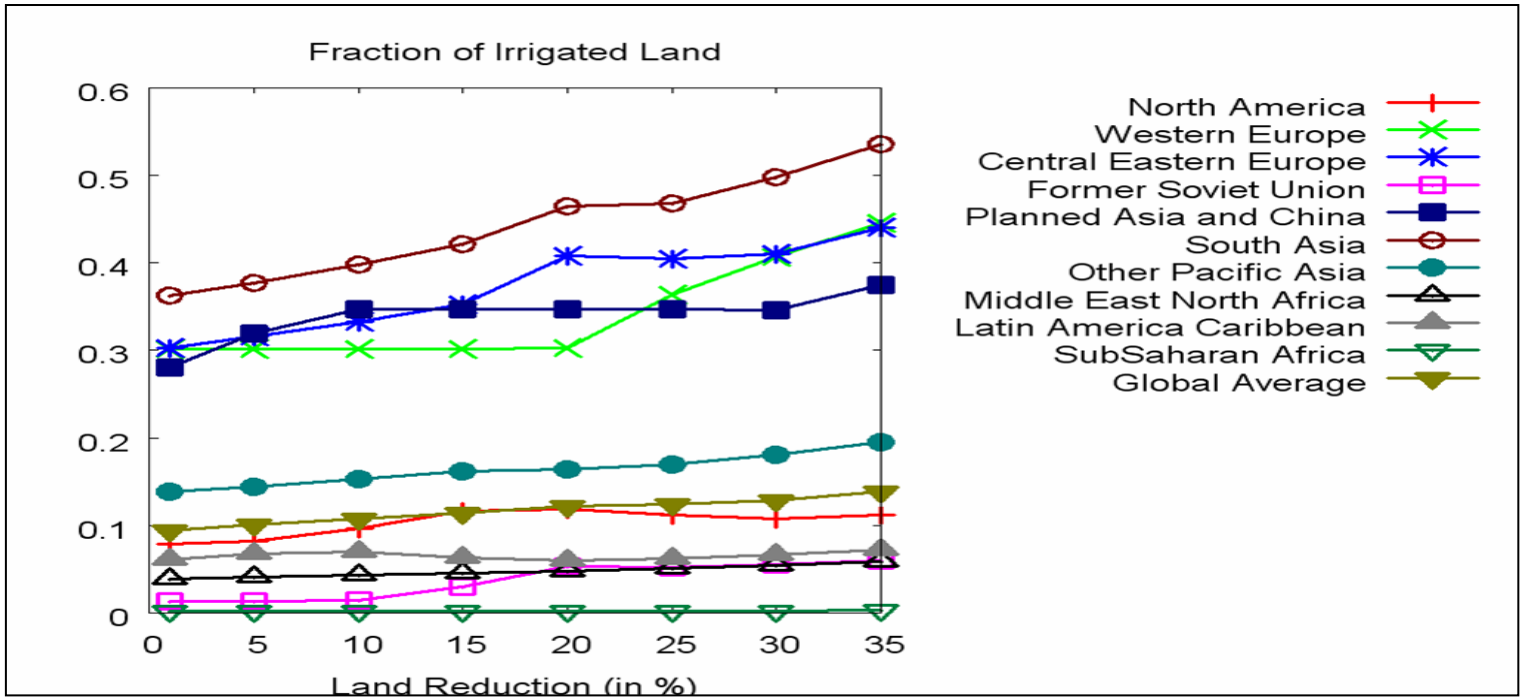


Individual crops



KLUM-W @ Global-FASOM

Generated data and computation routines on irrigation by KLUM-W have been linked with *Global-FASOM* (Forest and Agricultural Sector Optimization Model) to obtain first results on the relation between land scarcity, crop prices, trade, irrigation cost and water-use intensity.

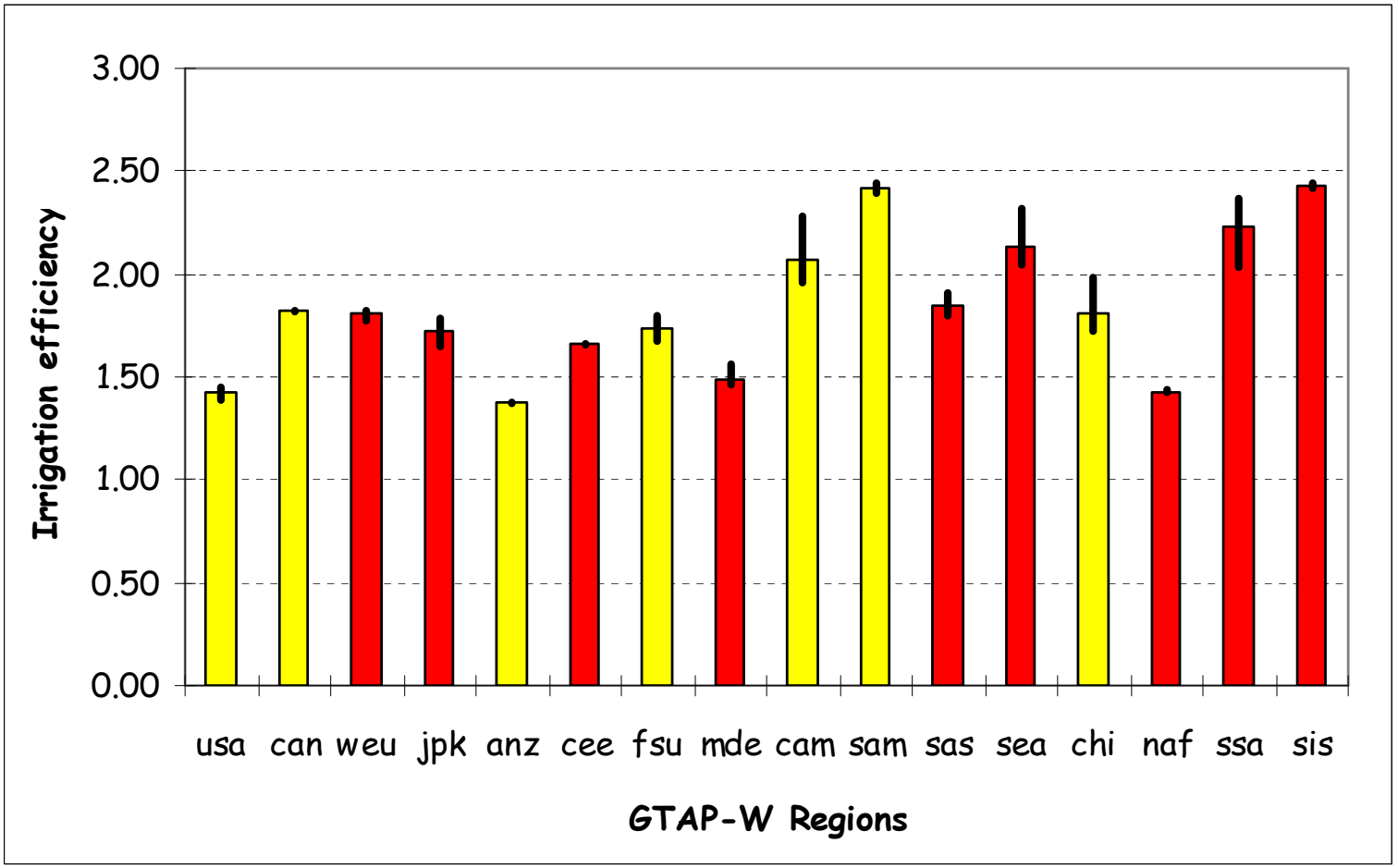


Results from the modeling framework Global FASOM / KLUM-W:
Relation between land scarcity and irrigation intensity

Modeling framework *GTAP-W*

- *GTAP-W* (v2) is a standard static CGE model calibrated for 2001 using agriculture and water data from IMPACT
- 16 regions
- 22 sectors (7 agricultural sectors)
- 6 primary factors (rainfed land, irrigated land, irrigation, labor, capital and natural resources)
- new production structure: separation of rainfed and irrigated agriculture
- substitution possibilities between irrigation and other primary factors

Mean irrigation efficiency

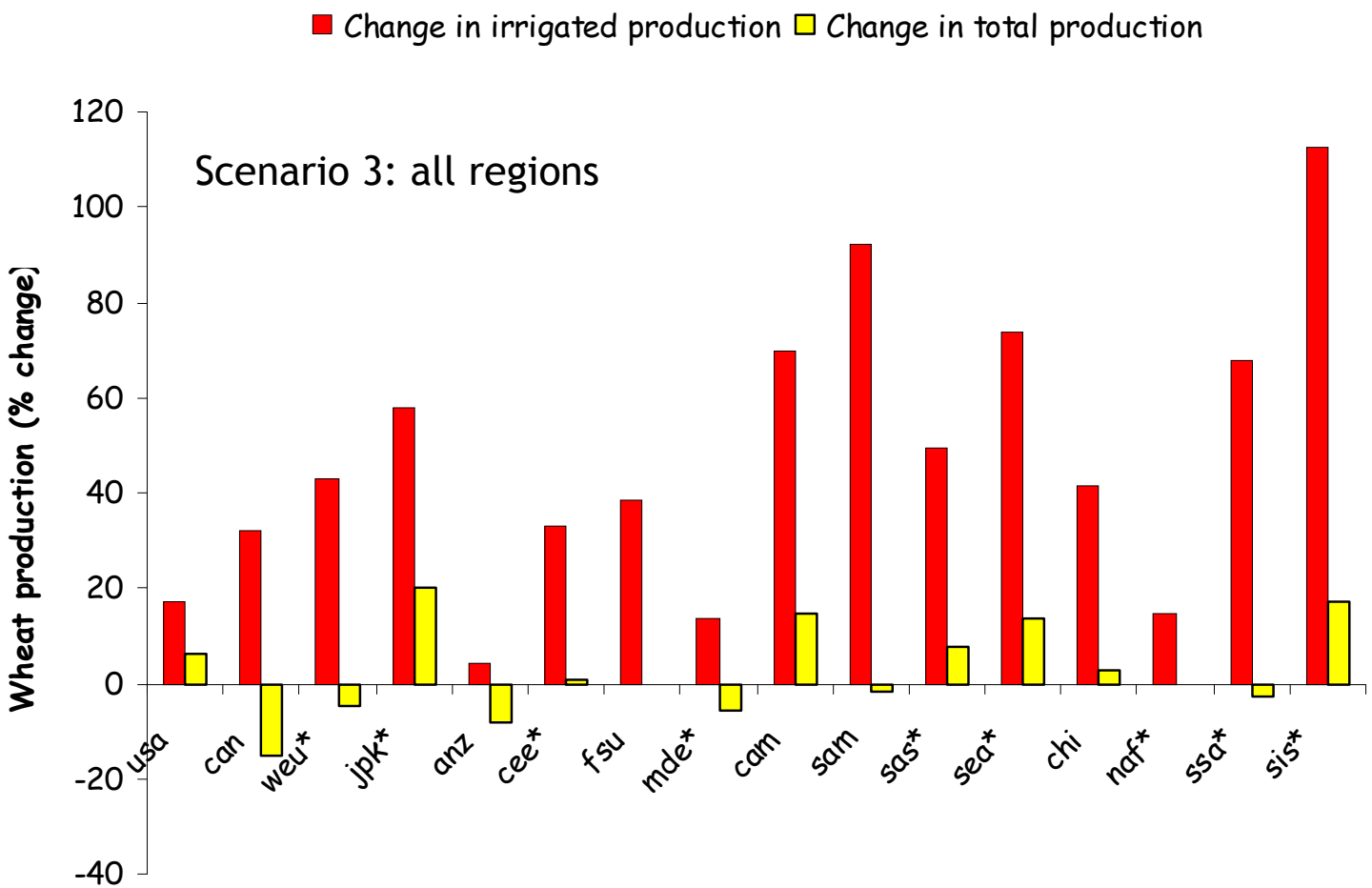


Red: Water stressed regions

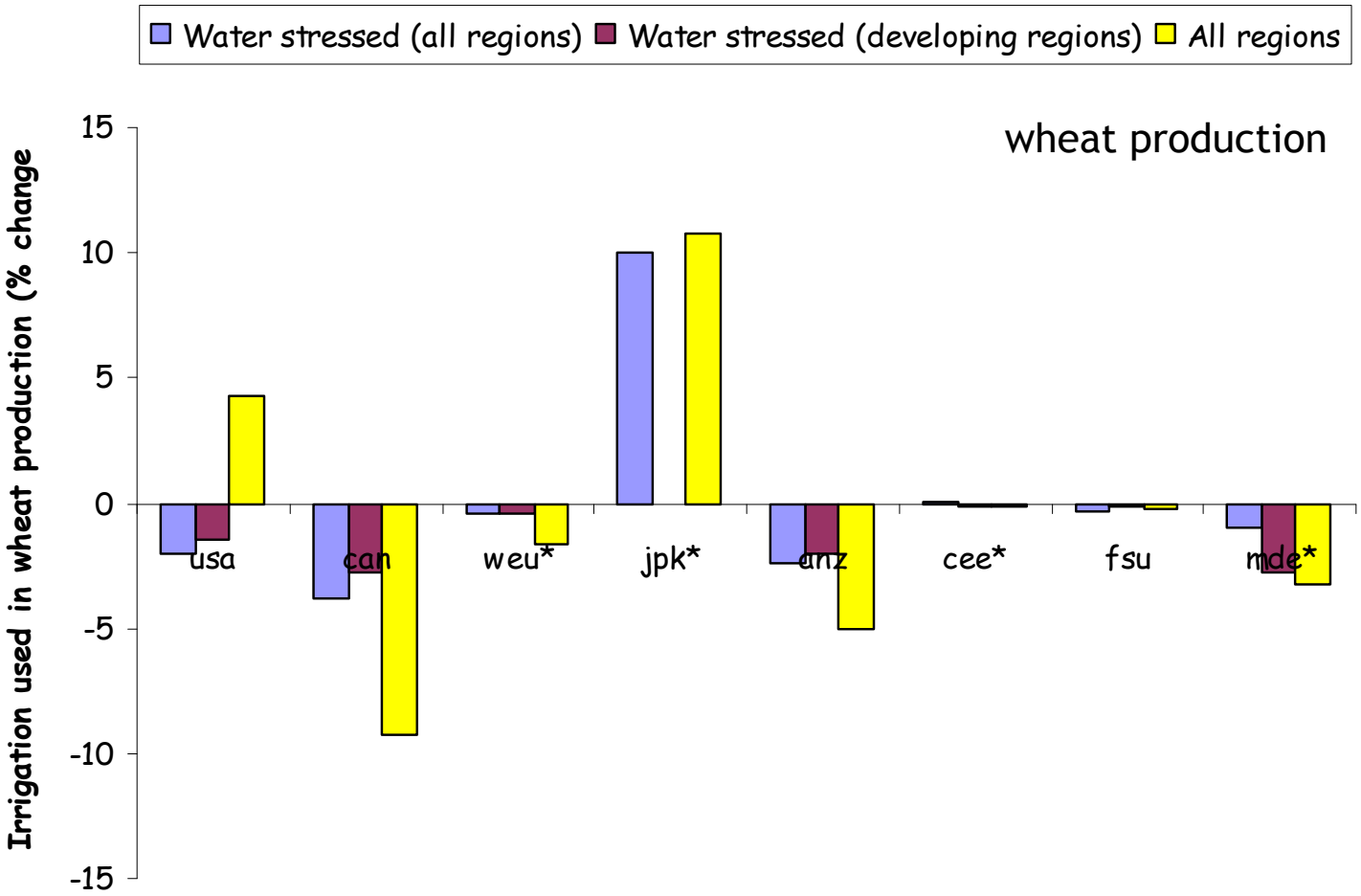
Scenarios

- Scenario 1:
  enhanced irrigation efficiency in all water stressed regions including developed regions
  - water stressed (all regions)
- Scenario 2:
  enhanced irrigation efficiency in all water stressed developing regions
  - water stressed (developing regions)
- Scenario 3:
  enhanced irrigation efficiency in all regions including non-water stressed regions
  - all regions

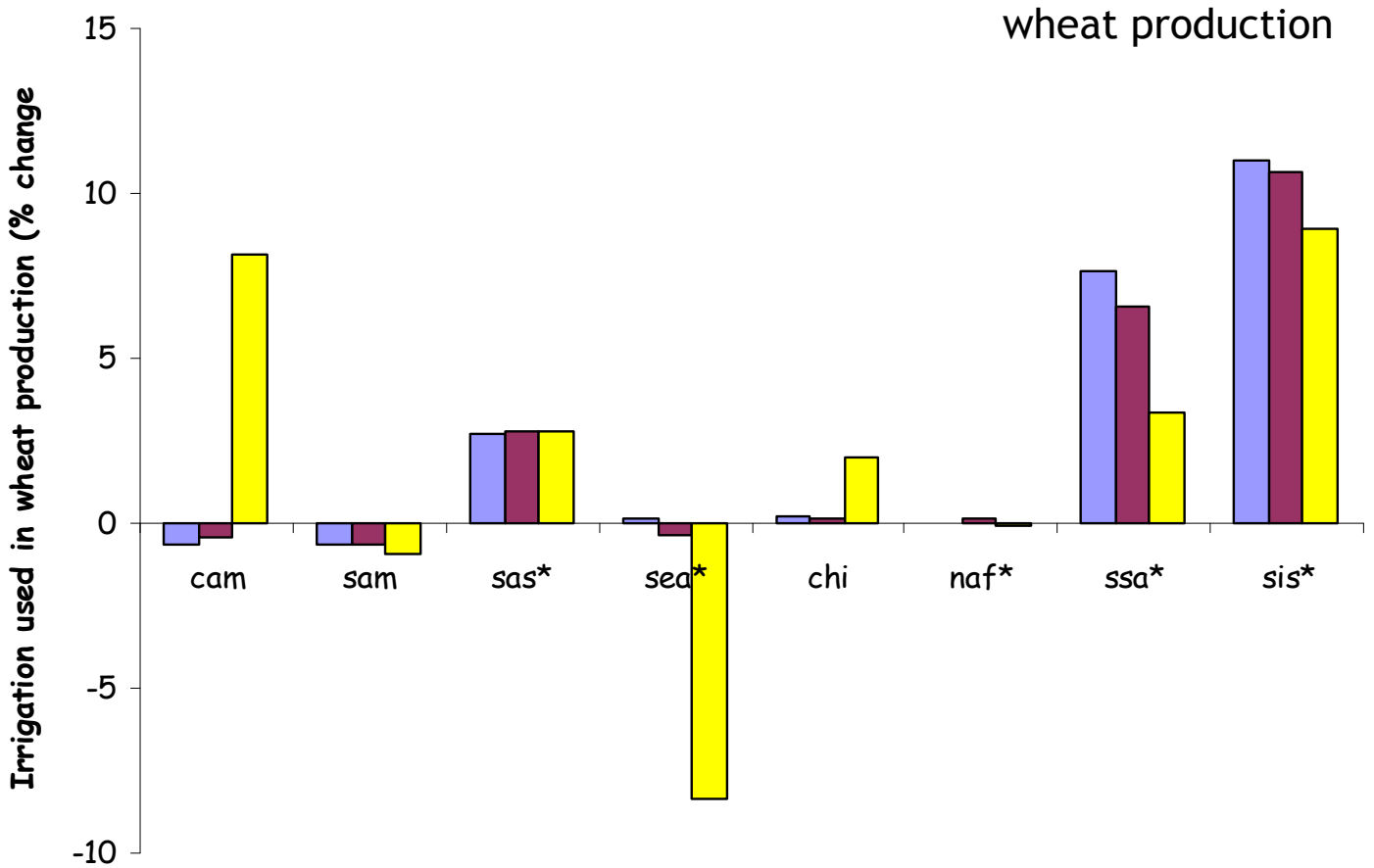
Change in production



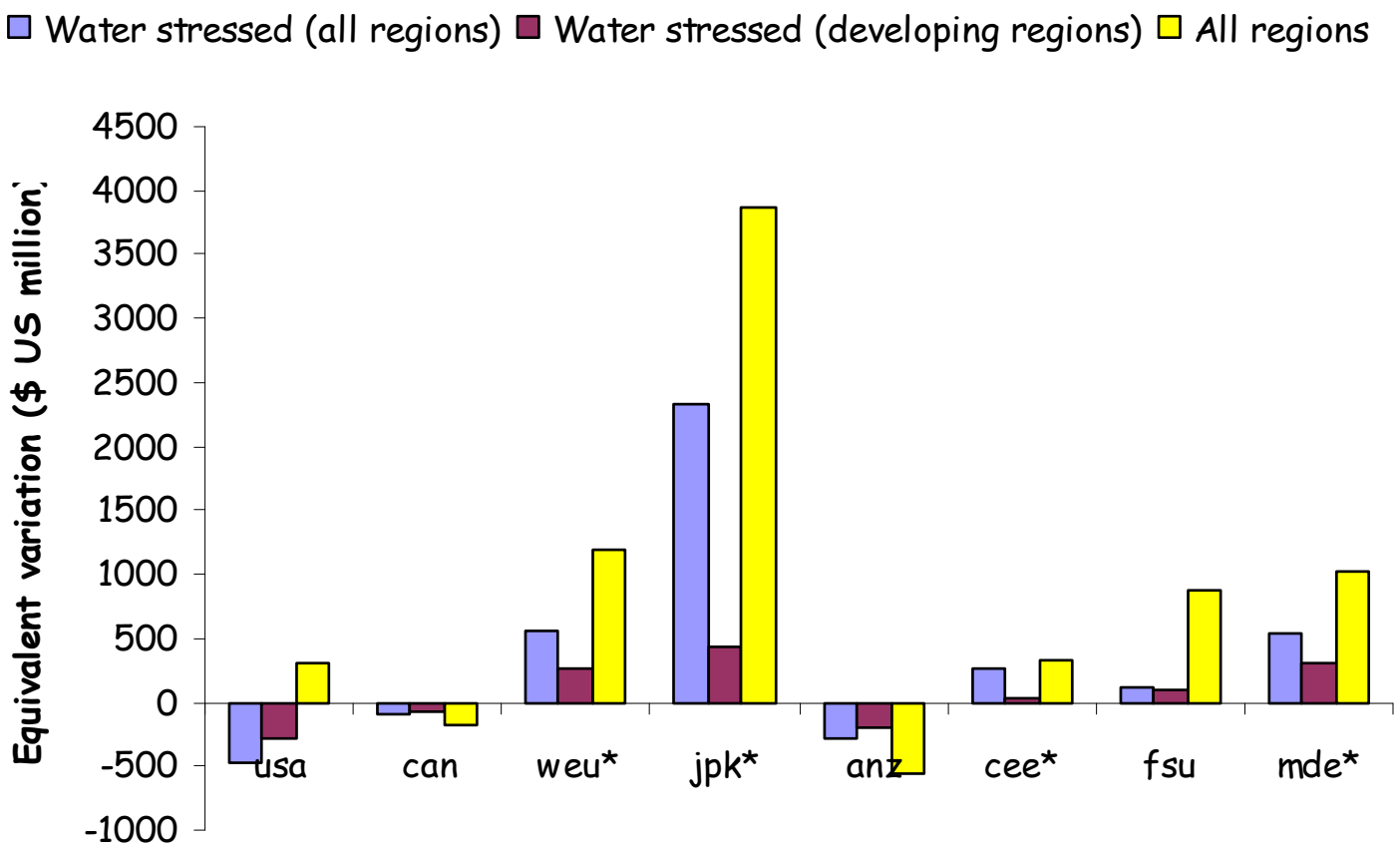
Change in irrigation (1)



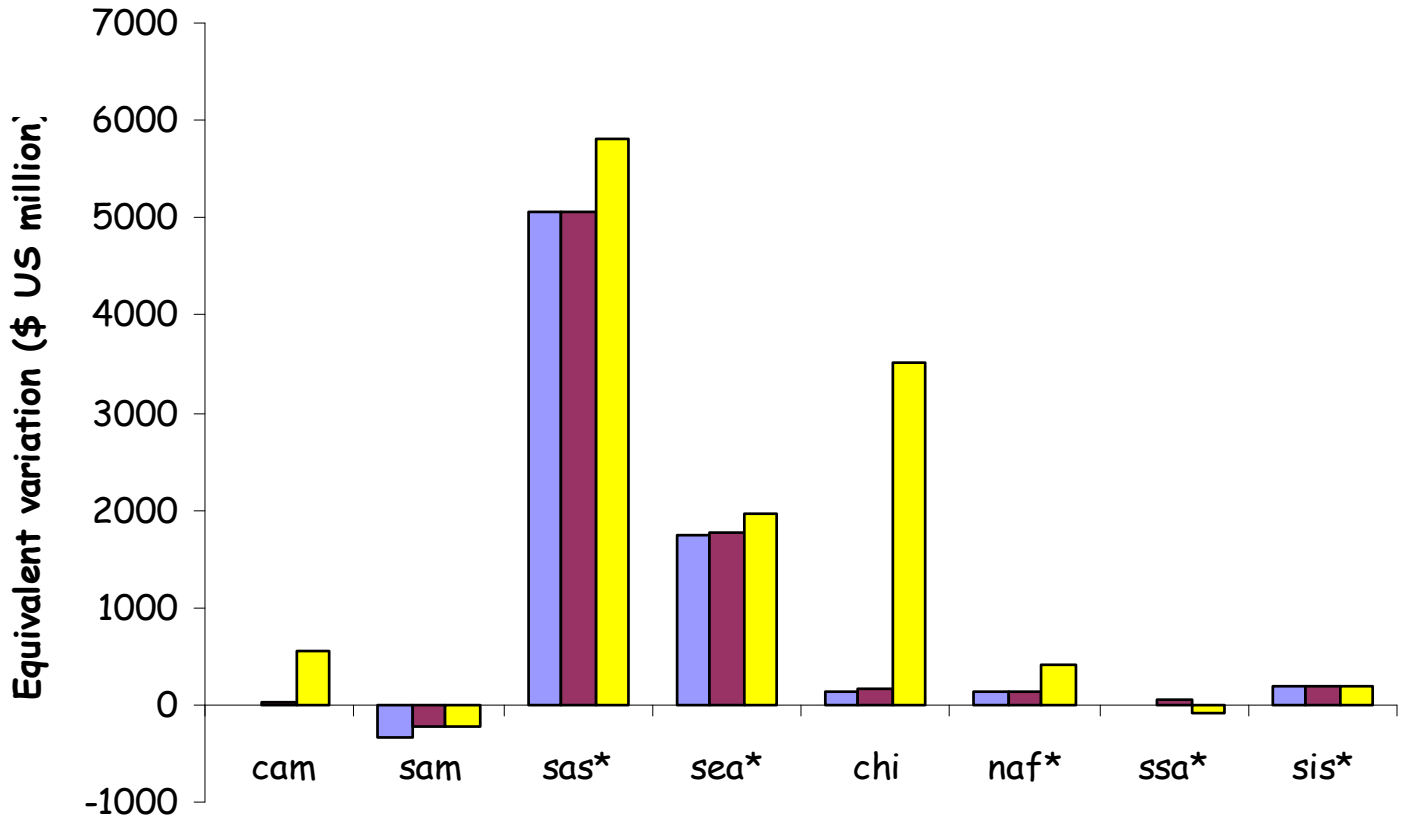
Change in irrigation (2)



Change in regional welfare (1)



Change in regional welfare (2)



Conclusion

- in a global context, economists have long ignored water use for methodological and data reasons
- *KLUM-W* and *GTAP-W* are an attempt to close this gap
- domestic policies to conserve water have ramifications for international trade
- national policies are interconnected and should not be set in ignorance of other countries' water policies

Thank you for your attention.

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