Impacts of climate change on water resources and interactions with human needs

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I will…

- Point to recent „clusters“ of research on climate change impacts upon water resources
- Demonstrate the ever-increasing complexity
- Use some examples from LPJmL model applications
- Give some indications of how climate change interferes with water demand (→ modelling challenges)

The classic: changes in runoff by 2050/2100

SRES/RCPs → GCMs → GHMs

ELSEVIER

Global Environmental Change 14 (2004) 31–52

GLOBAL ENVIRONMENTAL CHANGE

www.elsevier.com/locate/gloenvcha

Climate change and global water resources: SRES emissions and socio-economic scenarios

Nigel W. Arnell

School of Geography, University of Southampton, Southampton SO17 1BJ, U

Climatic Change (2014) 122:127–140
DOI 10.1007/s10584-013-0948-4

The global-scale impacts of climate change on water resources and flooding under new climate and socio-economic scenarios

Nigel W. Arnell • Ben Lloyd-Hughes

Earth Syst. Dynam., 4, 129–144, 2013
www.earth-syst-dynam.net/4/129/2013/
doi:10.5194/esd-4-129-2013
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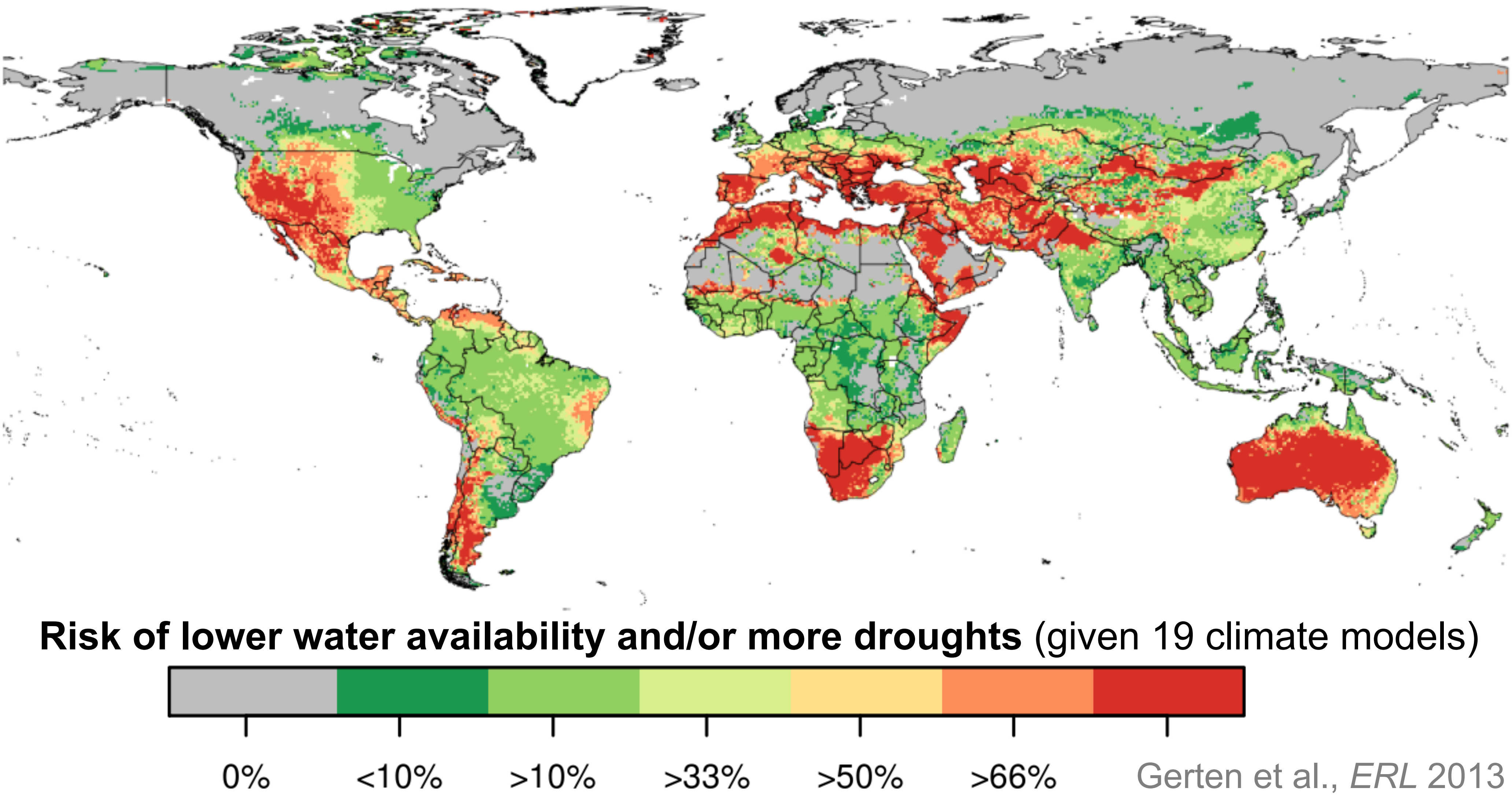
Climate change impact on available water resources obtained using multiple global climate and hydrology models

S. Hagemann[1], C. Chen[1], D. B. Clark[2], S. Folwell[2], S. N. Gosling[3], I. Haddeland[4], N. Hanasaki[5], J. Heinke[6], F. Ludwig[7], F. Voss[8], and A. J. Wiltshire[9]

The climate policy focus: impacts at +2–5°C

LPJmL
future projections

+5.0°C (business-as-usual scenario)



Gerten et al., *ERL* 2013

The ensemble view: lessons from ISIMIP

ISIMIP
Inter-Sectoral Impact Model
Intercomparison Project

www.isimip.org

>100 global and regional impact models

climate projections
RCP scenarios from CMIP
& CORDEX archives

Socio-economic input
SSP scenarios

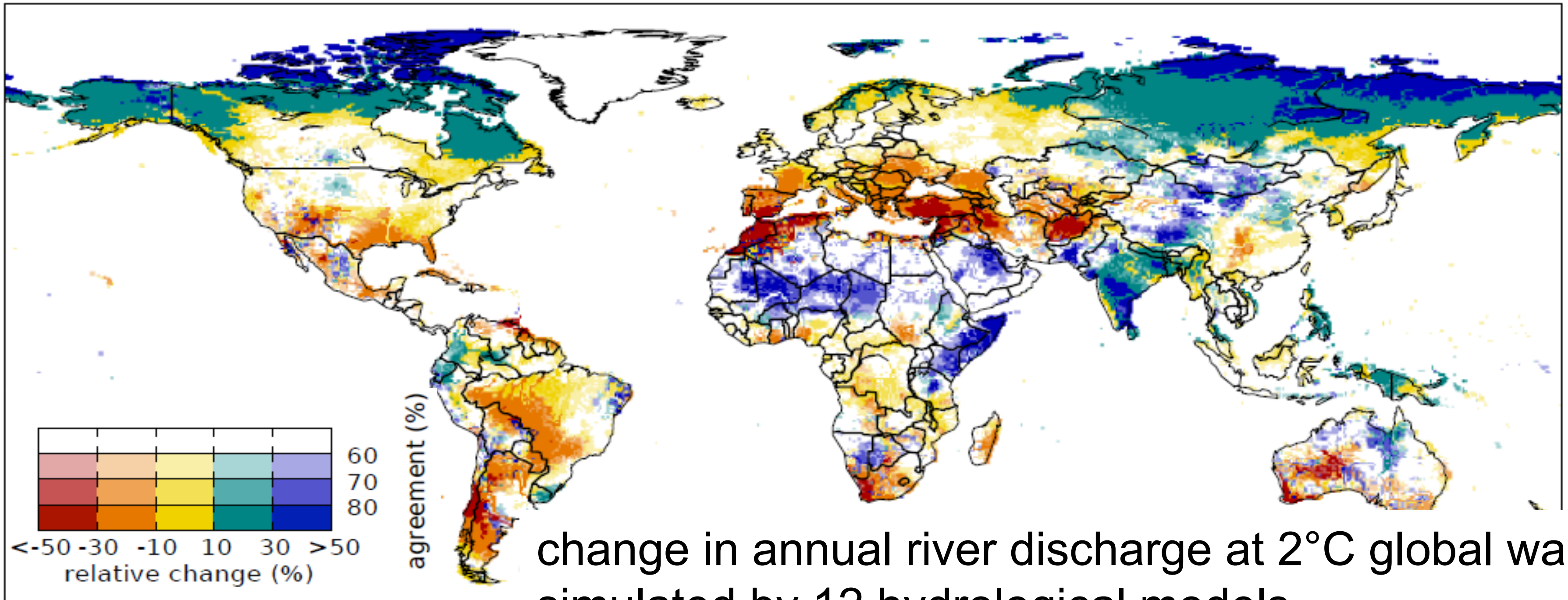
Impact models global & regional

agriculture
biomes
coastal infrastructure
fisheries
agro-economics
water
Forests
health
energy
permafrost

- Synthesis of impacts at different levels of global warming
- Quantification of uncertainties
- Model improvement
- Cross-sectoral interactions
- Cross-scale intercomparison
- Focus topics (e.g. extreme events, adaptation)

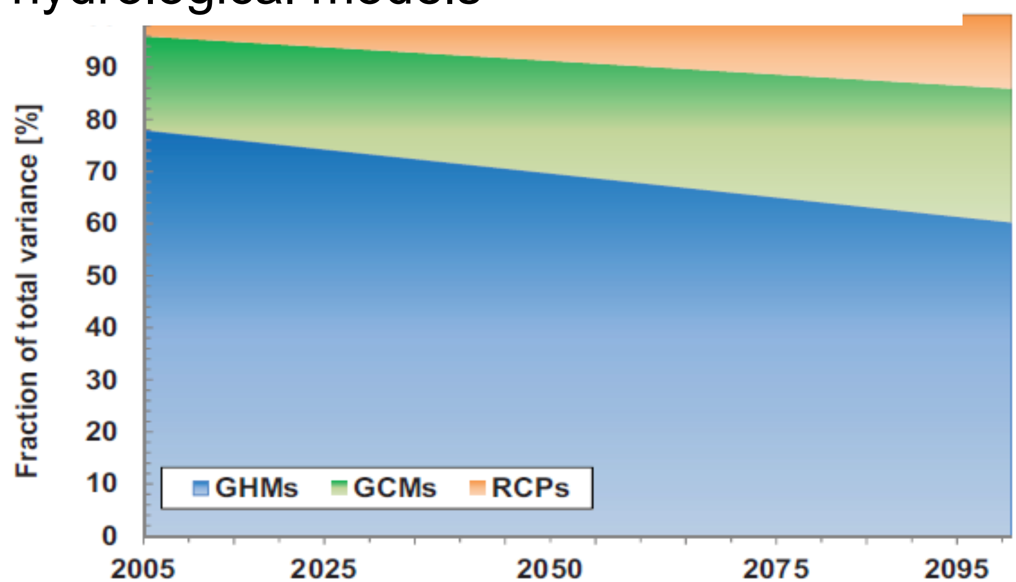
Project phases: I **Fast-Track •** ***IIa*** **Historical runs •** ***IIb*** **1,5K warming**

The ensemble view: lessons from ISIMIP



change in annual river discharge at 2°C global warming simulated by 12 hydrological models

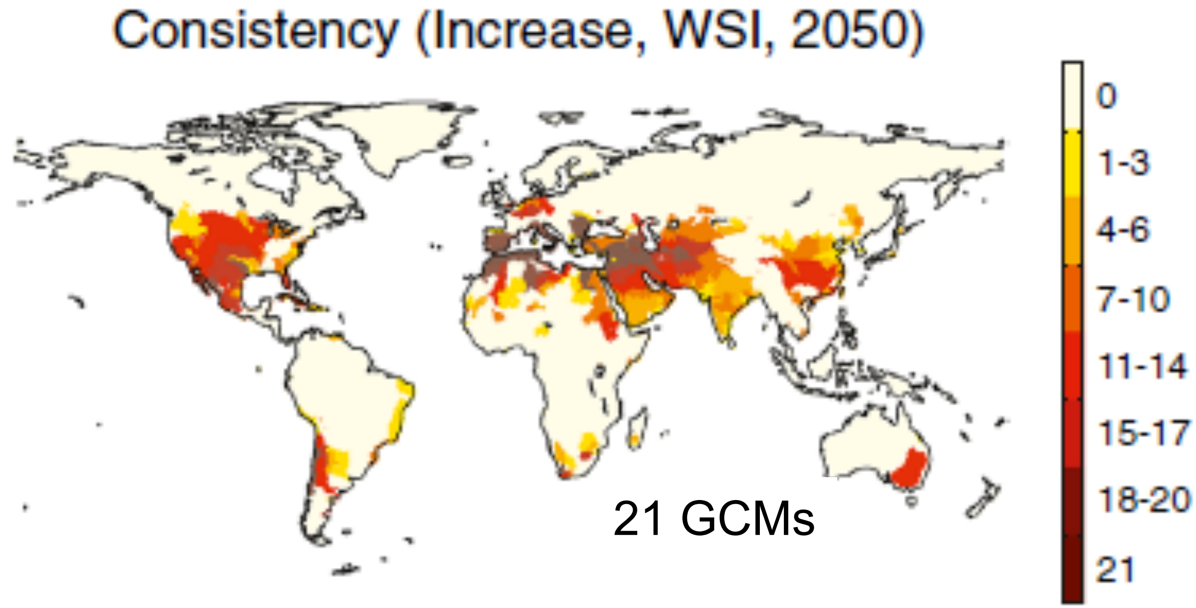
Uncertainty sources regarding simulated change in irrigation demands

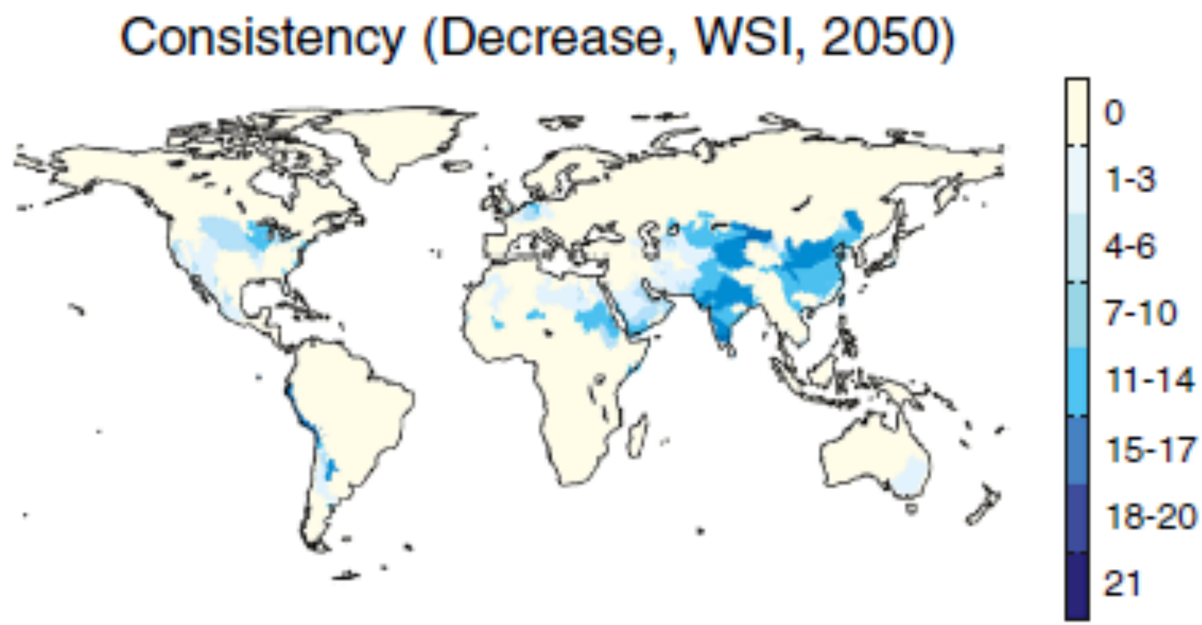


Schewe et al., *PNAS* 2014; IPCC 2013;
Wada et al., *GRL* 2013

Societal impacts I: water scarcity

Climate change effect upon exposure to water scarcity, SRESA1b, MacPDM model





Gosling et al., *Clim. Ch.* 2016

Societal impacts II: water for food production

- Falkenmark 1989 Blue water availability

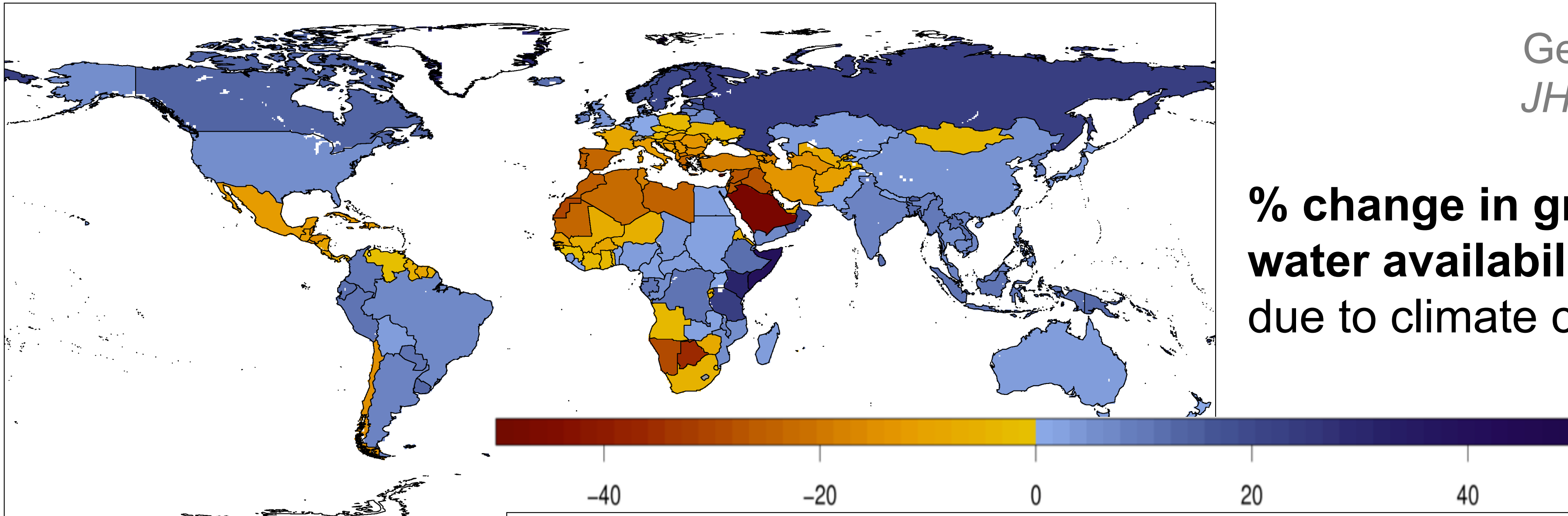
  $<1{,}000\ m^3\ cap^{-1}\ yr^{-1}$: chronic water scarcity

- Gerten et al. 2011 Blue + green water-for-food availability (green =: ET on cropland)

  $400–4000\ m^3\ cap^{-1}\ yr^{-1}$ for growing balanced diet ($3{,}000\ kcal\ cap^{-1}\ d^{-1}$) depending on local "water productivity" (yield produced per unit of water)

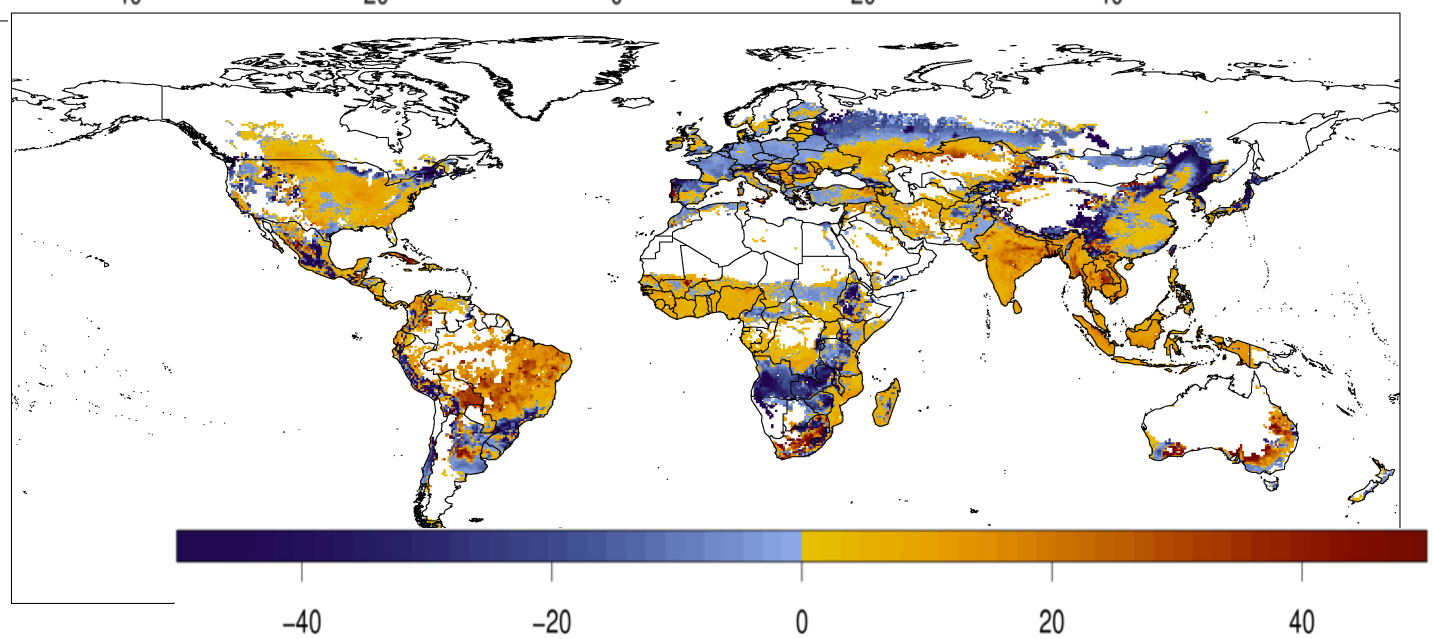
Societal impacts II: green+blue water for food

Ensemble median change given 17 climate models, SRES A2



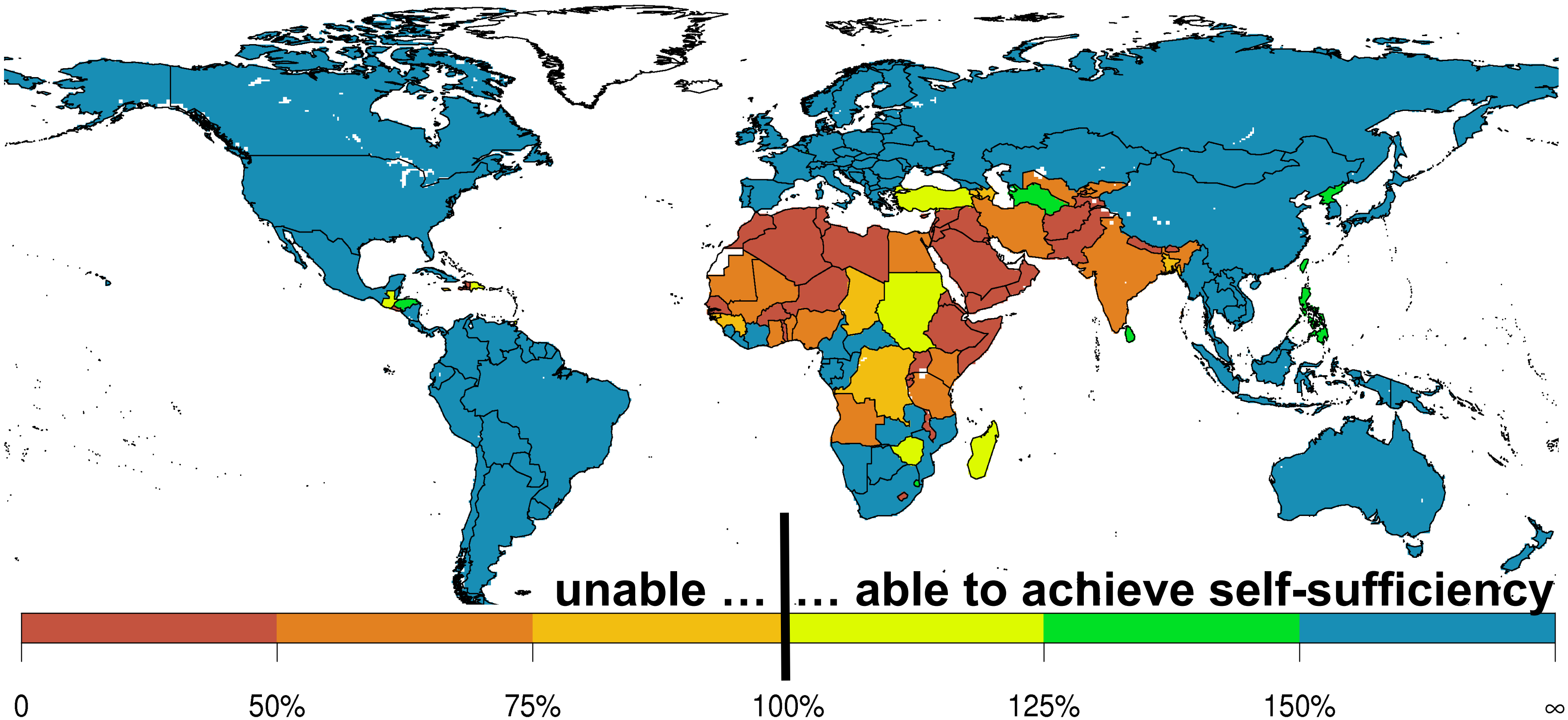
Gerten et al., *JHyMet* 2011

% change in green-blue water availability due to climate change



% change in food water demand (water productivity) without CO_2 effects, current management

Societal impacts II: green+blue water for food



Climate model ensemble average, A2r population scenario

~6 billion people (43-50% of world population) in water-limited countries

Today

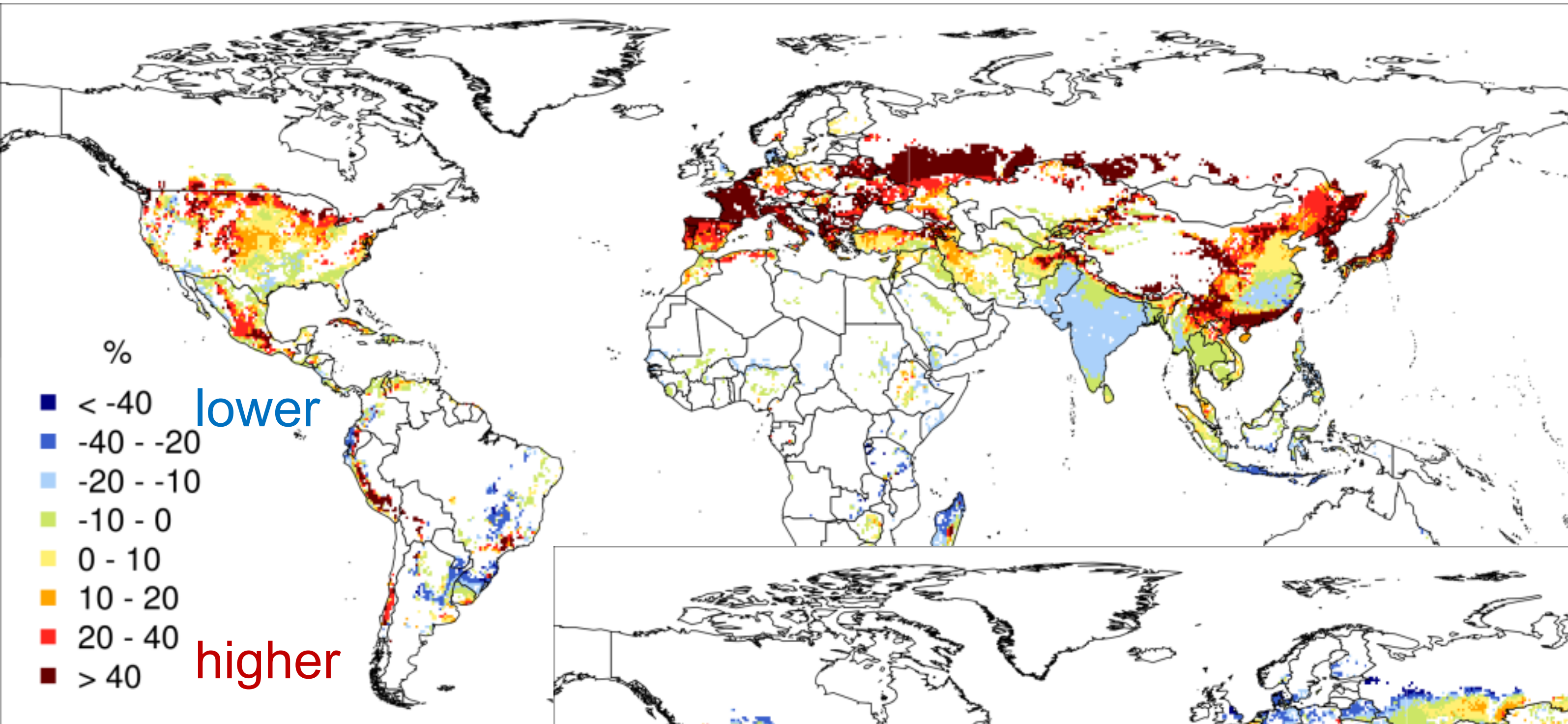
1.7 billion (28%)

Sectoral water demand in the future

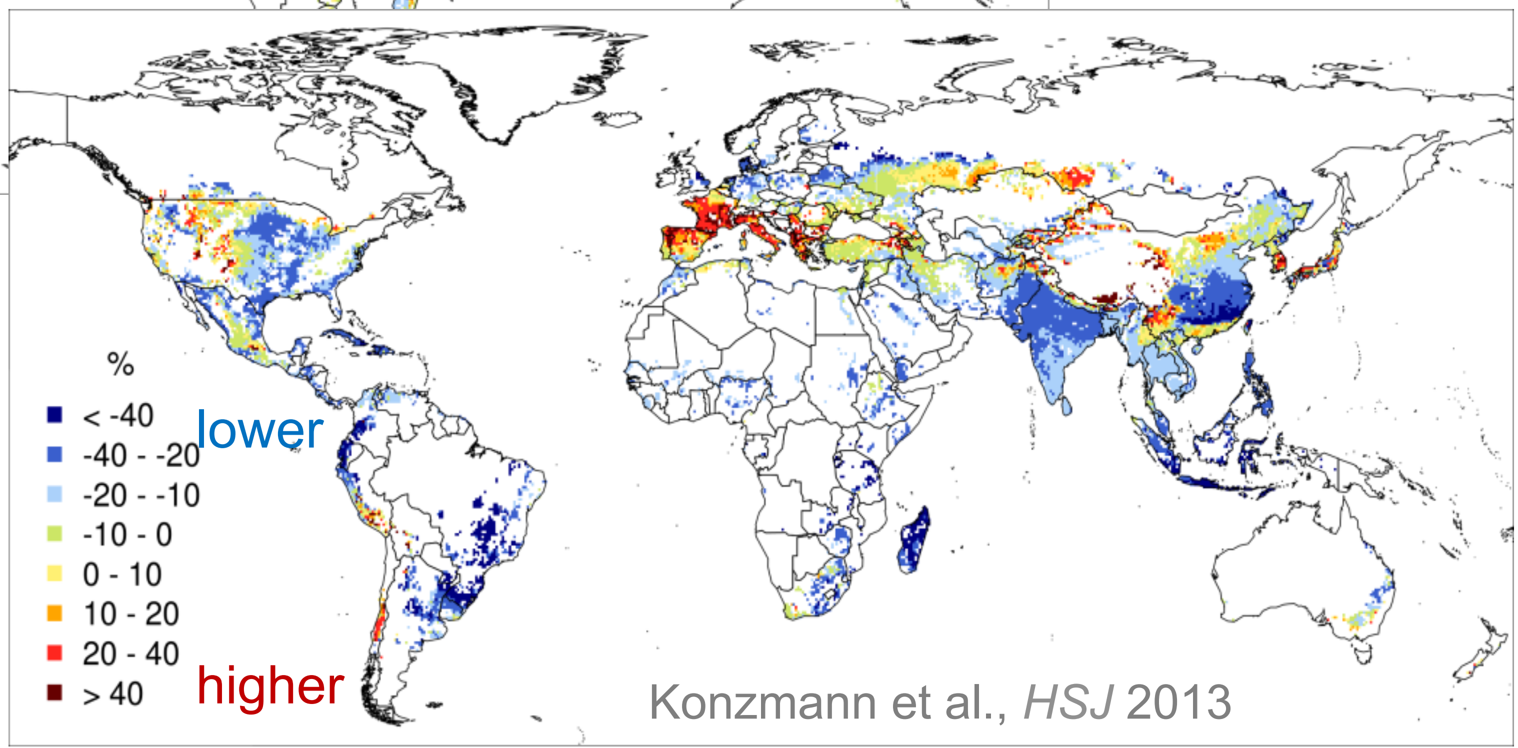
Indicative estimates of sectoral blue water consumption, 2050s
(conservative and highly uncertain!):

Current total blue water consumption:	***1,600 km^3/yr***	*Various sources*
############		
Future demand for food production: (~10 billion people)	2,300 km^3/yr	Falkenmark & Lannerstad 2010
Possible consumption for bioenergy:	2,000 km^3/yr	Various sources
Future industrial & domestic demand:	500 km^3/yr	Wada et al. 2015
Total (future):	**4,800 km^3/yr**	

Ecologic effects I: direct CO_2 effects



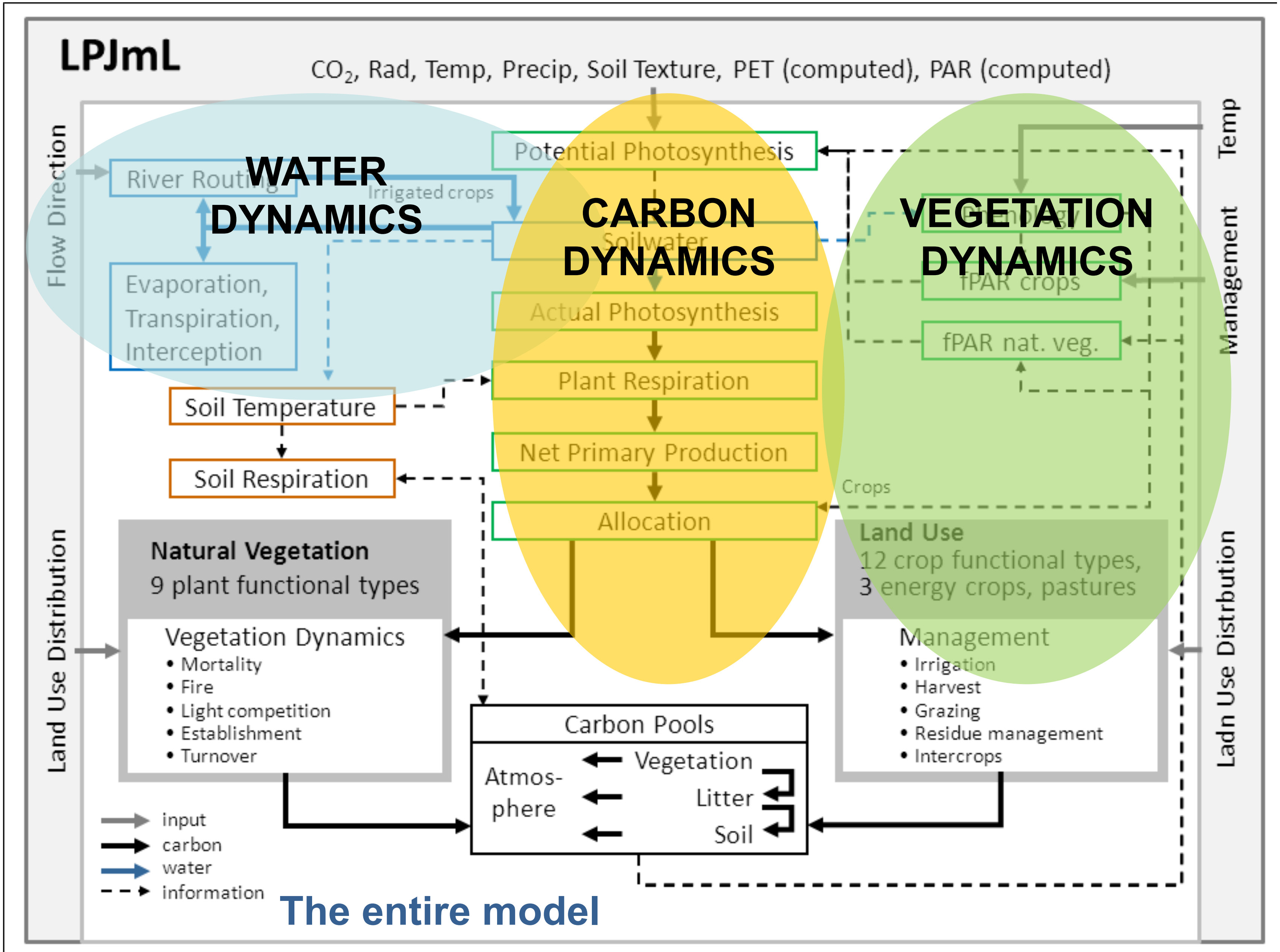
Change in **irrigation demand** without CO_2 effects on plants



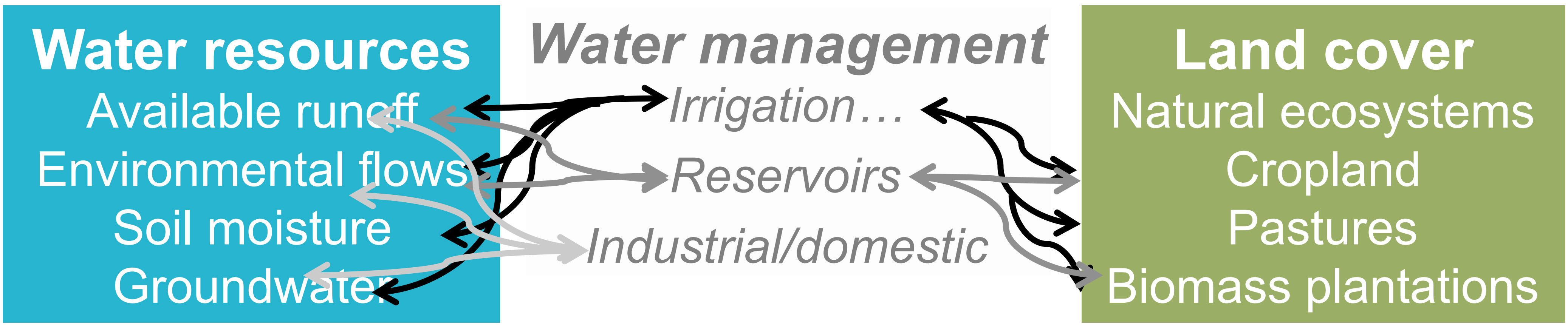
dto.
with CO_2 effects

Konzmann et al., *HSJ* 2013

Coupled processes in the LPJmL model



Interacting effects



Irrigation effect on environmental flows

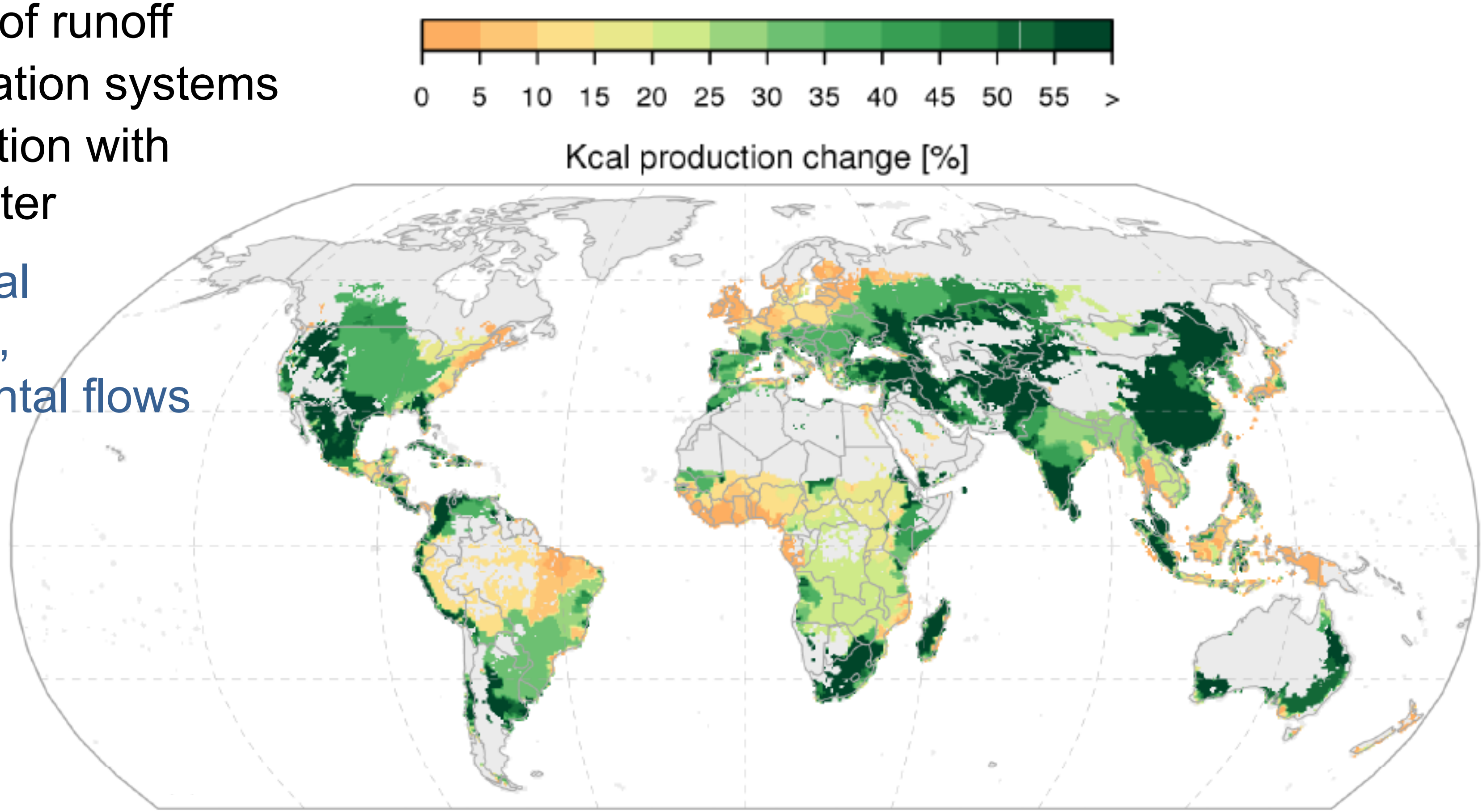
Sustainable water use can balance yield loss

Jägermeyr et al., *HESS* 2015, *ERL* 2016

<u>Scenario for all cropland:</u>

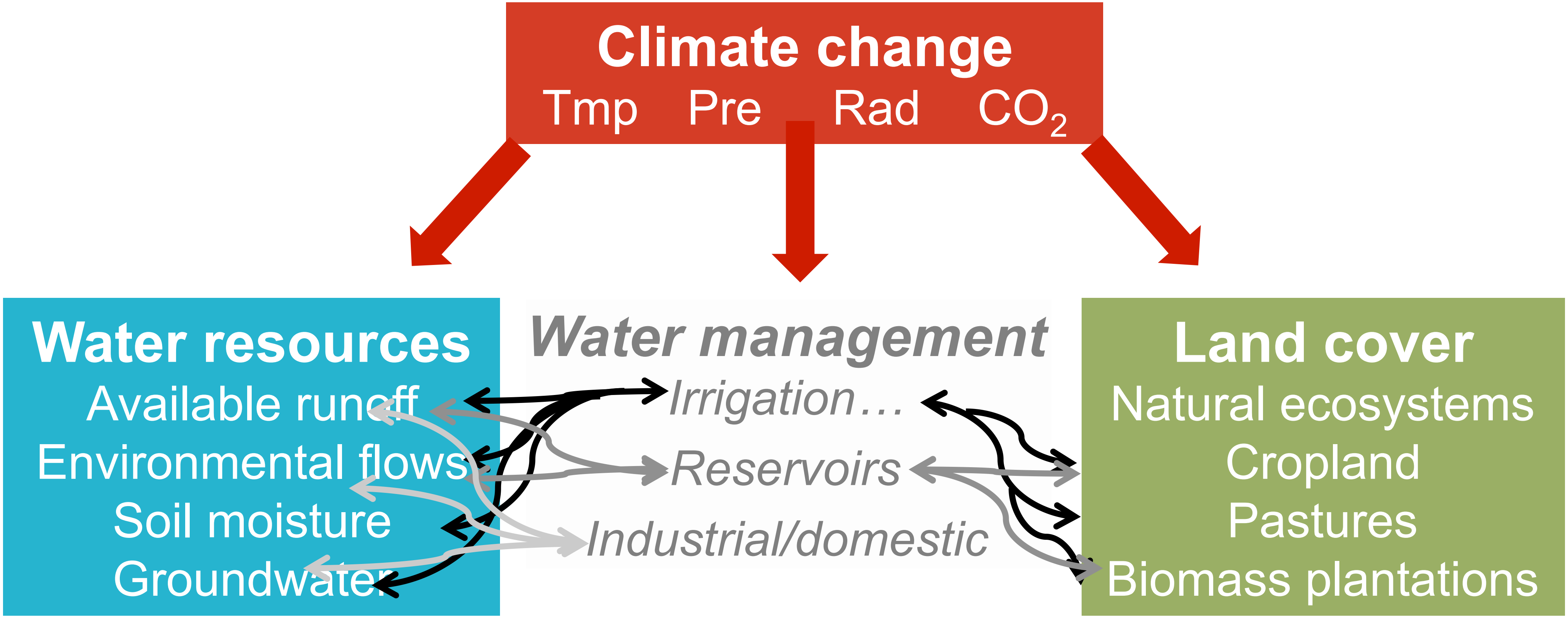
- avoid 50% soil evaporation
- harvest 50% of runoff
- upgrade irrigation systems
- expand irrigation with the saved water

→ no additional water required, i.e. environmental flows are respected

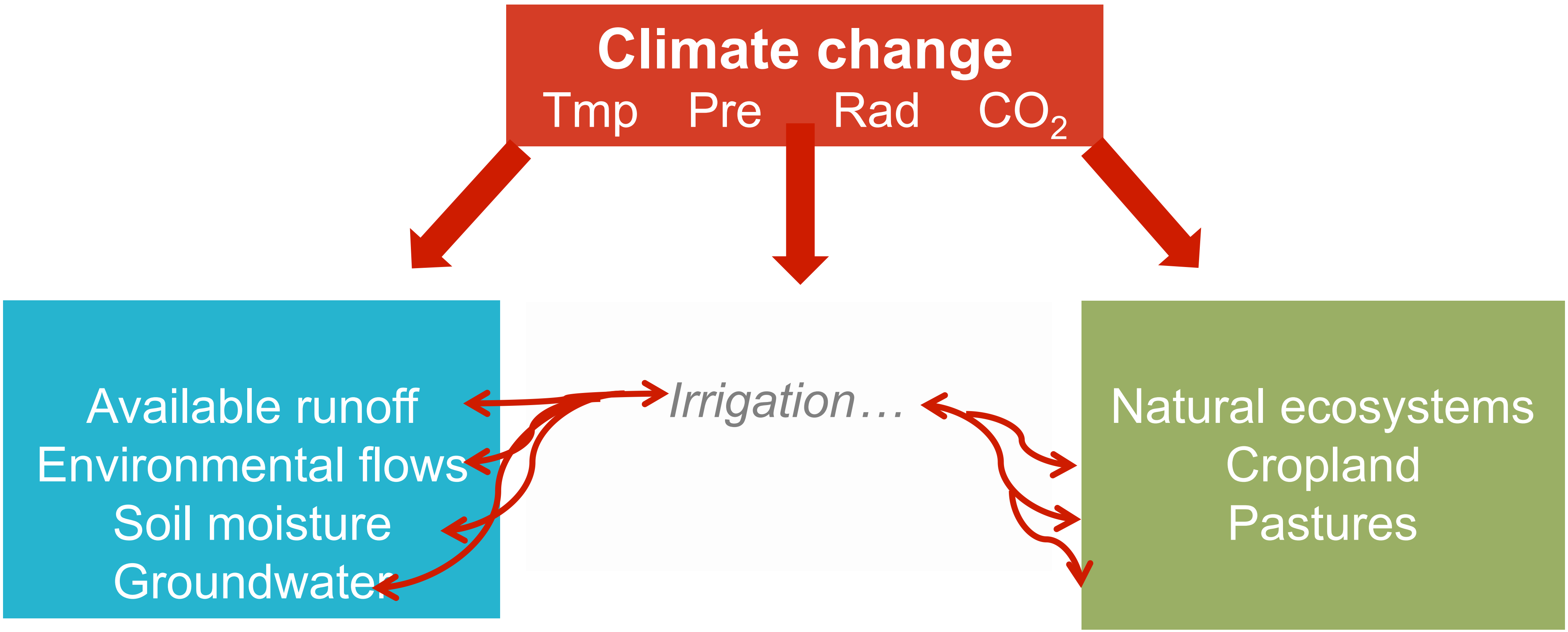


→ Increase of global crop yield by ~40%
→ Reduction of global water consumption by ~500 km^3/yr

Impacts of and feedbacks with climate change

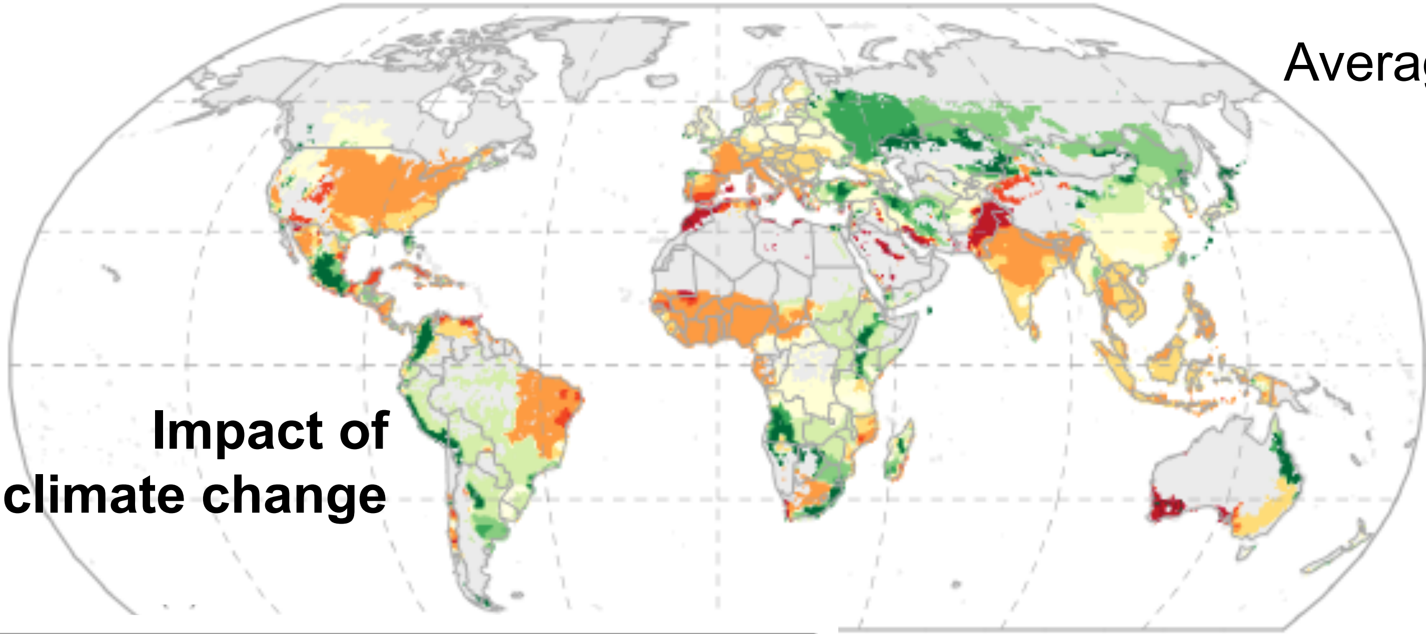


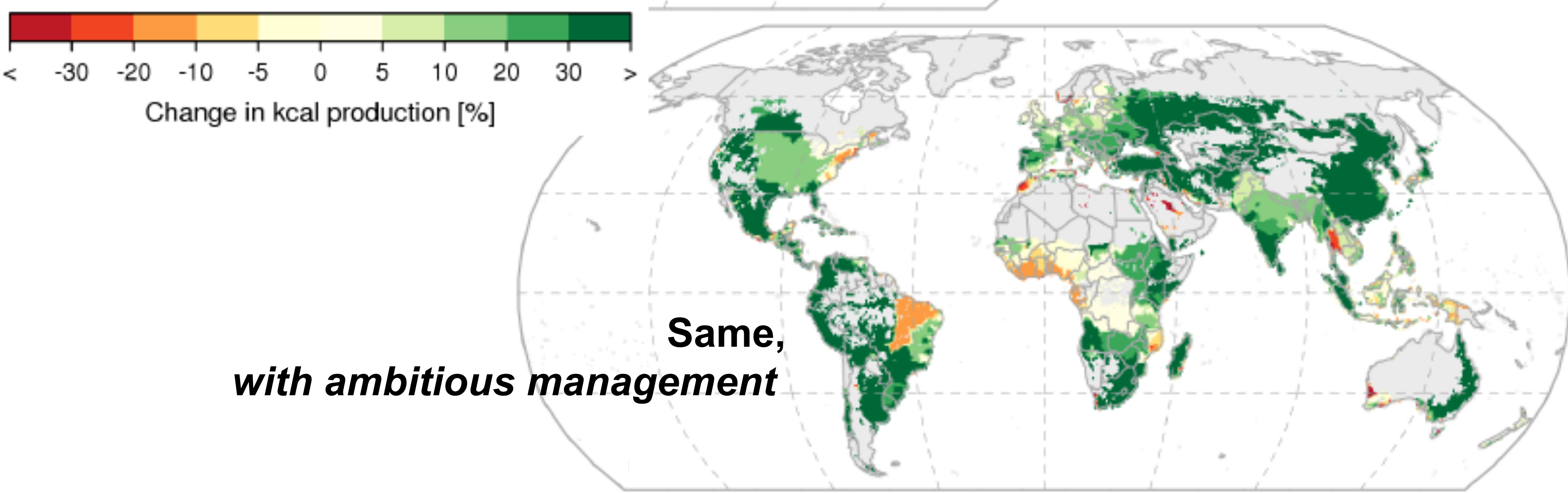
Impacts of and feedbacks with climate change



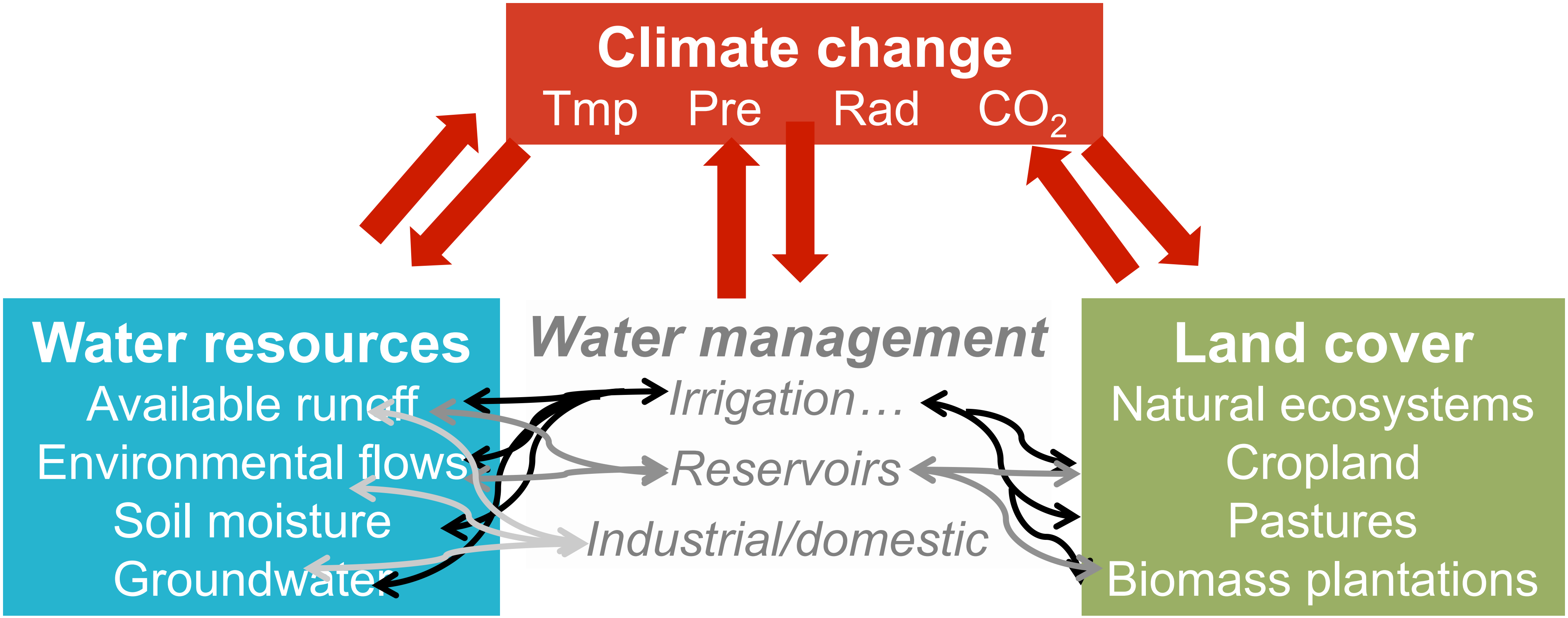
CC impacts buffered by water management

Average of 20 climate scenarios
RCP8.5 forcing
moderate CO_2 effect





Some missing links: dynamic feedbacks to CC



Some conclusions

- Many climate impacts studies, more and more ensemble-based (GCMs + GHMs)
- Increasingly complex modelling of human processes (demand, management, …)
- Huge uncertainty in demand modelling approaches (and datasets)
- Climate impacts upon these human interactions rarely studied or ‚hidden' in IAMs
- Feedbacks from management changes to climate largely unexplored (save irrigation effects)
- Thus, online simulations needed (single-model)
- Yet, conceptualisation of demand is decisive (→ intercomparisons)

On the relevance of the agenda…

Raworth et al.,
Oxfam Report 2012