Workshop on Data and Methods for Modelling Migration Associated with Climate Change

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Assessing Climate Impacts that May Generate Migration Flows

Hydrological Modeling and Impacts

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PCR-GLOBWB

Universiteit Utrecht

UNESCO United Nations Educational, Scientific and Cultural Organization

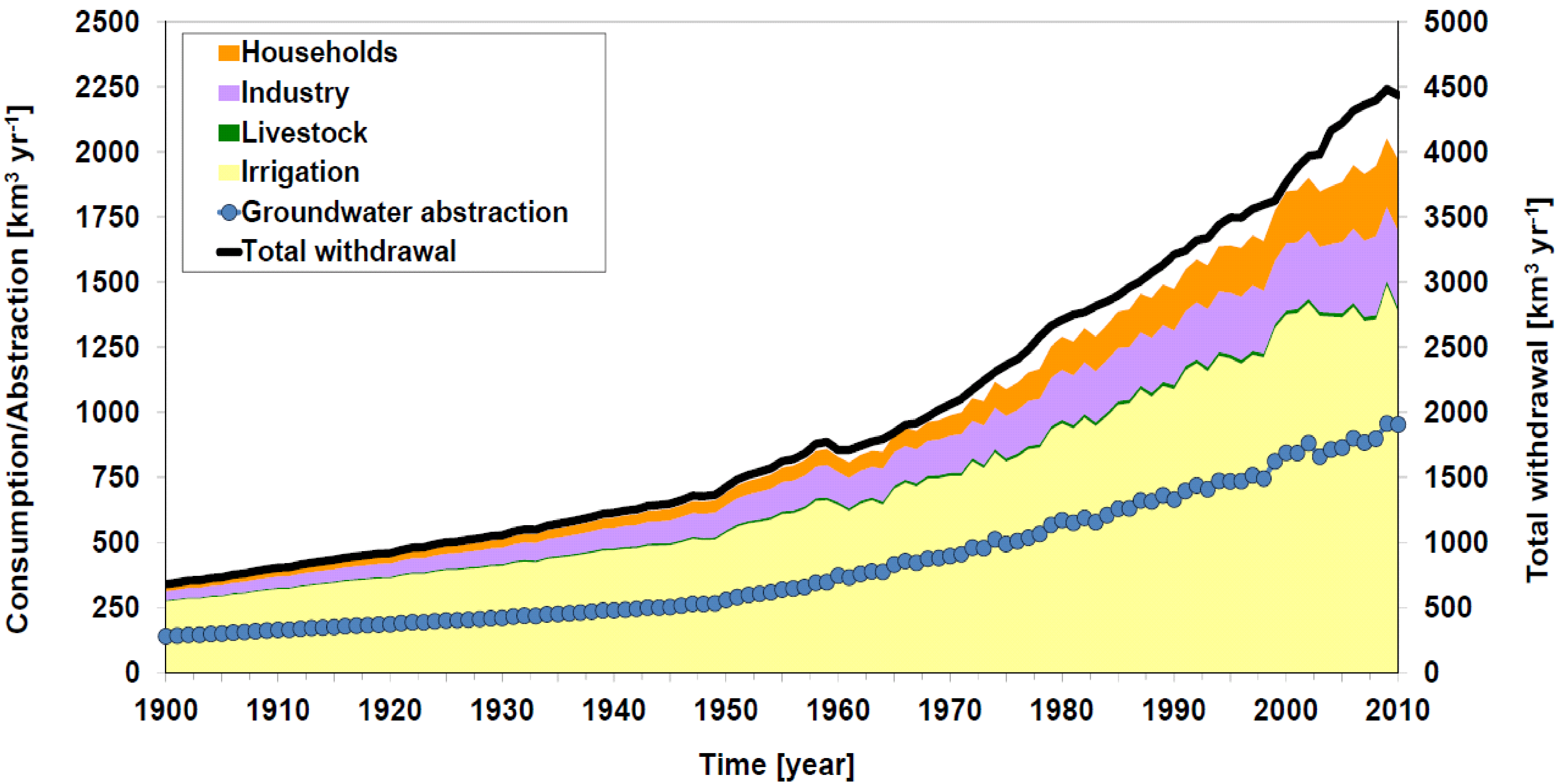
IIASA

ISI-MIP

Columbia University in the City of New York

National Aeronautics and Space Administration Goddard Institute for Space Studies

20th and Early 21st Century Groundwater and Surface Water Use

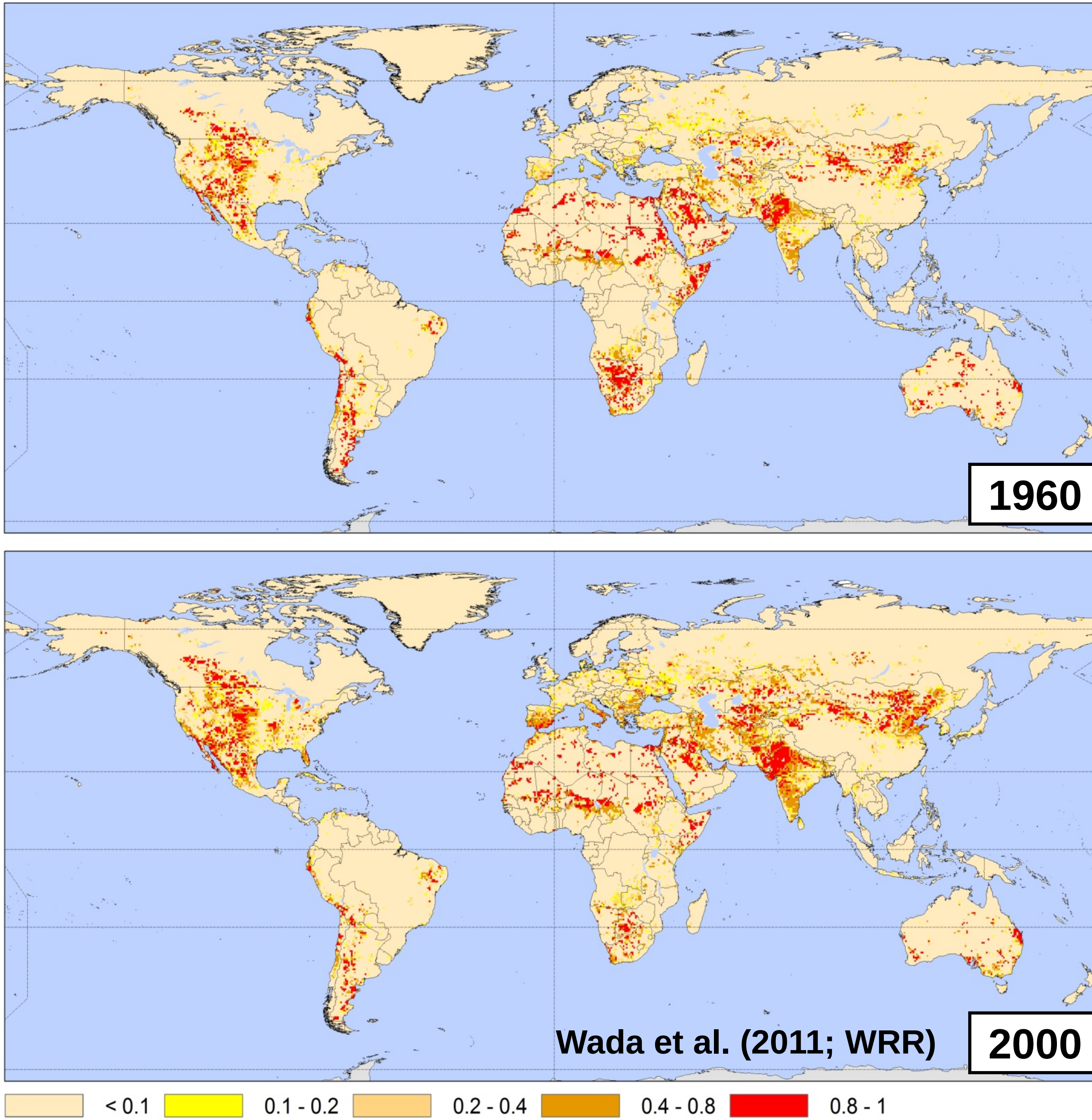


Water Scarcity Index

$$WSI = \frac{D}{A}$$

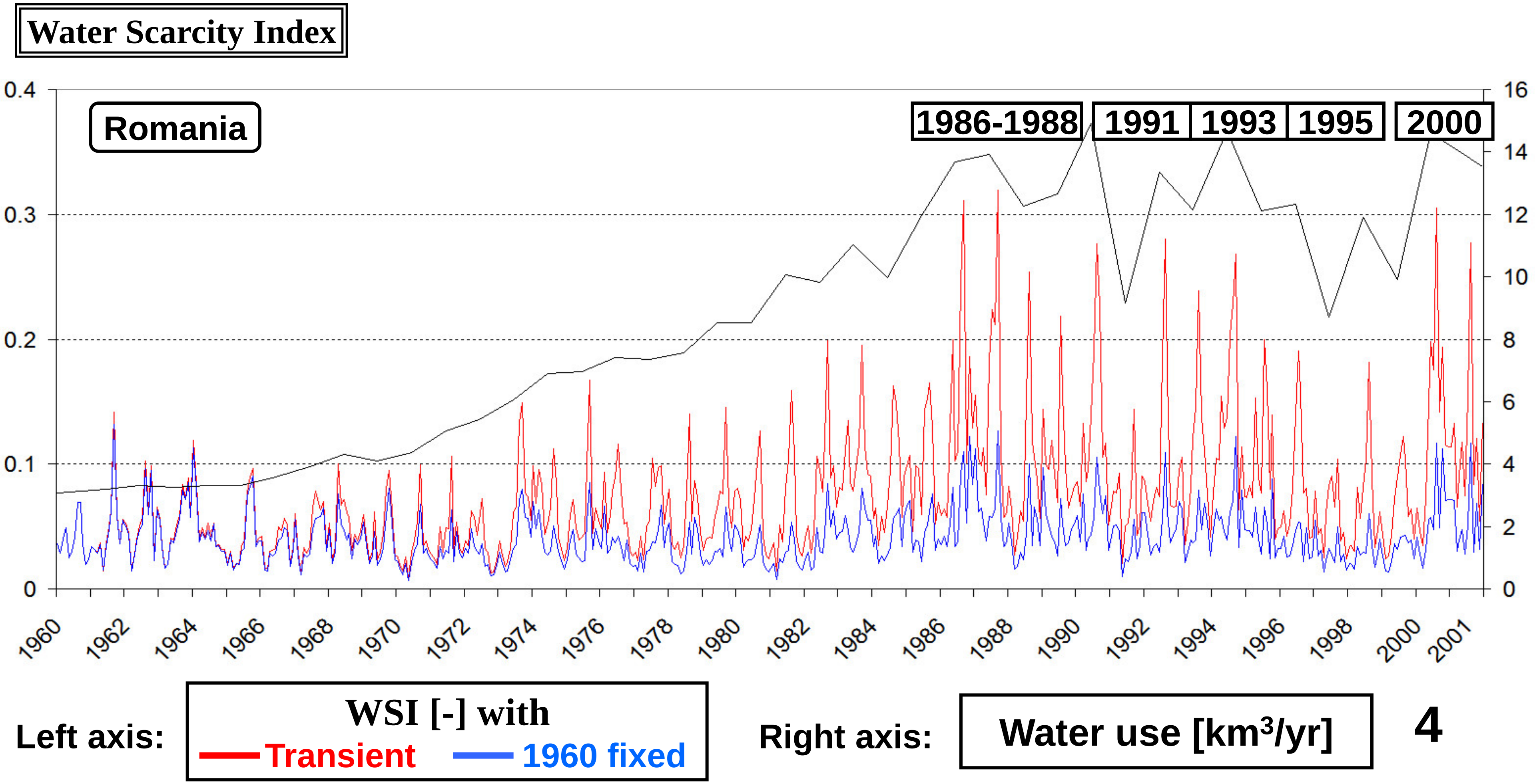
Global population under high water stress (WSI > 0.4)

Year	Billions (% of total)
1960	0.5 (17%)
1970	0.7 (19%)
1980	1.0 (23%)
1990	1.2 (23%)
2000	1.8 (30%)

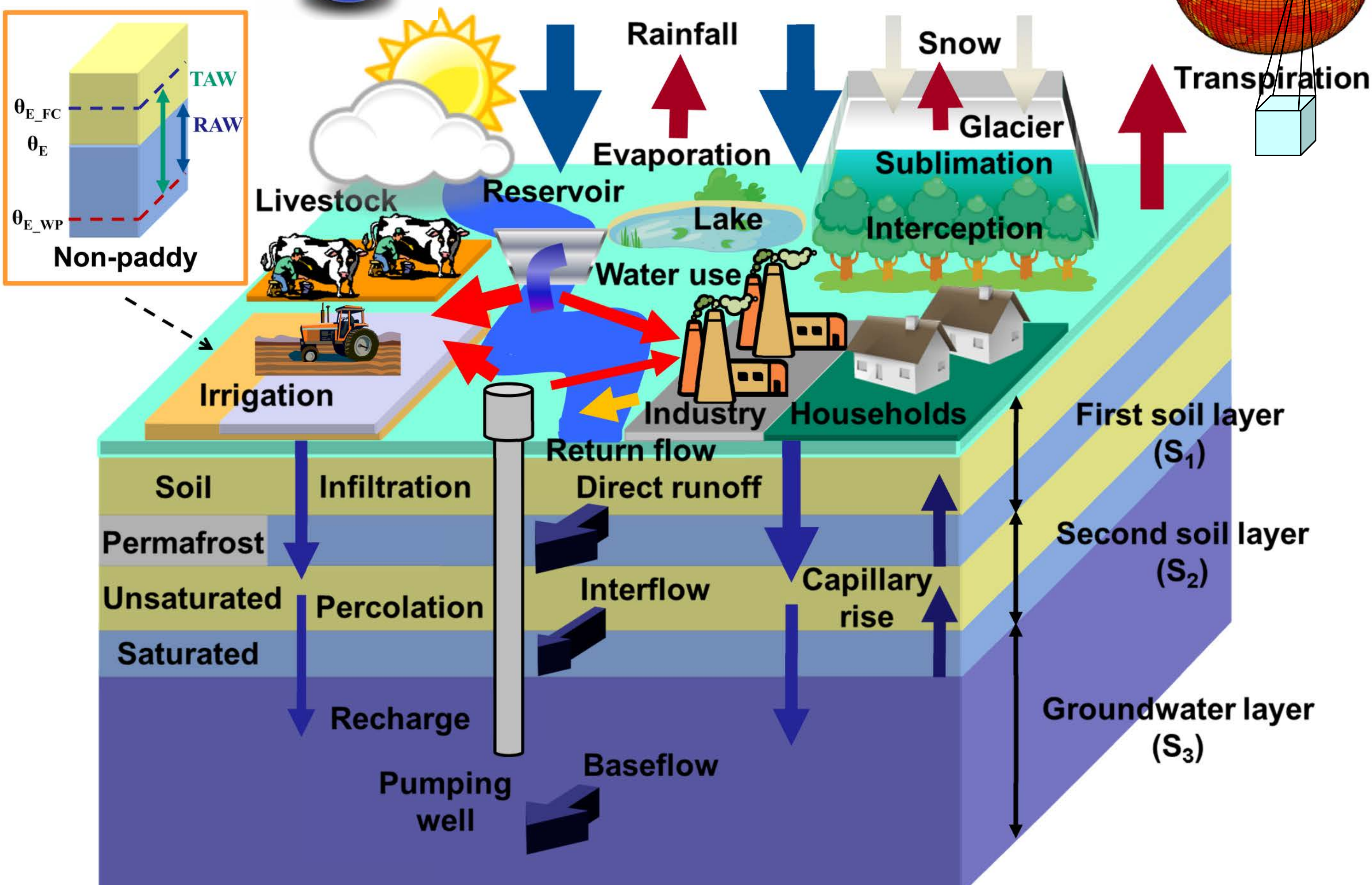


Human and Climate Impacts

- **Water use quintupled from 1960 to 2001 in Romania.**
- **Agriculture: 60%, Industry: 30% and Households: 10%**
- **High water stress since 1980s has been anthropogenically driven rather than climate induced.**



PCR-GLOBWB v2.0



Wada et al. (2014; Earth System Dynamics)

Hydrological Impact Assessment

- How climate change affects future hydrology and water resources?

- How certain are we? Where are the sources of the uncertainties in ensemble projections?

Methods (socio-economic fixed to the present):

11 Global Hydrological or Impact Models (GHMs/GIMs):
DBH, H08, JULES (CO_2), LPJmL (CO_2), Mac-PDM, MATSIRO, MPI-HM, PCR-GLOBWB, VIC, WaterGAP, WBM

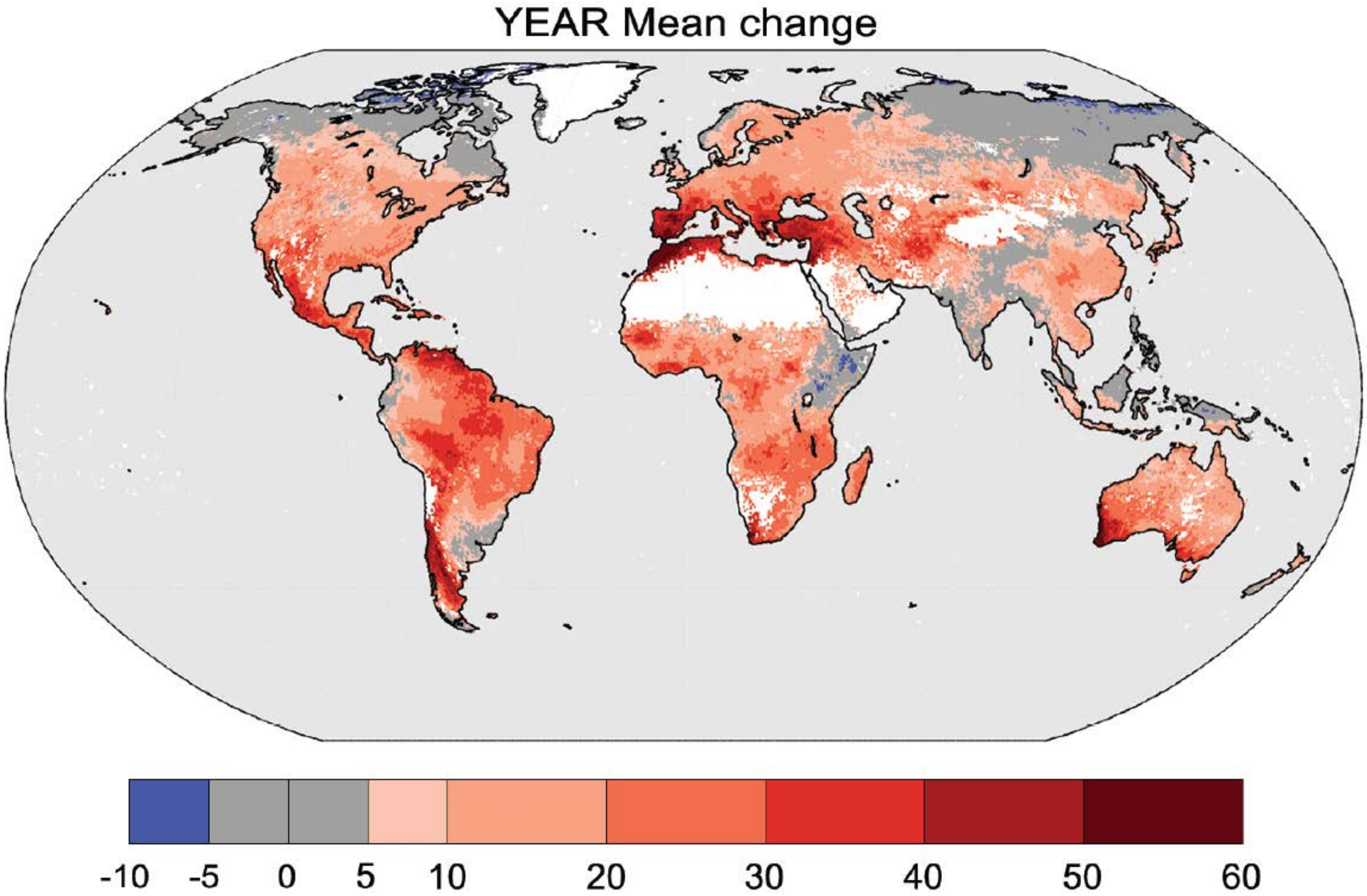
5 Global Climate Models (GCMs) :
HadGEM2-ES, IPSL-CM5A-LR, MIROC-ESM-CHEM, GFDL-ESM2M, NorESM1-M (0.5 degree, bias-corrected; Hempel et al. (2013; ESD))

4 Representative Concentration Pathways (RCPs): **2.6, 4.5, 6.0, 8.5**
Simulation period: 1971-2099

Impact Assessments and Associated Uncertainty:

- River discharge/Runoff
- Groundwater recharge
- Hydrological drought
- Flood
- Irrigation
- Water scarcity

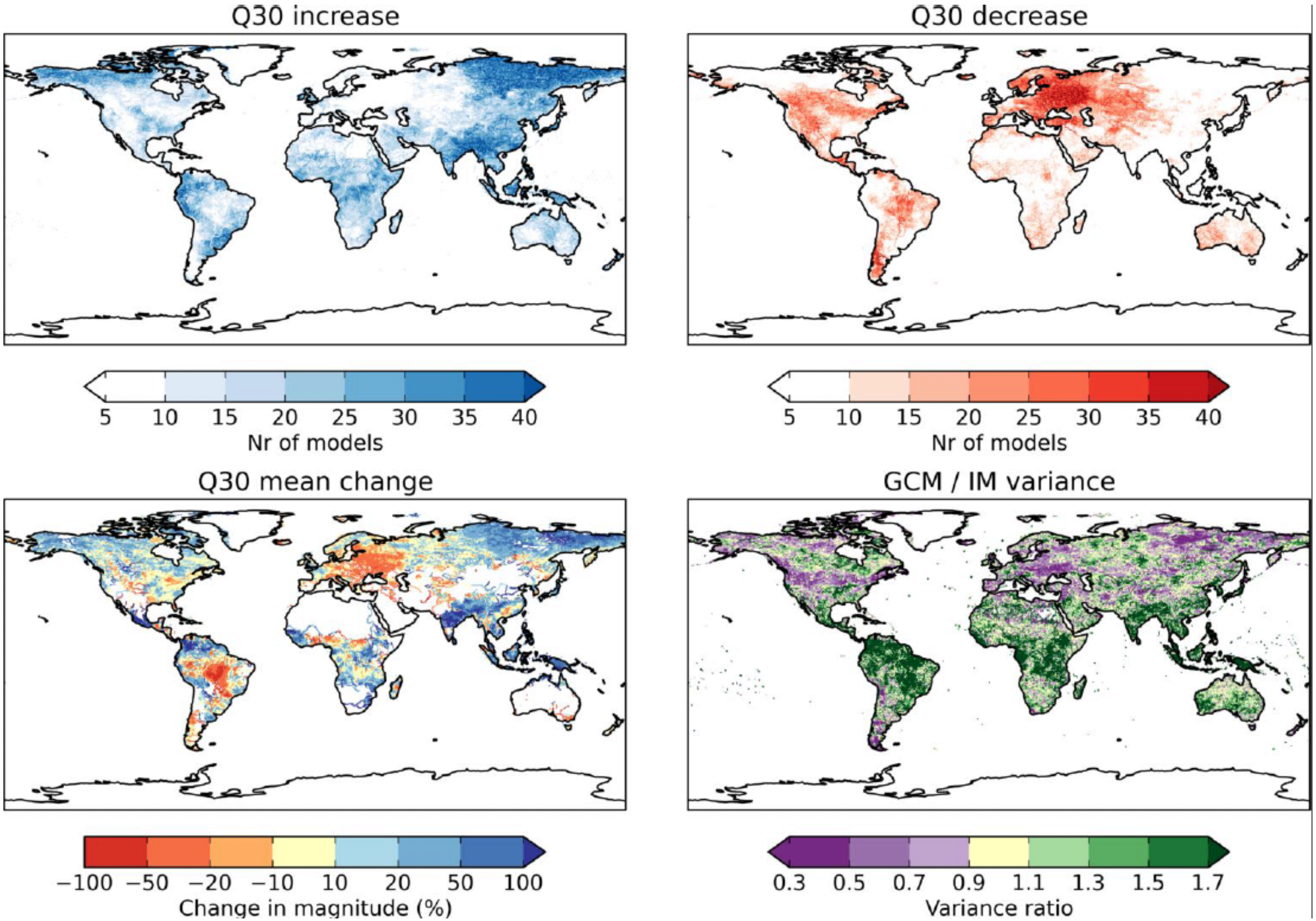
Change in hydrological drought occurrence



Percentage change in the occurrence of days under drought conditions by the end of this century (2070–2099) relative to the present (1976–2005) under RCP8.5

Prudhomme et al. (2014; PNAS)

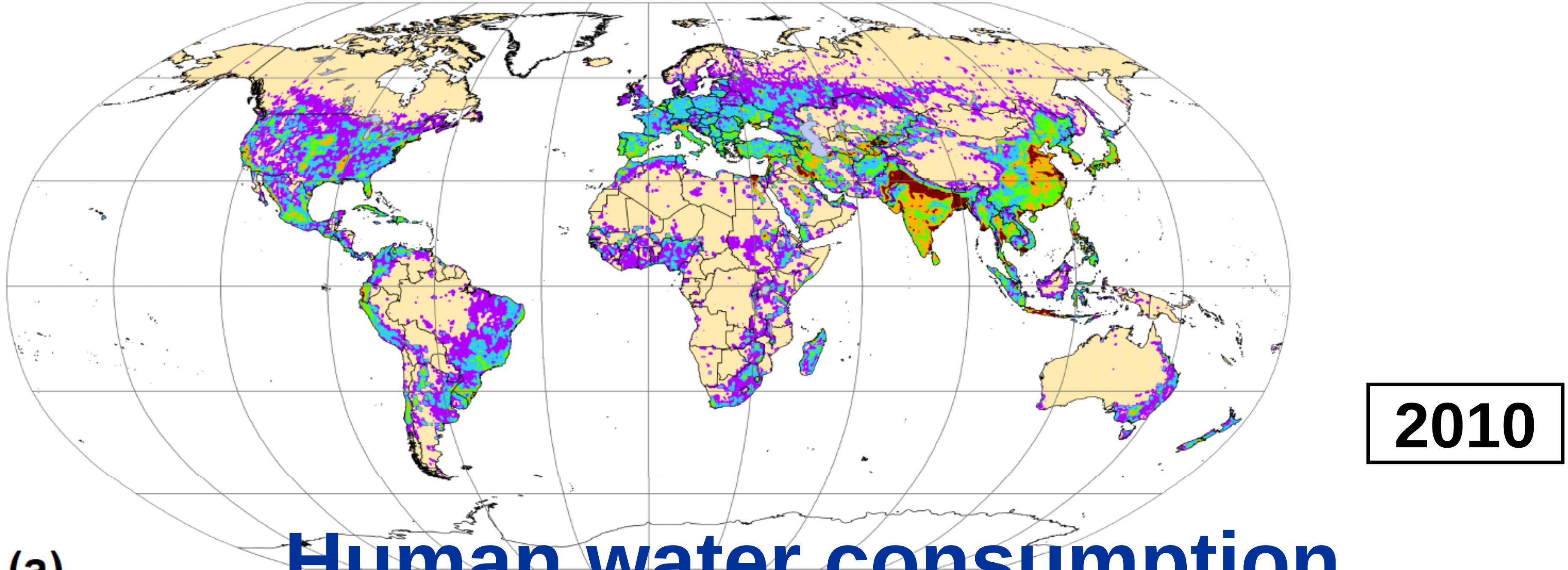
Change in potential flood hazard



Ensemble projections (45 in total) showing an increase or decrease in the magnitude of Q_{30} of more than 10% by the end of this century relative to the present under RCP8.5 with the 30-y return level of river flow (Q_{30})

Dankers et al. (2014; PNAS)

Human water consumption

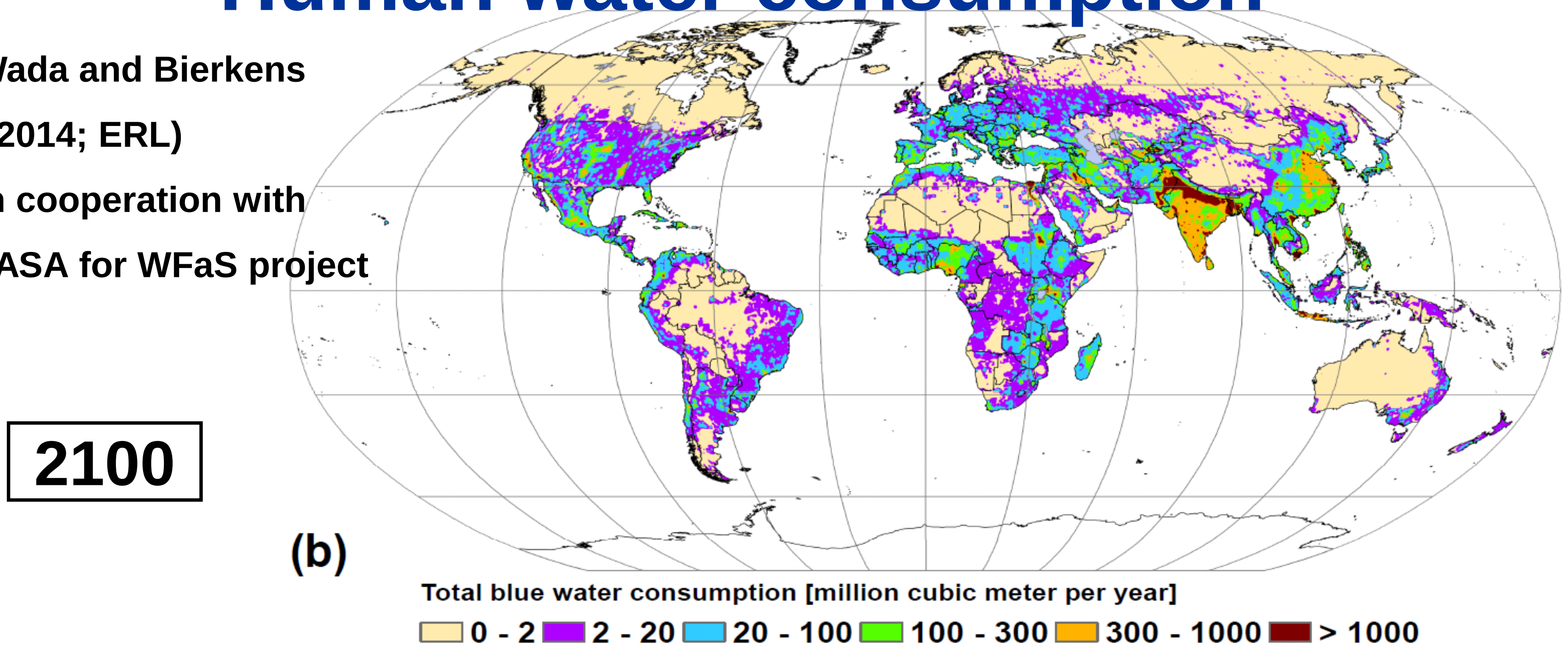


Wada and Bierkens

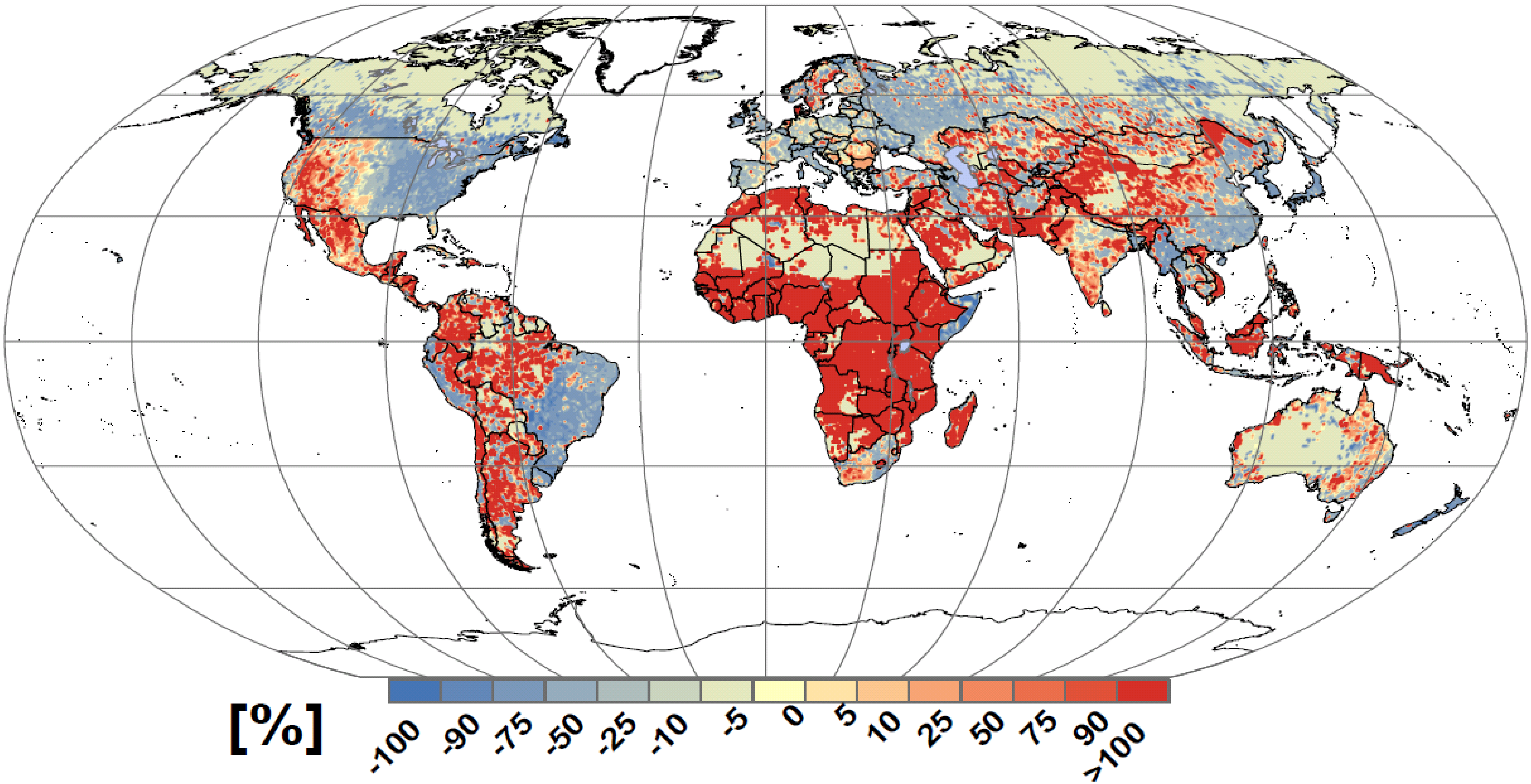
(2014; ERL)

In cooperation with

IIASA for WFaS project

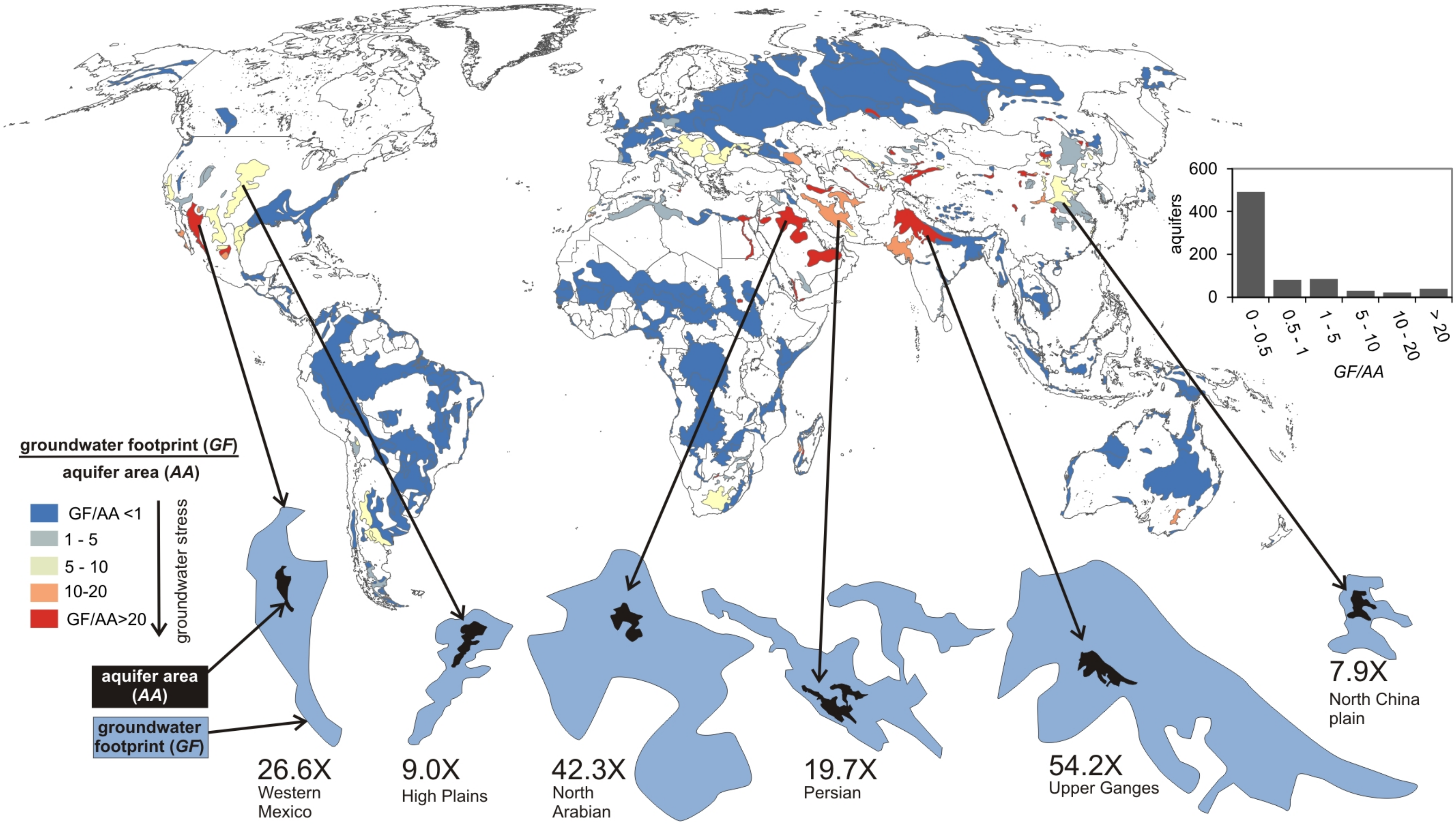


Relative change in human water consumption

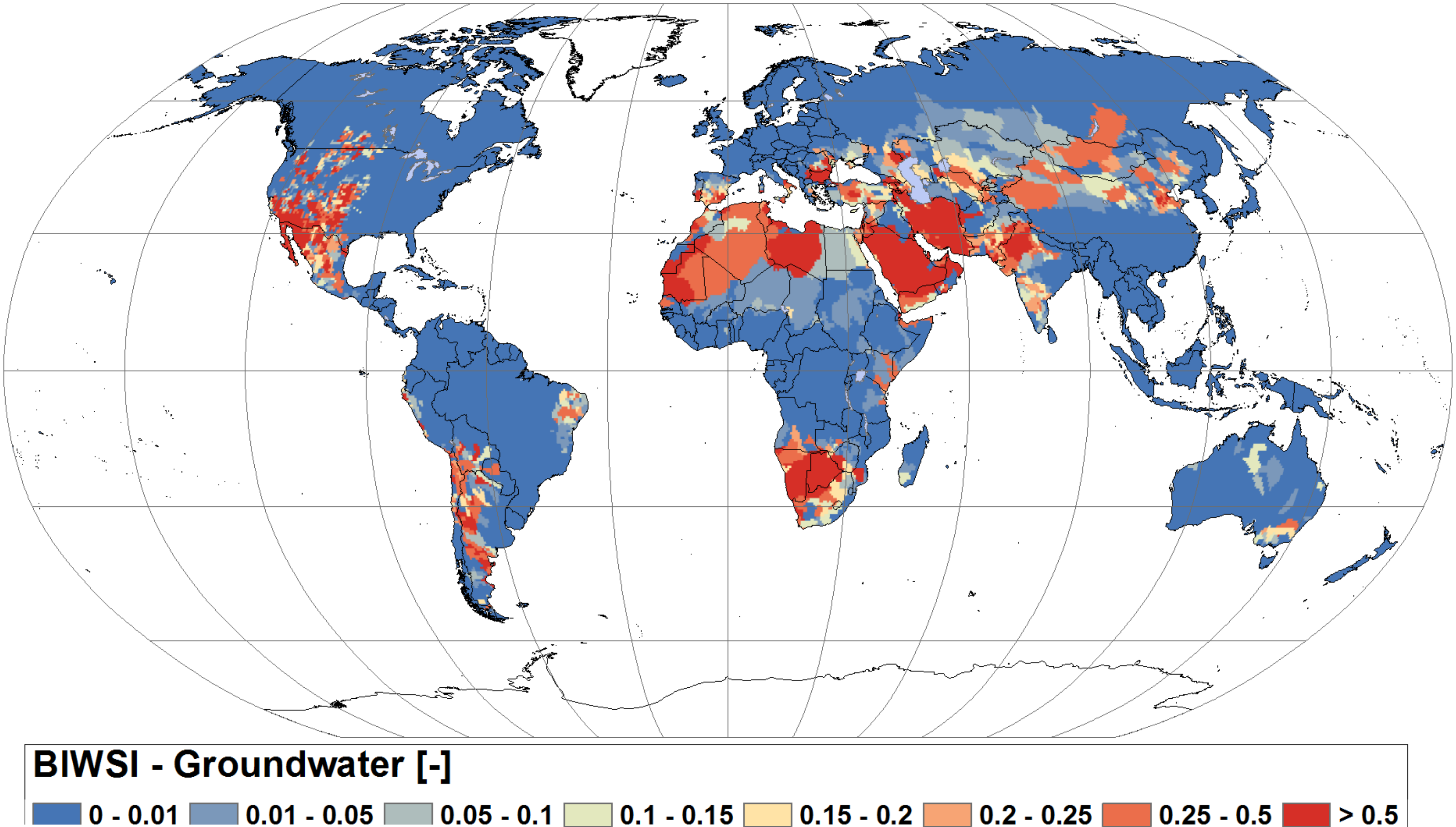


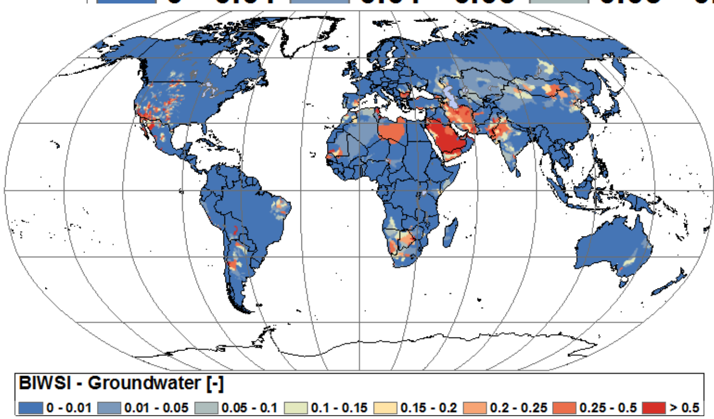
2100 – 2010

Global groundwater stress



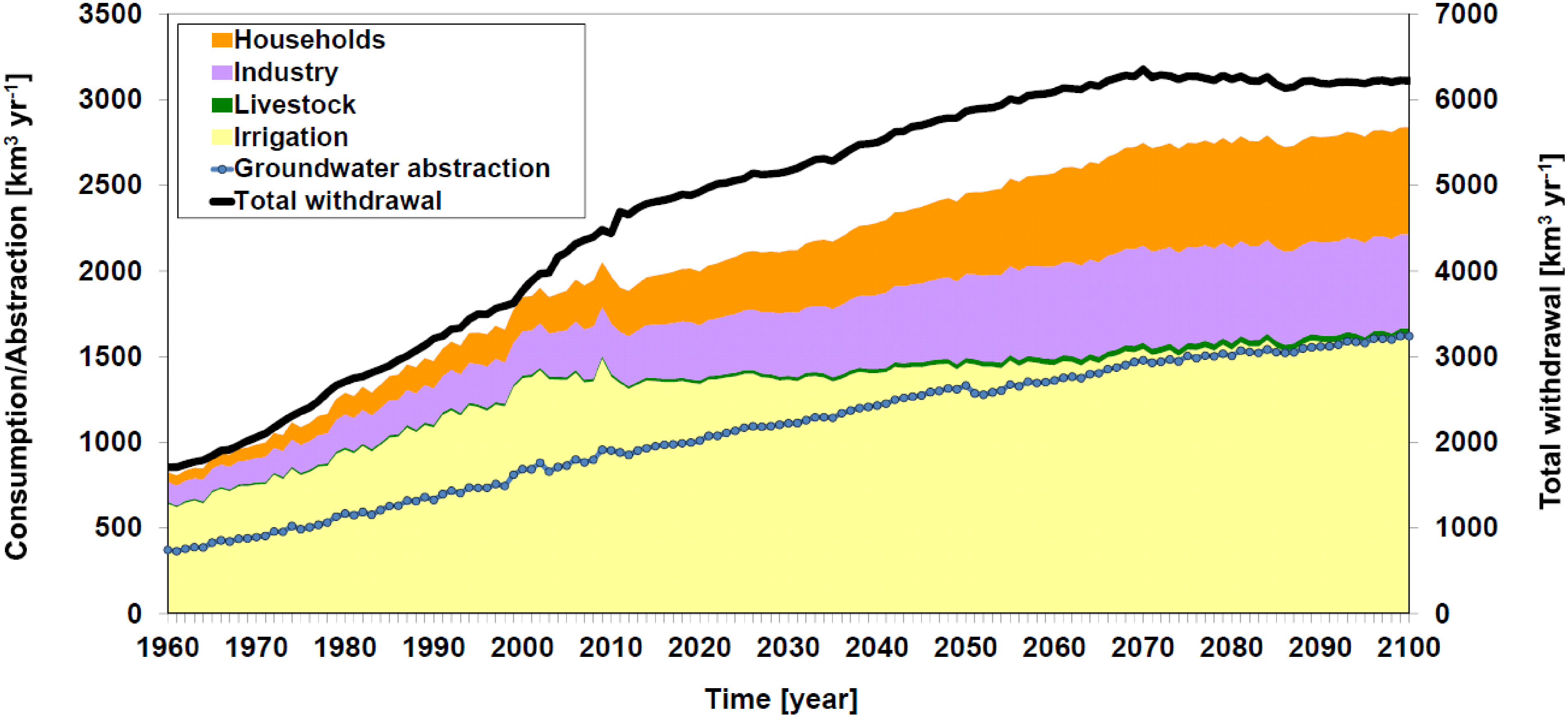
Gleeson et al. (2014; Nature)





Average nonrenewable groundwater abstraction over the total (2069-2099)

Wada and Bierkens (2014; ERL)



Past trends and future projections of human water use (SSP2; 1960-2100)

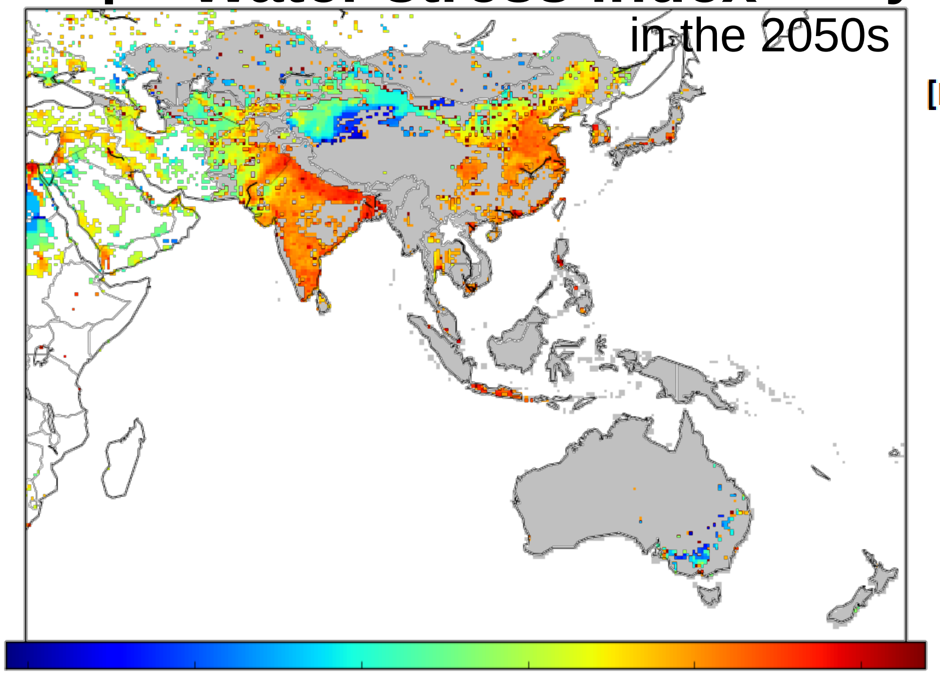
Imbalance between demand and supply

Middle of the Road

Population under water scarcity

Water stress index

in the 2050s

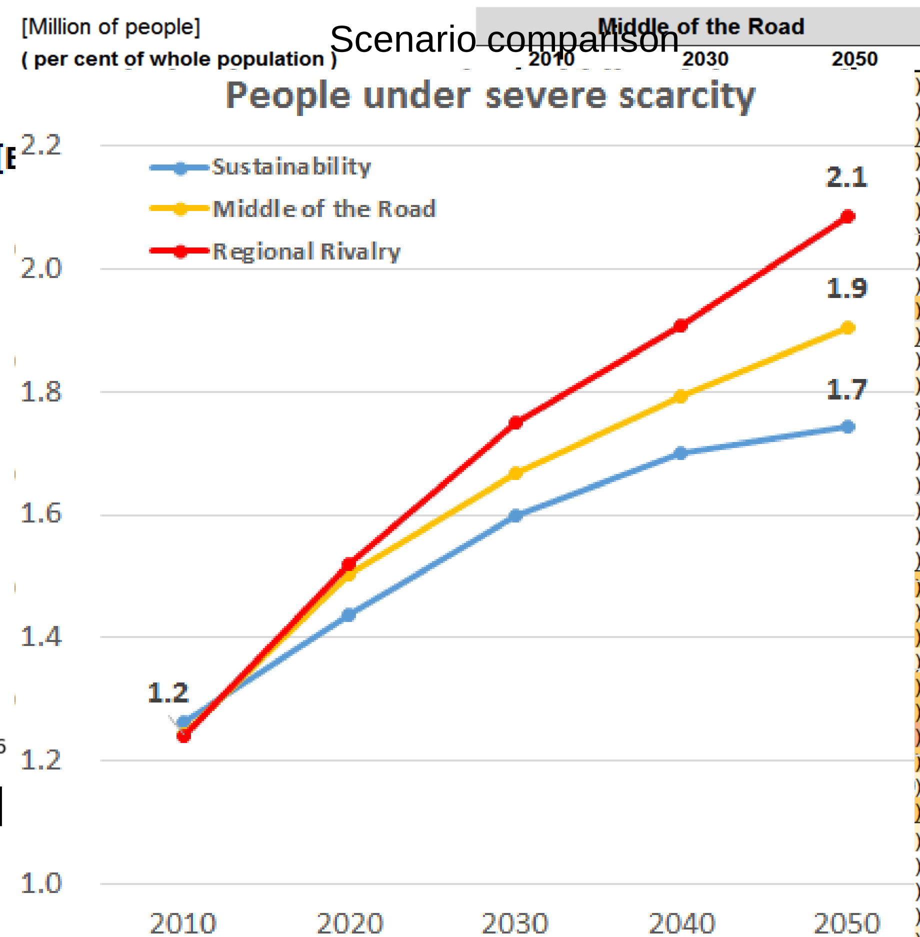


Safe

water scarce

Severe water scarce

[cap (log)]



Water scarcity index =

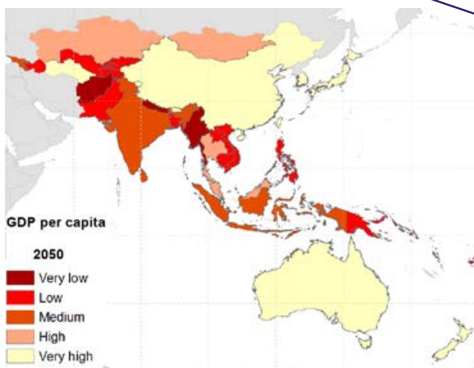
$$\frac{\text{Water demand}}{\text{Available water resource}}$$

increase under all scenarios, in the range of 1.7 to 2.1 billion, which represents approximately 40% of Asian total population

Country level
Hydro-Economic Analysis

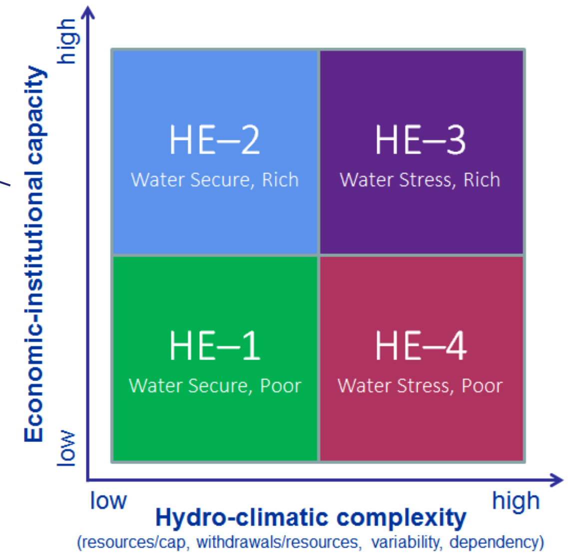
in the 2050s
Middle of the Road scenario

Economic-institutional capacity

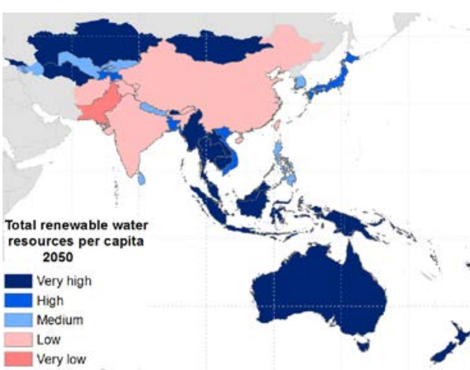


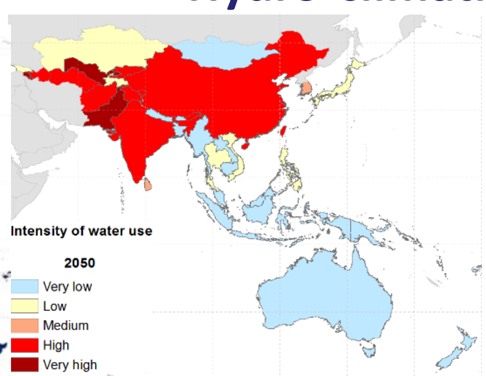
Very low: CL1 … 3000 > GDPC > 250
Low: CL2 … 10000 > GDPC > 3000
Medium: CL3 … 10000 > GDPC > 20000
High: CL4 … 35000 > GDPC > 20000
Very high: CL5 … 90000 > GDPC > 35000

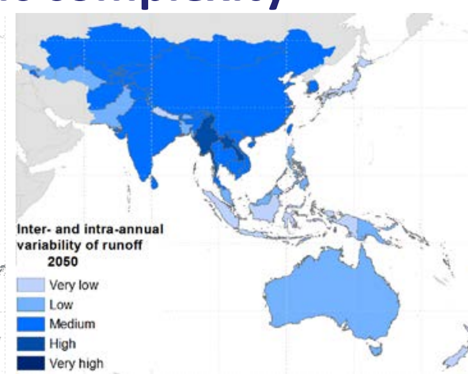
GDP per capita

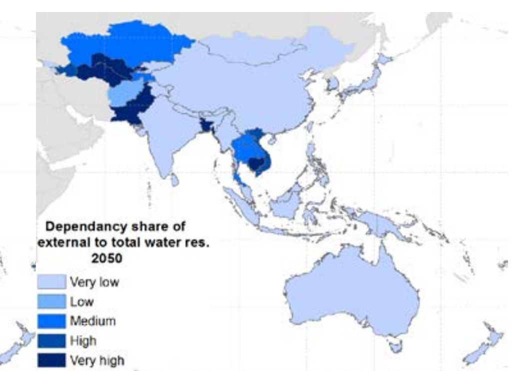


Hydro-climatic complexity









Total renewable surface water resources per cap

Very high: CL1 … 20000 > TWRC > 10000
High: CL2 … 10000 > TWRC > 5000
Medium: CL3 … 5000 > TWRC > 2000
Low: CL4 … 2000 > TWRC > 1000
Very low: CL5 … 1000 > TWRC > 100

Intensity of water use

Very low: CL1 … 0.01 < TWD/TWR < 0.05
Low: CL2 … 0.05 < TWD/TWR < 0.15
Medium: CL3 … 0.15 < TWD/TWR < 0.30
High: CL4 … 0.30 < TWD/TWR < 0.60
Very high: CL5 … 0.60 < TWD/TWR < 1.00

Inter- and intra annual variability of runoff

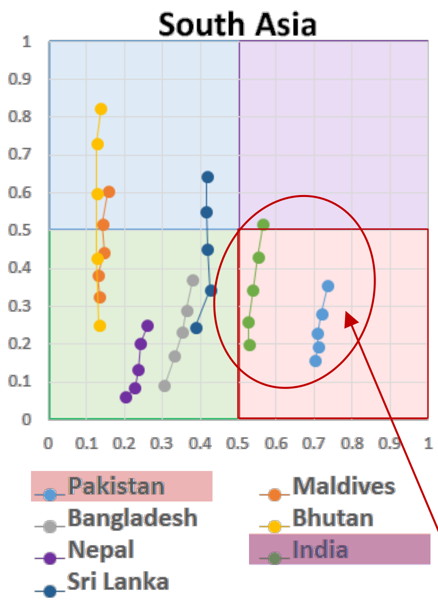
Very low: CL1 … 0 < CVTWR < 30
Low: CL2 … 30 < CVTWR < 60
Medium: CL3 … 60 < CVTWR < 100
High: CL4 … 100 < CVTWR < 150
Very high: CL5 … 150 < CVTWR < 225

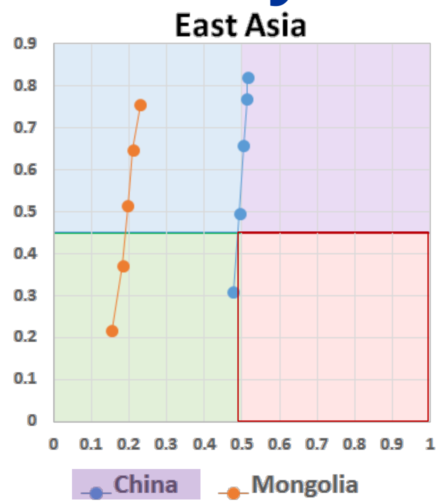
Dependency share of external water resources

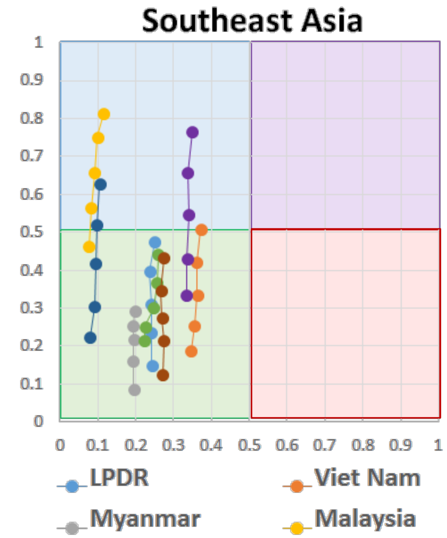
Very low: CL1 … 0.05 < DPC < 0.30
Low: CL2 … 0.30 < DPC < 0.45
Medium: CL3 … 0.45 < DPC < 0.55
High: CL4 … 0.55 < DPC < 0.70
Very high: CL5 … 0.70 < DPC < 0.95

Country level

Hydro-Economic Analysis

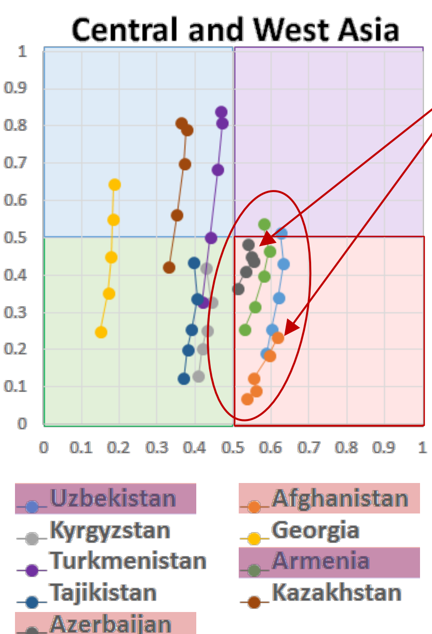


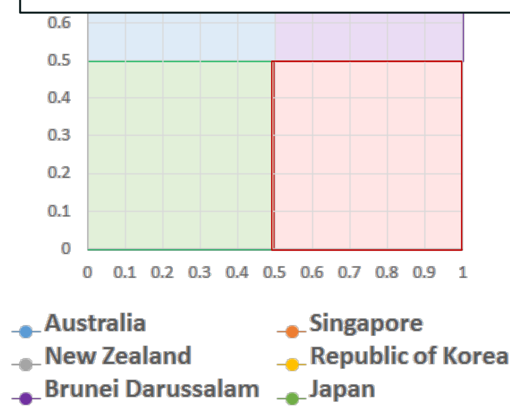


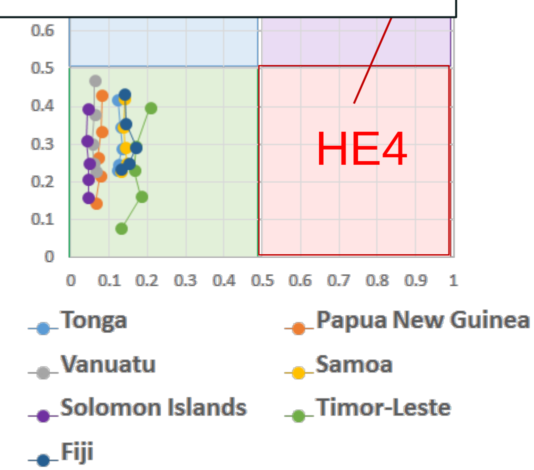


Pakistan, **Afghanistan**, and **Azerbaijan** will remain the most vulnerable countries in Asia, as they will be highly stressed with low adaptive capacity under all scenarios

ter challenge
ing capacity







Conclusions and Outlook

- Growing water use and scarcity is projected for Africa, new hotspot.
- ~30% of the present human water consumption is supplied from nonsustainable water resources, and is projected to increase to 40% by the end of this century.
- Nonrenewable groundwater is a major source for irrigation: India, Pakistan, Iran, the Middle East (20-50%), but may not last…
- Some countries are more vulnerable under growing water demands and climate change, e.g. Pakistan, Afghanistan, and Azerbaijan.
- Current degree of nonsustainable use may compromise the future food production.