H08

An open source global hydrological model with human activities

A global water scarcity assessment under Shared Socio-economic Pathways

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and collaborators

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Papers in press

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Outline

- Conducted a global water scarcity assessment in the 21st century

Balance → Water use | Socio-economic scenario | RCP/SSP

Balance → Water availability | Climate scenario | CMIP5

- Key questions

Hydrol. Earth Syst. Sci., 17, 2375–2391, 2013
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Hydrology and Earth System Sciences
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A global water scarcity assessment under Shared Socio-economic Pathways – Part 1: Water use

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Abstract. A novel global water scarcity assessment for the 21st century is presented in a two-part paper. In this first paper, water use scenarios are presented for the latest global hydrological models. The scenarios are compatible with the socio-economic scenarios of the Shared Socio-economic ... for global water scarcity assessments that identify the regions vulnerable to water scarcity and analyze the timing and magnitude of scarcity conditions.

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A global water scarcity assessment under Shared Socio-economic Pathways – Part 2: Water availability and scarcity

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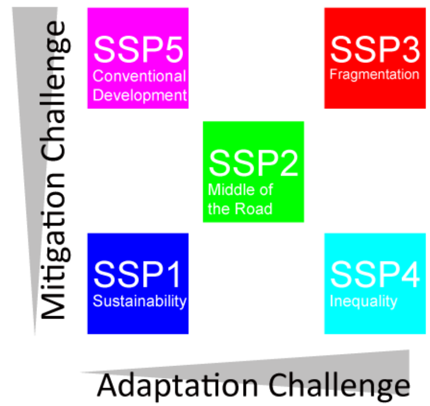
Abstract. A global water scarcity assessment for the 21st century was conducted under the latest socio-economic scenario for global change studies, namely Shared Socio- ... tively, if climate policies are not adopted. Even in SSP1 (the scenario with least change in water use and climate) global water scarcity increases considerably, as compared to the ...

Shared Socio-economic Pathways

SSPs: New socio-economic scenarios for global change study (after SRES)

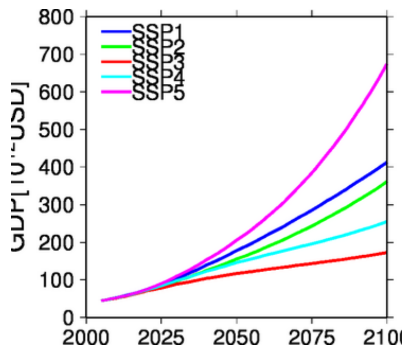
SSP	Description of the world
SSP1	Sustainability
SSP2	Middle of the Road
SSP3	Fragmentation
SSP4	Inequity
SSP5	Conventional Development



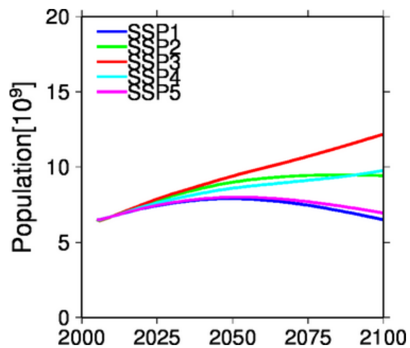
O'Neil et al. 2012

Similar to SRES, major socio-economic factors are quantitatively available

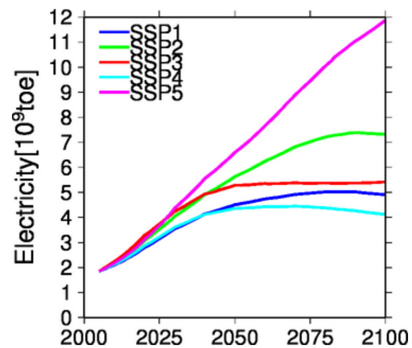
GDP (global total)



Population



Electricity production



SSP database

AIM/CGE's estimates

How do people use water in each SSP?

No water use scenario in SSPs

→ Tried to develop a water use scenario <u>COMPATIBLE</u> with SSPs.

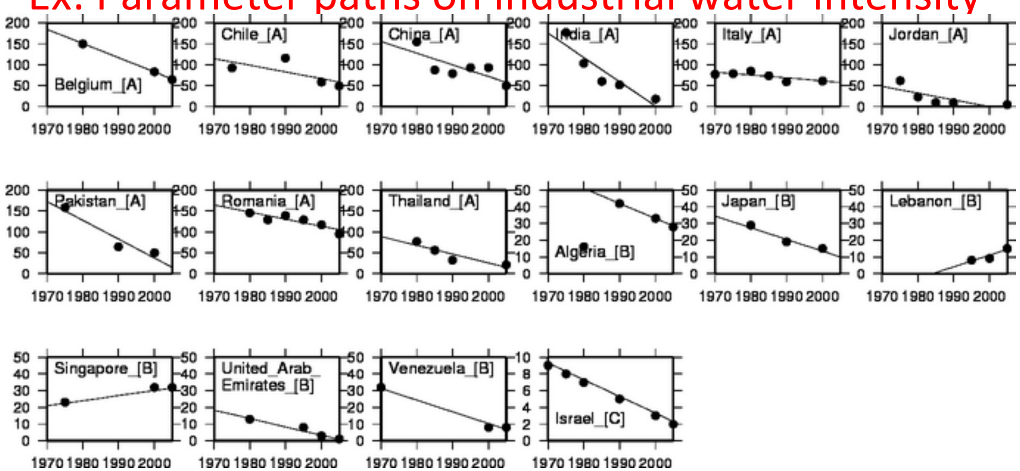
Step 1. Developed simple models on water use

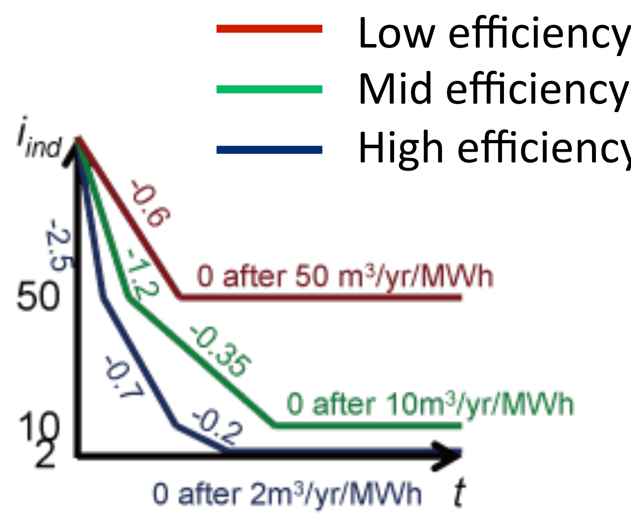
$$IndustrialWater = Electricity \times intensity$$

- *intensity*: Scenario/time-dependent parameter
- *Electricity*: Quantitative scenarios of SSPs

Step 2. Analyzed historical intensity change and developed parameter paths.

Ex: Parameter paths on industrial water intensity



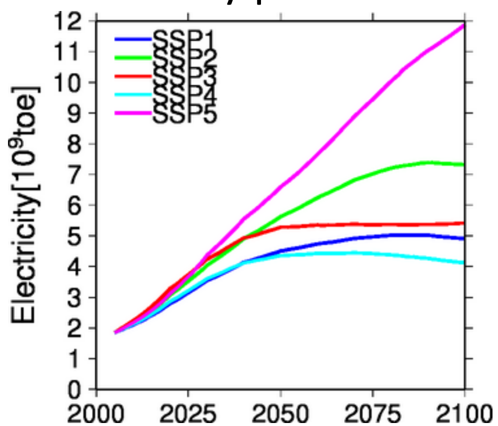


How people use water in each SSP?

Step 3. Linked three parameter paths and five SSPs focusing on narrative scenarios

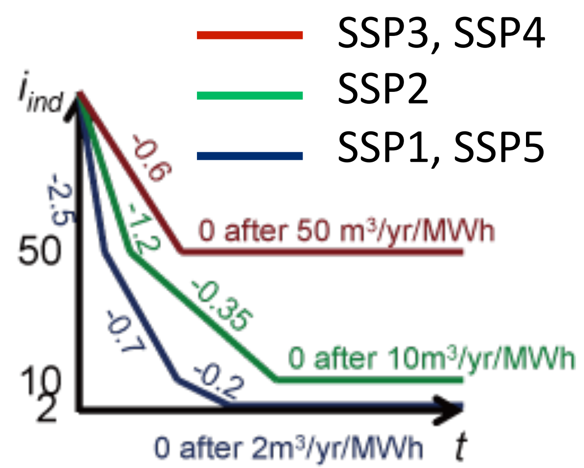
SSP	Description	Technological change
SSP1	Sustainability	Rapid
SSP2	Middle of the Road	Moderate
SSP3	Fragmentation	Slow
SSP4	Inequity	Rapid/Slow
SSP5	Conventional Development	Rapid

Electricity production



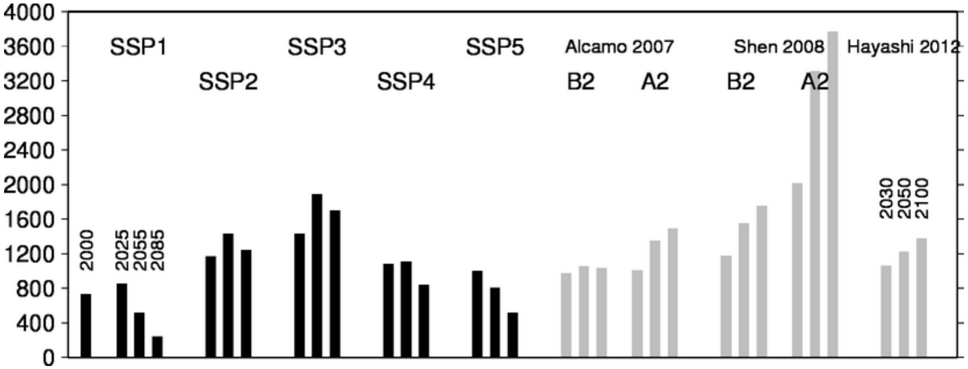
$$IndustrialWater$$
$$= Electricity \times intensity$$

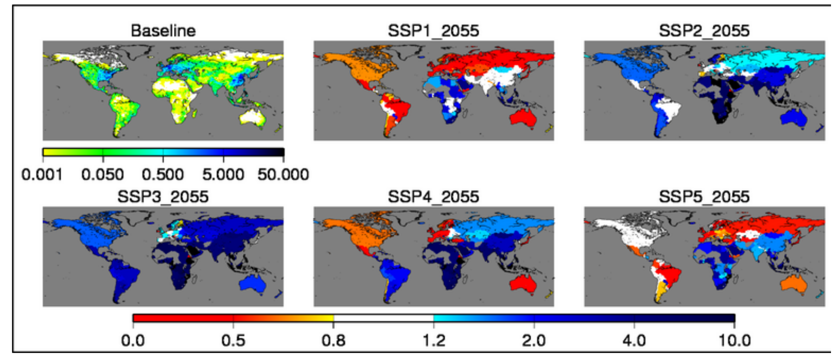
Industrial water withdrawal



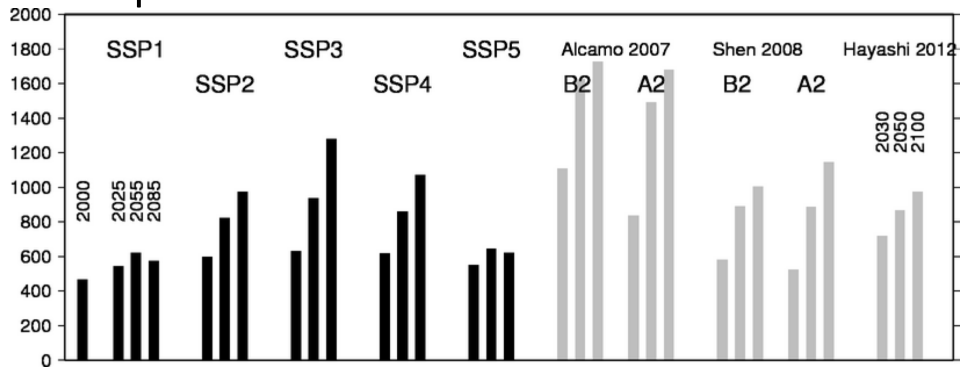
Water use scenarios

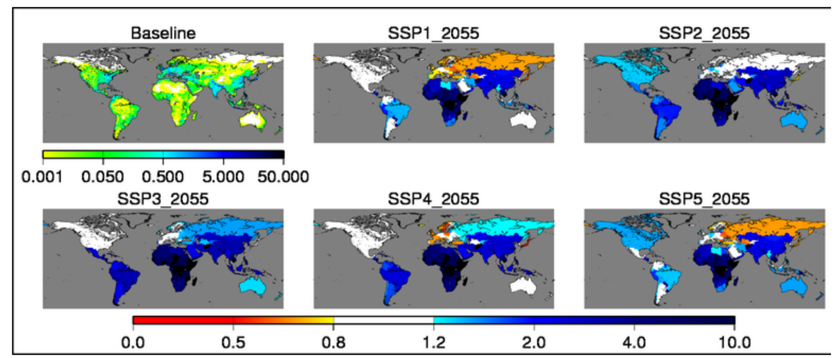
Industrial water withdrawal scenarios





Municipal water withdrawal scenarios

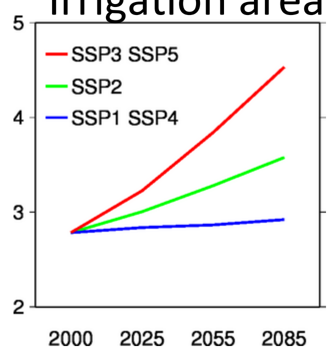




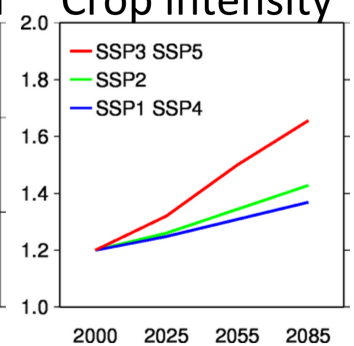
Irrigation scenarios:

(based on literature review)

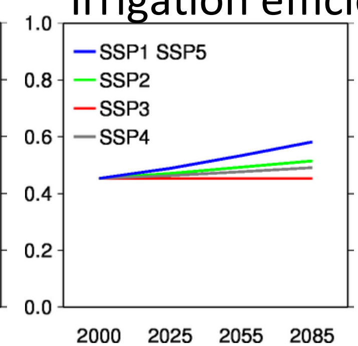
Irrigation area



Crop intensity



Irrigation efficiency



Is water available?

In Part 1 “potential water demand” was projected.
→ Investigated the amount of water is hydrologically available.

What will be the future climate?

Scenario matrix

	RCP2.6	RCP4.5	RCP6.0	RCP8.5
SSP1			SSP1 BAU	
SSP2				SSP2 BAU
SSP3				SSP3 BAU
SSP4			SSP4 BAU	
SSP5				SSP5 BAU

GCM

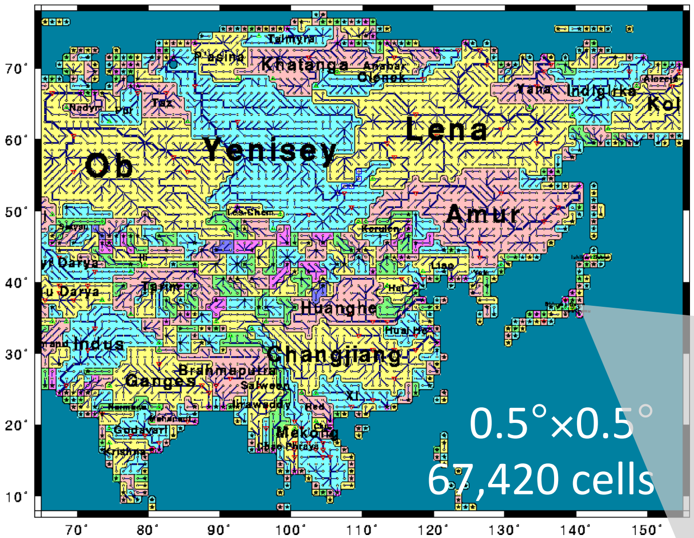
MIROC-ESM-CHEM
HadGEM2 ESM
GFDL ESM2M

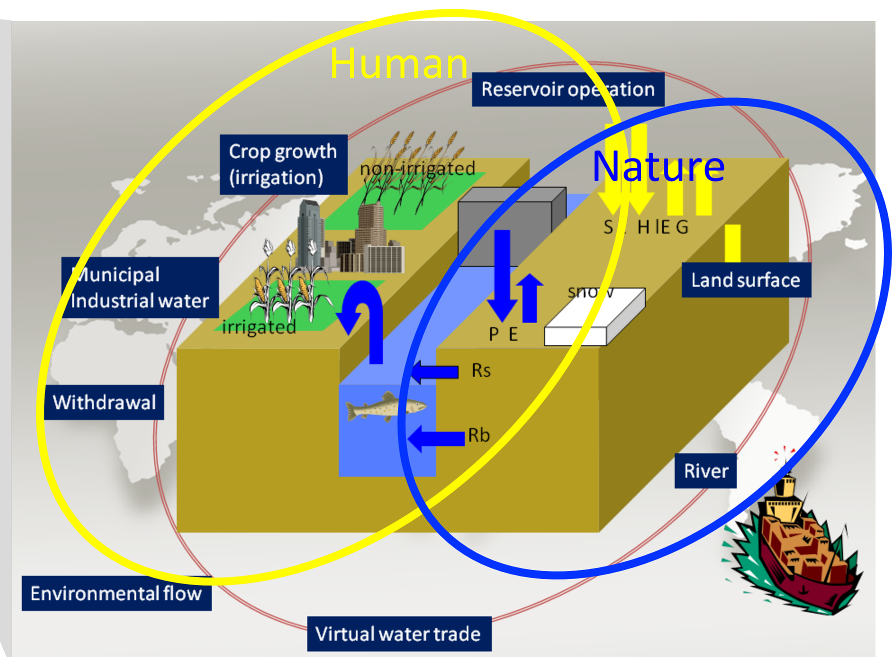
Time

1971-2000 (base period)
2011-2040
2041-2070
2071-2100

Global water resources model H08

1. Distributed hydrological model
2. Interaction between natural water cycle and major human activities
3. High temporal resolution (daily interval)





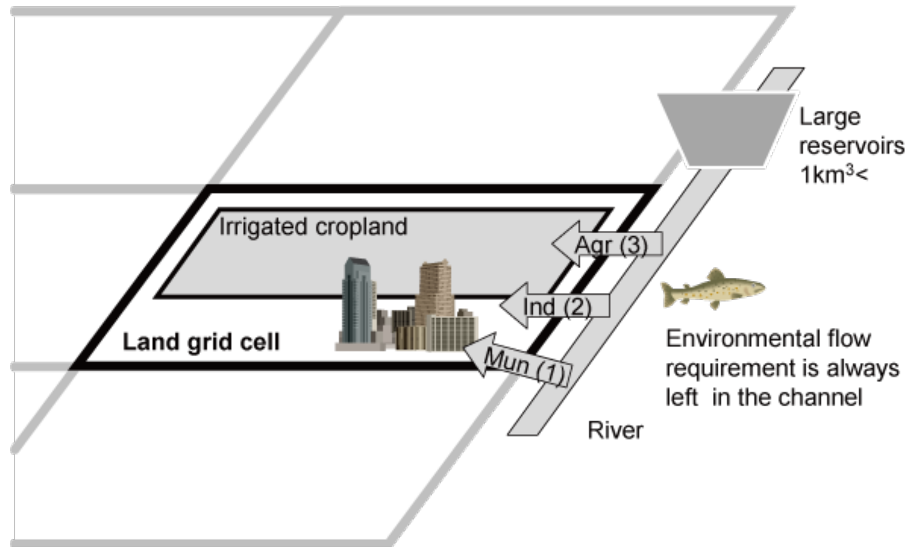
Hanasaki et al., 2006, 2008a,b, 2010

How can we define “water scarcity”?

Method used in this study

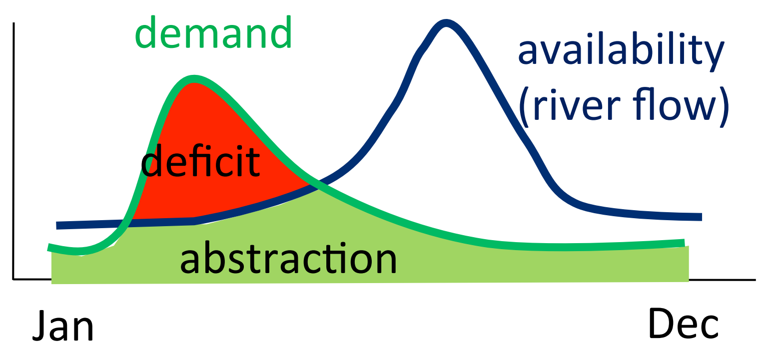
Water abstraction simulations

- Abstract only from rivers
- Daily interval
- Rivers can be depleted, and withdrawal can fall below demand



Water scarcity index: Cumulative Abstraction to Demand Ratio

$$CAD = \frac{\sum_{DOY=1}^{365} abstraction_{DOY}}{\sum_{DOY=1}^{365} demand_{DOY}}$$



Water scarcity: CAD<50%

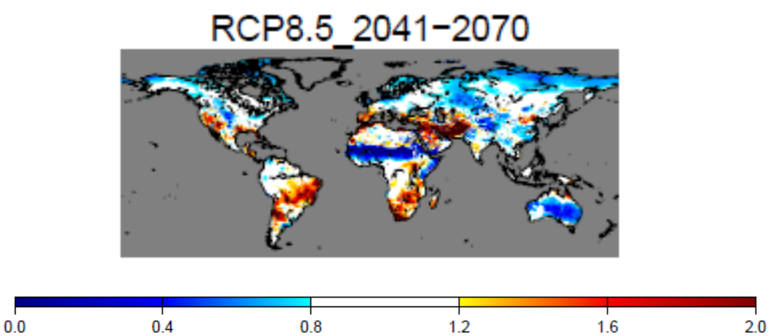
Water scarcity assessment

Change in CAD index

→Africa is most vulnerable?

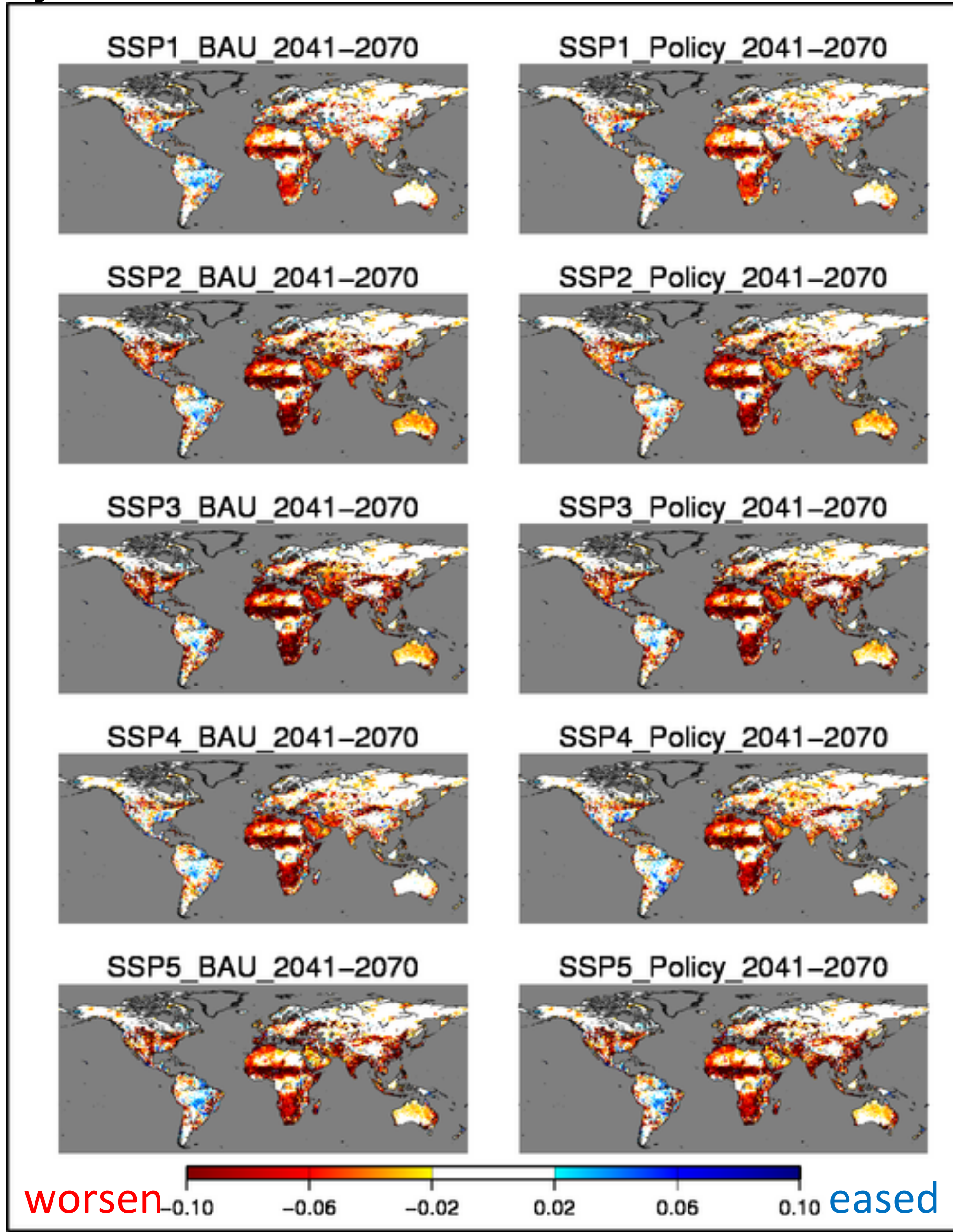
→Stress increases including regions mean annual runoff increases

Annual based index(WWR)



eased worsen

The mean annual runoff increases in Sub-Sahara → annual based indicator becomes better but CAD shows opposite

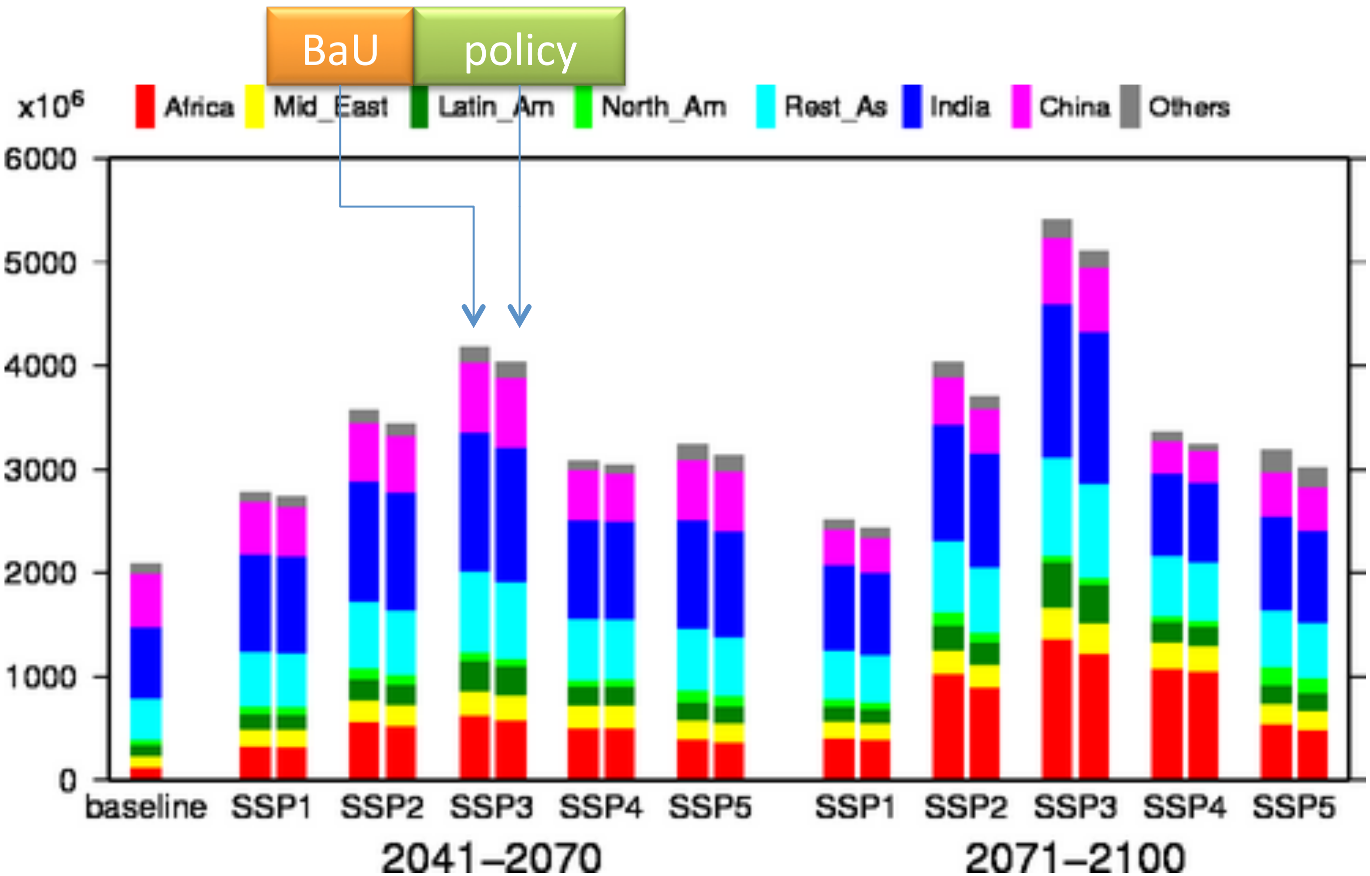


The effect of climate policy

Water stressed population

→Population living in grid cells with the condition of CAD < 50%

→ Climate policy has limited effect.



Summary & Discussion

- Summary
  - Developed water use scenario compatible with SSPs.
  - Assessed water scarcity globally taking into account sub-annual variability in water availability and use.
- Discussion
  - Consistency among models and scenarios
  - Adaptation?
- More information
  - Two papers are available online.

Climate policy has only little effect?

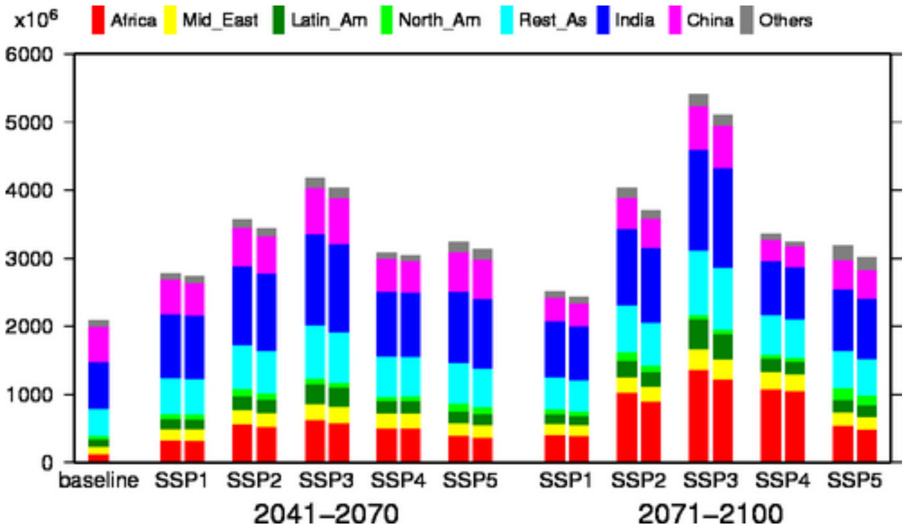


Figure 15 Region-wise total global population living in grid cells where CWD < 0.5. The bars in left and right show the results of no climate policy and with climate policy respectively.

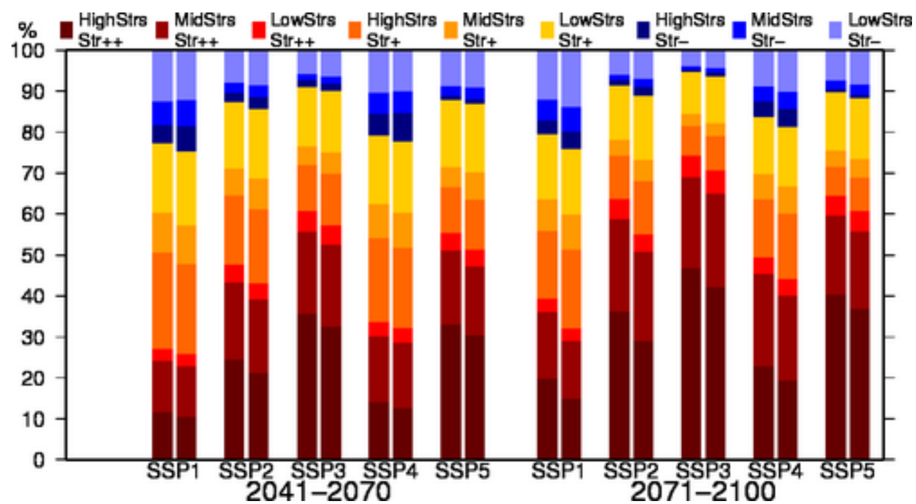


Figure 16 Percentage of global population living in grid cells categorized as Significant Degradation (ΔCWD<-0.05, red), Moderate Degradation (-0.05≤ΔCWD<0, orange), and Alleviation or no change (0≤ΔCWD, blue). Each category was subdivided into three by the change in the CWD recorded as Highly Stressed (CWD<0.5, dark), Moderately Stressed (0.5≤CWD<0.8, medium), and Less Stressed (0.8≤CWD, pale). The bars in left and right show the results of no climate policy and with climate policy respectively.

Framework

Meteorological (0.5°×0.5°,daily)	
Air temperature	For example: WATCH Forcing Data (Weedon et al., 2010)
Specific humidity	
Air pressure	
Wind speed	
Shortwave radiation	
Longwave radiation	
Precipitation	

Geographical/other (0.5°×0.5°)	
River map	Oki and Sud, 1998
Reservoir map	Hanasaki et al., 2006
Irrigated area	Siebert et al., 2005
Crop intensity	Döll and Siebert, 2002
Crop type	Monfreda et al., 2008
Industrial water dem.	FAO, 2011
Domestic water dem.	FAO, 2011

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Output (0.5°×0.5°, daily)	
Land sub-model	Evapotranspiration
	Runoff
	Soil moisture
	Snow water equivalent
	Energy term
River sub-model	Streamflow
	River channel storage
Crop growth sub-model	Planting date
	Harvesting date
	Agricultural water dem.
	Crop yield (not used)
Reservoir sub-model	Reservoir storage
	Reservoir outflow
Withdrawal sub-model	Agri. water availability
	Ind. water availability
	Dom. water availability
Environmental flow	Env. flow requirement

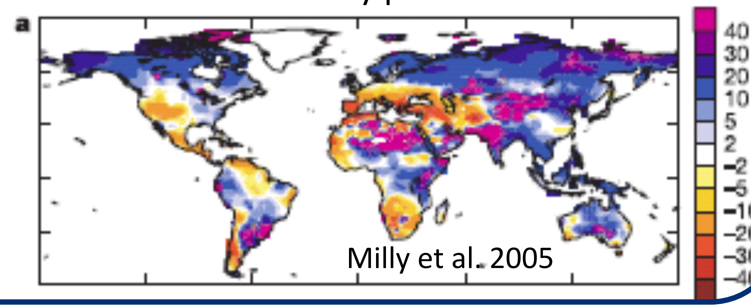
Why don't you use WWR index?

Popular water scarcity index: Withdrawal to Water Resources Ratio

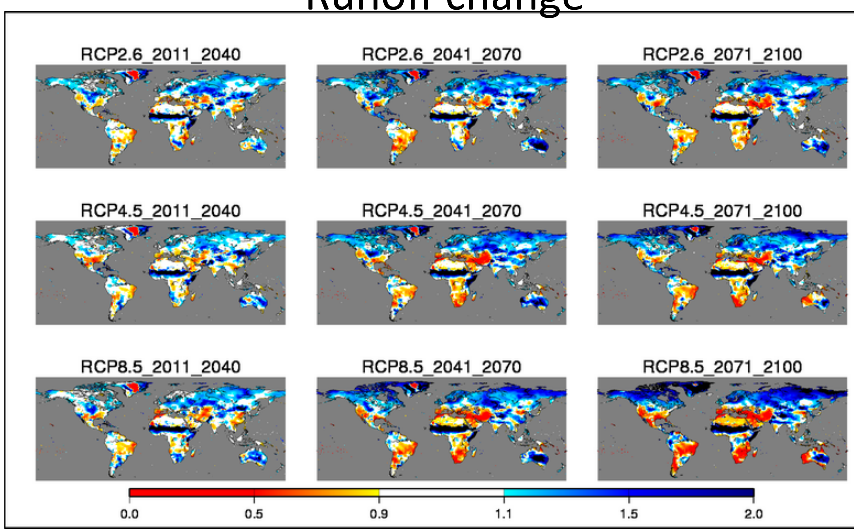
$$WWR = \frac{AnnualWithdrawal}{AnnualRiverDischarge}$$

Water scarcity: WWR>40%

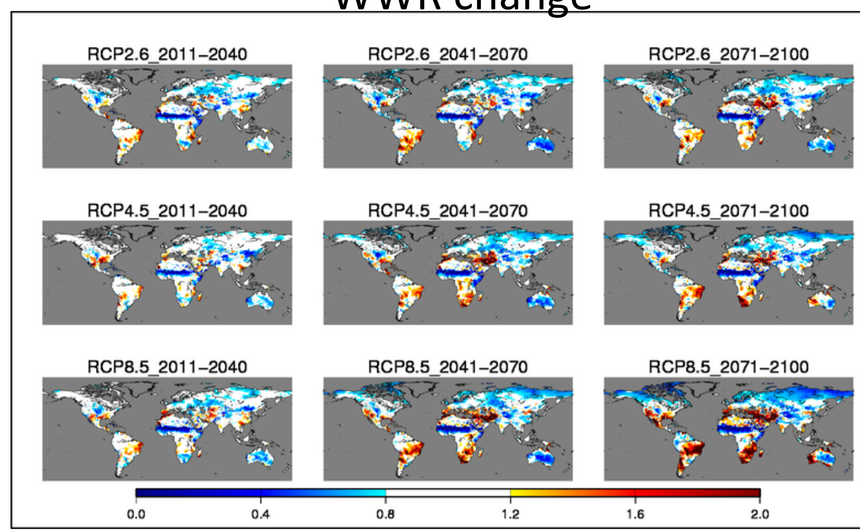
Annual river discharge change
→ Increases in many parts of the world



Runoff change



WWR change



Sometimes misleading results: if the mean annual runoff increases,
WWR automatically decreases indicating that water scarcity is alleviated