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AGU Fall Meeting 2017 in New Orleans

GC54B Climate-Hydrology-Human Interactions and Their Implications on Hydrological Extremes in a Changing Environment I

GC54B-02

Towards integrated solutions for water, energy, and land using an integrated nexus modeling framework

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United Nations Educational, Scientific and Cultural Organization

WATER FUTURES and SOLUTIONS WFaS

Columbia University in the City of New York

National Aeronautics and Space Administration
Goddard Institute for Space Studies

IIASA, International Institute for Applied Systems Analysis

Universiteit Utrecht

Half our planet's population still suffer from water insecurity

Absent/unreliable water supply

Poor sanitation

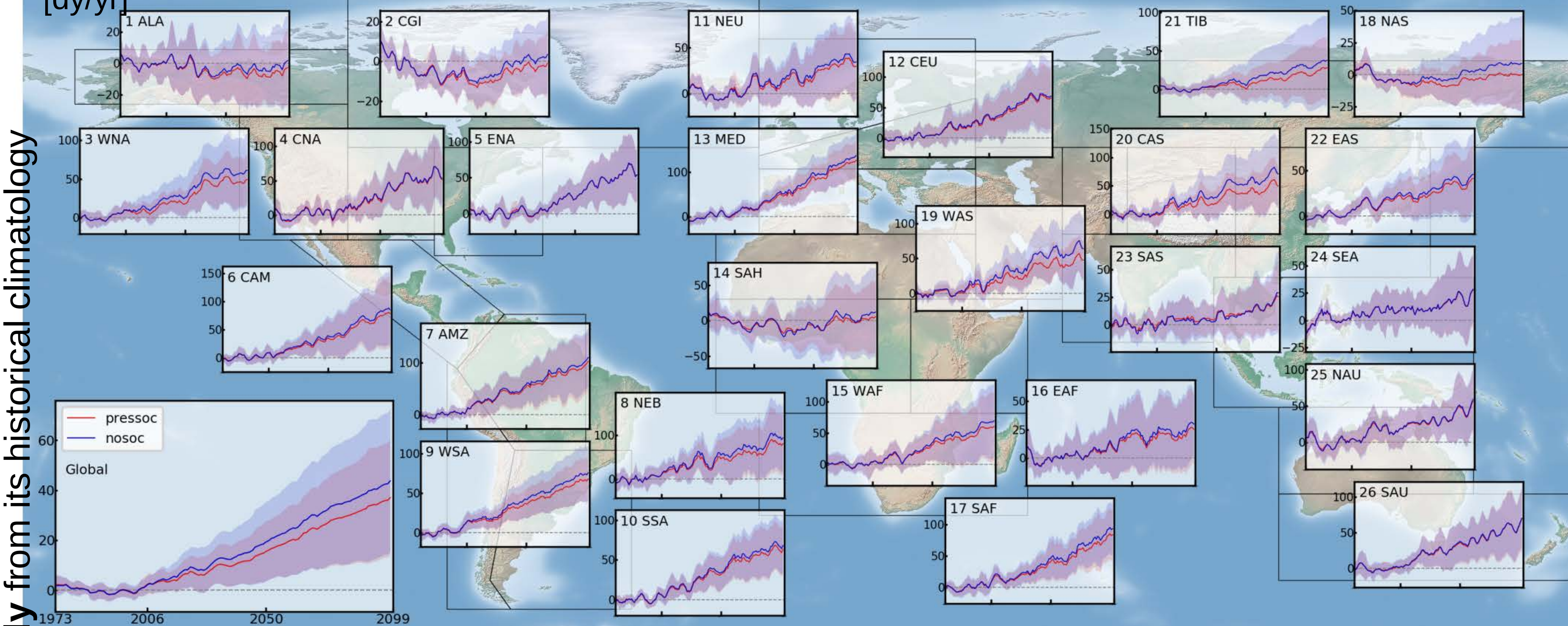
Floods & droughts

Poor irrigation and food production

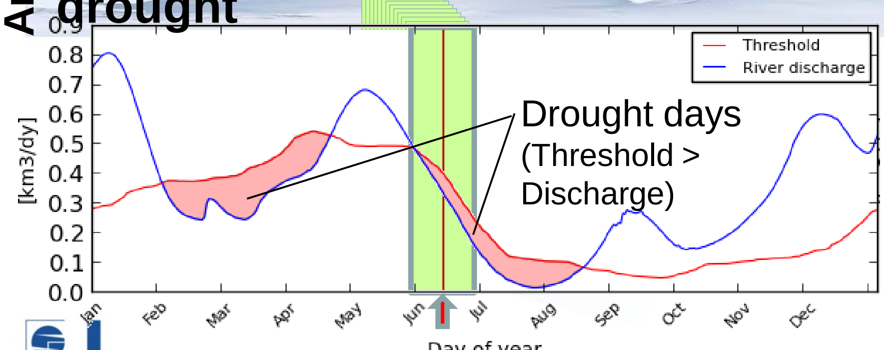
Time series variation in hydrological drought

RCP8.5

Index: Regional mean value of the total number of drought days in a year [dy/yr]



Hydrological drought



Data: Daily discharge derived from 25 ensemble

5 GCMs:
1. HadGEM2-ES
2. IPSL-CM5A-LR
3. GFDL-CM3
4. MIROC-ESM-CHEM
5. NorESM1-M

✖

5 GHMs:
1. H08
2. LPJmL
3. MATSIRO
4. PCR-GLOBWB
5. WBM

[ISI-MIP fast track]

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Time series variation in hydrological drought

RCP2.6

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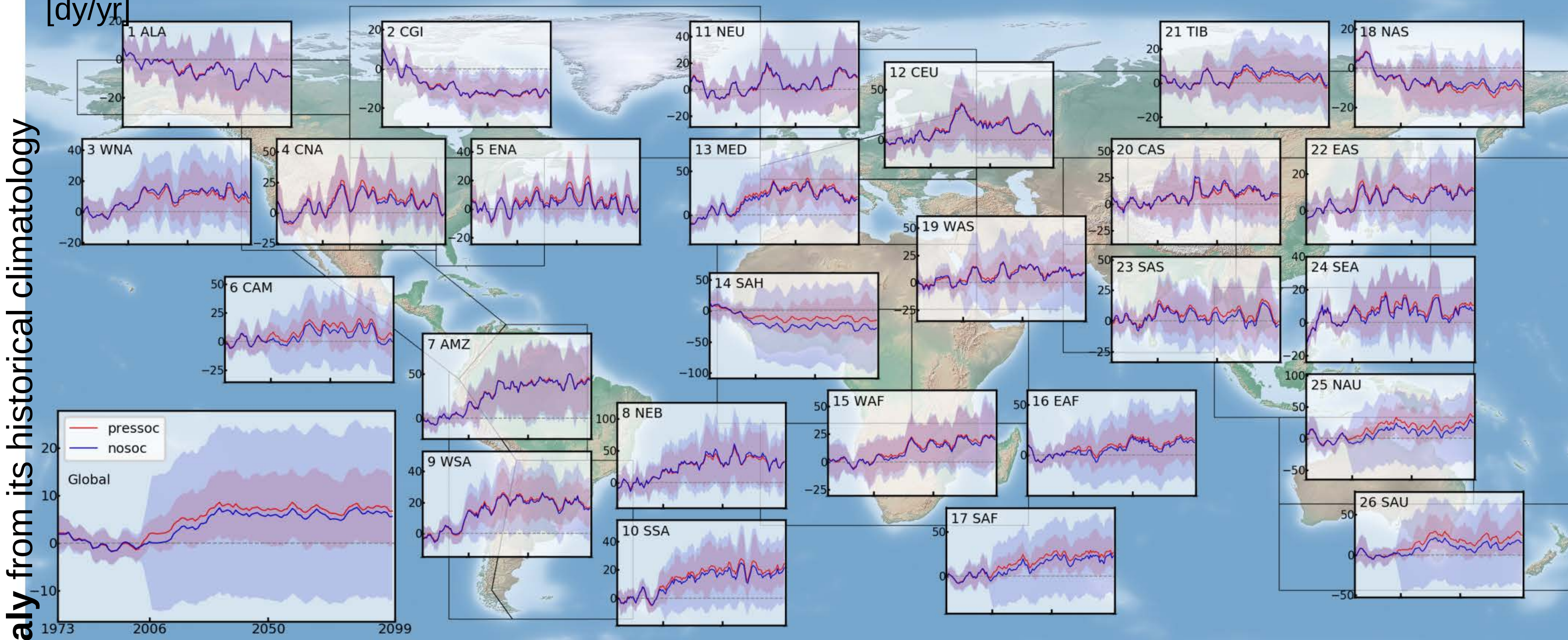
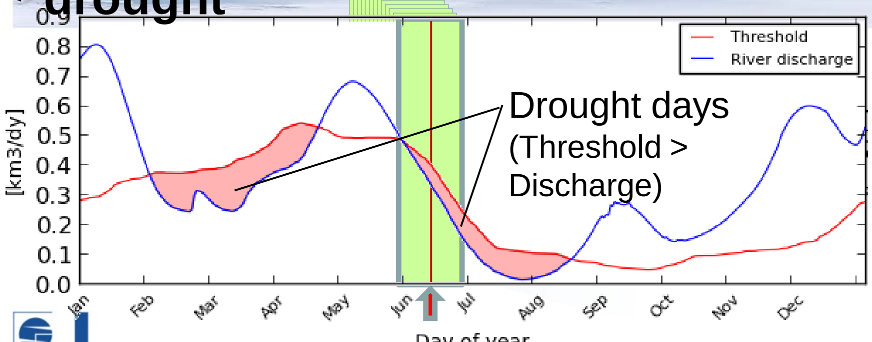


Hydrological drought



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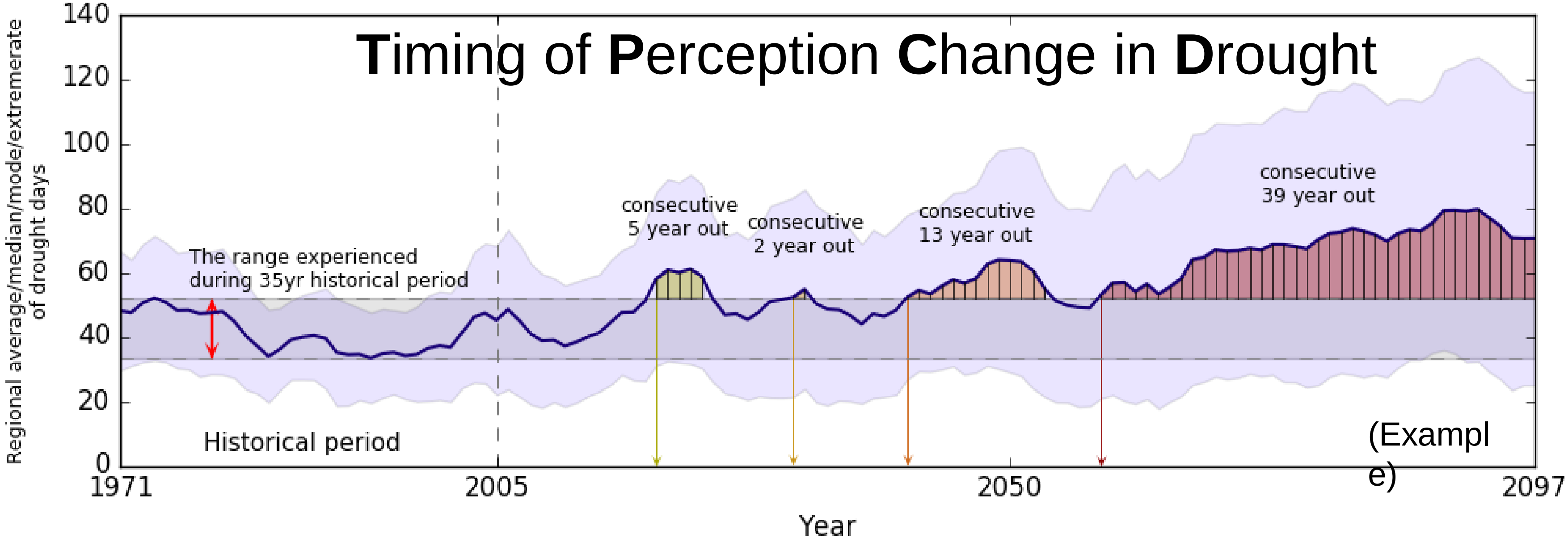
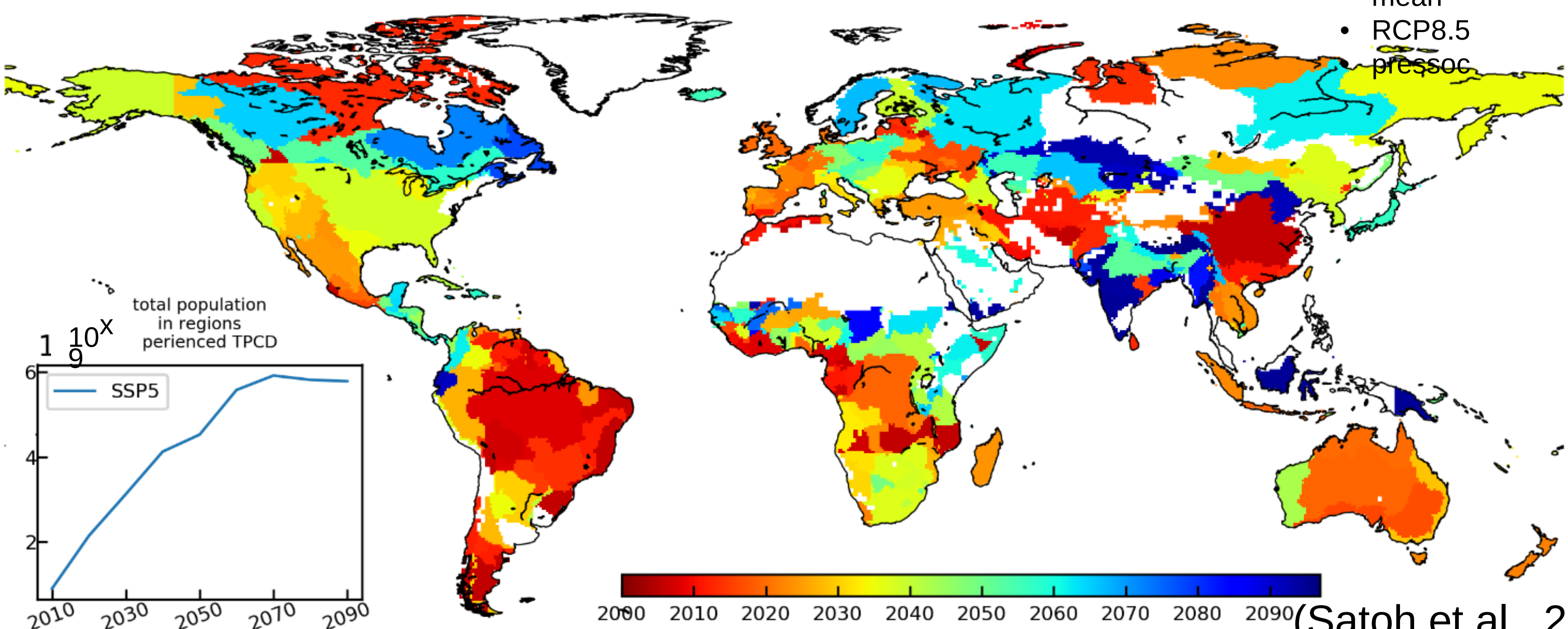


(Example)

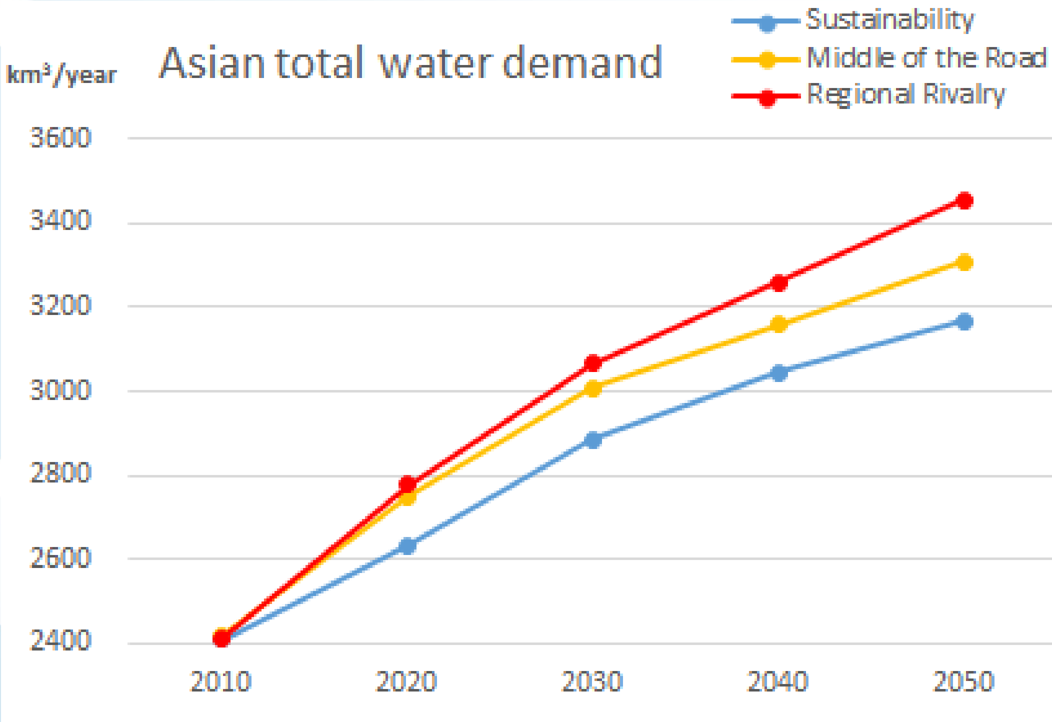
TPCD of consecutive 10 year overshoot at Basin-Country boundary scale

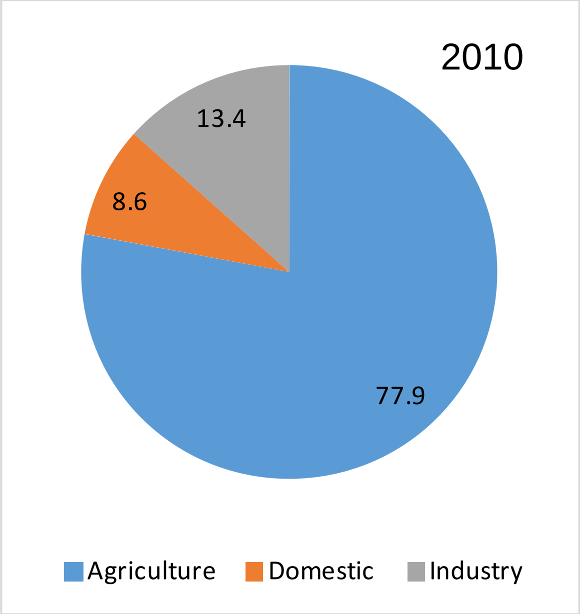
- Regional mean
- RCP8.5
- pressoc

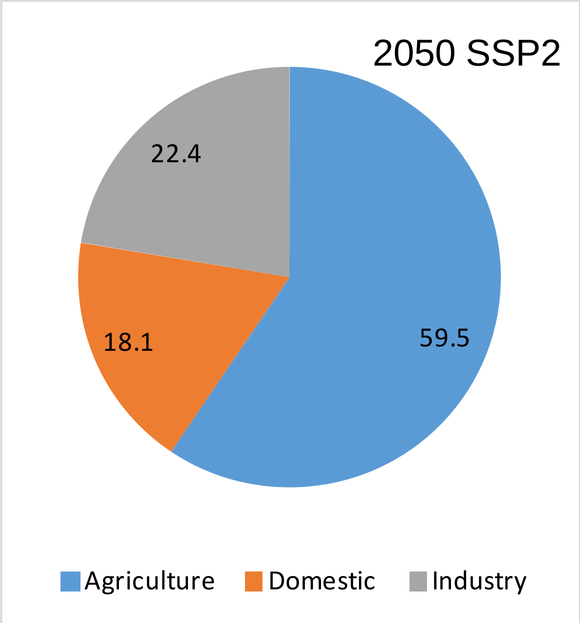


(Satoh et al., 2018)

Water Demand - Asia





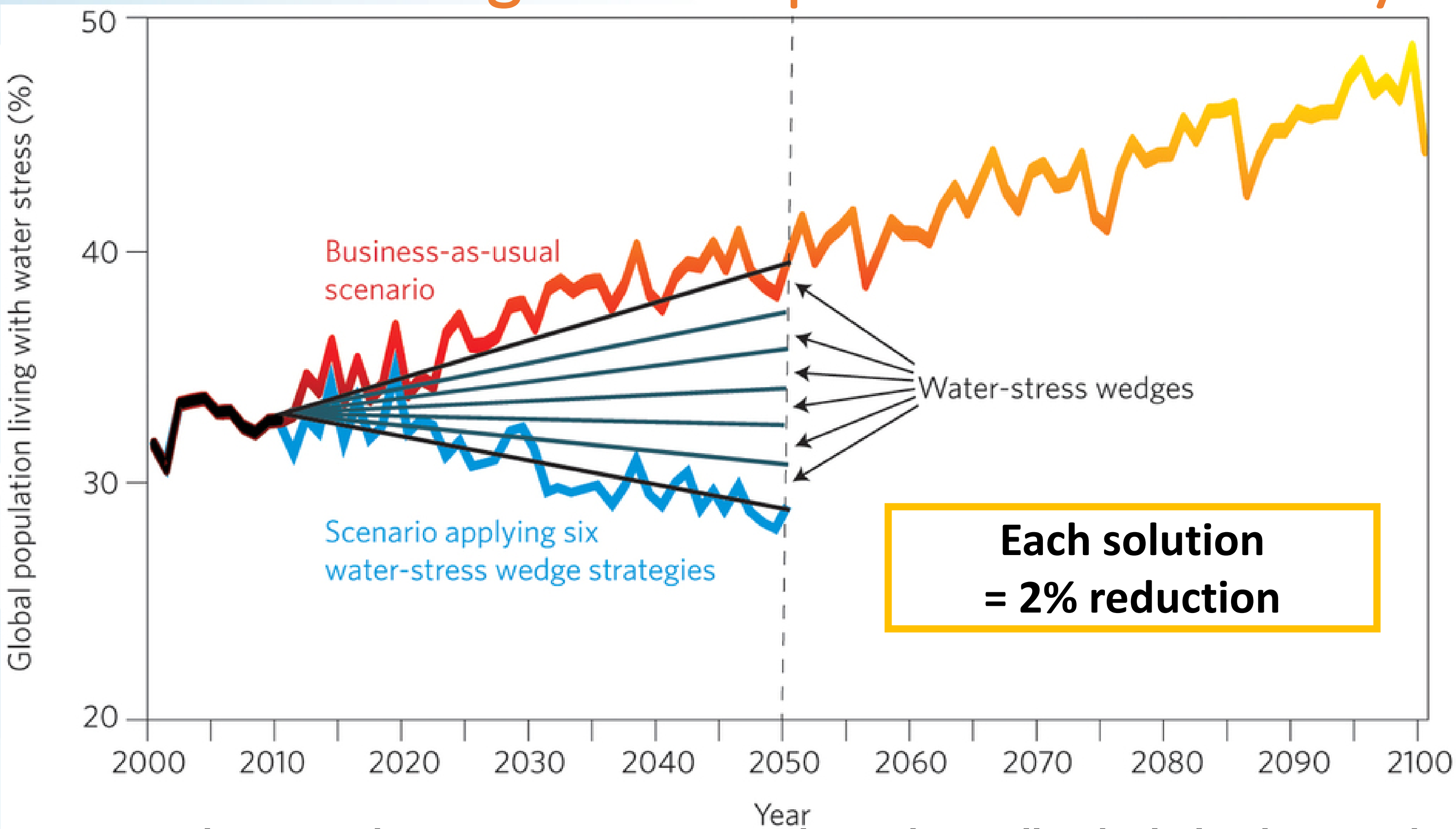


Water demand in Asia region, by sector (km^3/yr).

Asian total water demand in the 2010s is about 2410 km^3/year and will be 3170 - 3460 km^3/year (increase 30 - 40%) under the three scenarios

Satoh et al. (2017; Earth's Future)

Water Management Options and Economy?



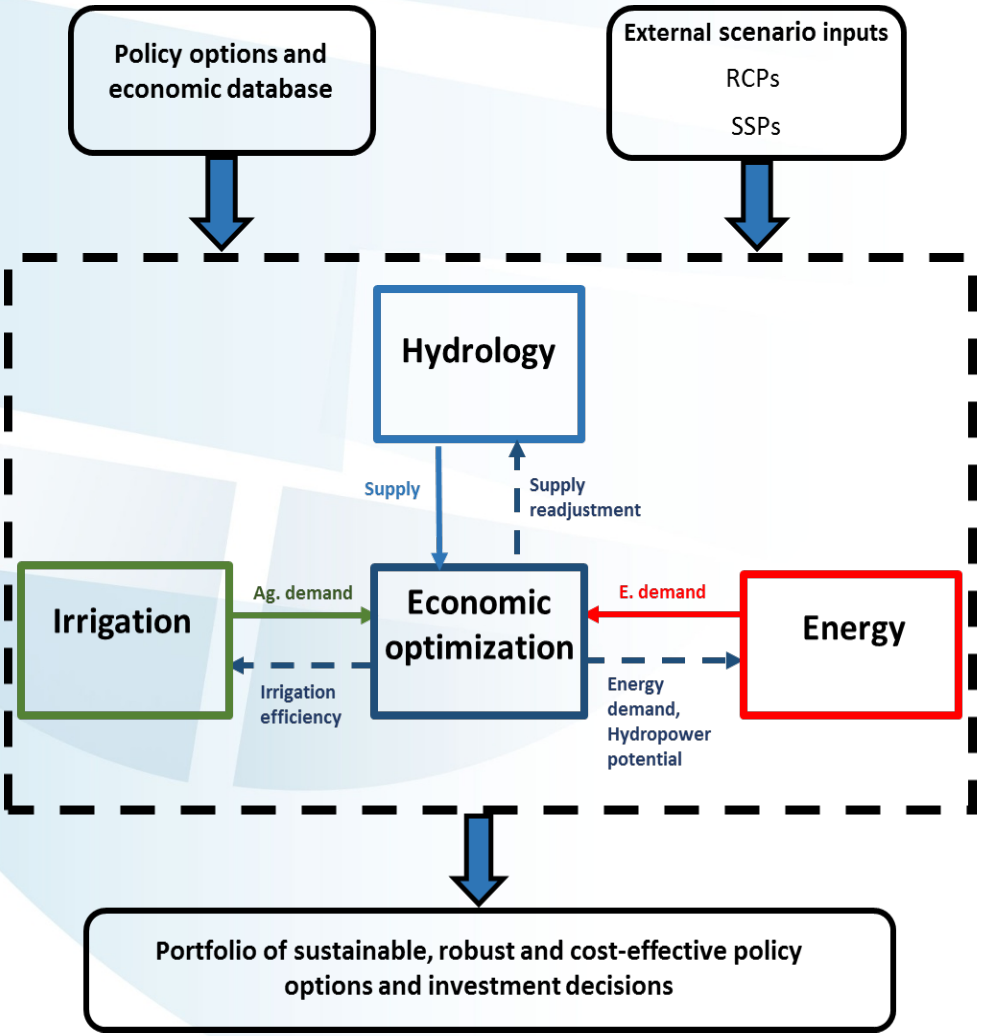
We present six strategies, or water-stress wedges, that collectively lead to a reduction in the population affected by water stress by 2050, despite an increasing population.

- **Water productivity – crop per drop**
- **Irrigation efficiency – decrease losses**
- **Water use intensity – industry and domestic**
- **Population**
- **Reservoir storage**
- **Desalination**

Soft path vs. Hard path

Wada et al. (2014), Nature Geoscience

Hydro-Economic framework for investment options



Key features represented in the model:

Drivers: Demand growth; Resource availability; Climate change; etc.

Processes: Reservoir management; Irrigation use; Electricity generation; Water pumping; End-use efficiency; Wastewater treatment; etc.

Impacts: Prices; Demands; Emissions; Water quality; Environmental flow; Groundwater depletion; Resource security; etc.

Decisions: Extract resources; Operate infrastructure; Expand infrastructure; Trade resources

(Kahil et al., 2018)

Assessment of adaptation measures: technical potential and costs

Supply enhancement	Demand management
▪ Build/enlarge dams ▪ Rainwater harvesting ▪ Drill/improve wells ▪ Reuse of wastewater ▪ Desalination ▪ Reprogram reservoir operation ▪ Inter-basin transfer	▪ Efficient irrigation technologies ▪ Efficient domestic water appliances ▪ Energy cooling technologies ▪ Better crop management ▪ Diet change ▪ Food loss reduction ▪ Improving education ▪ Controlling population growth

Model application: the case of Africa

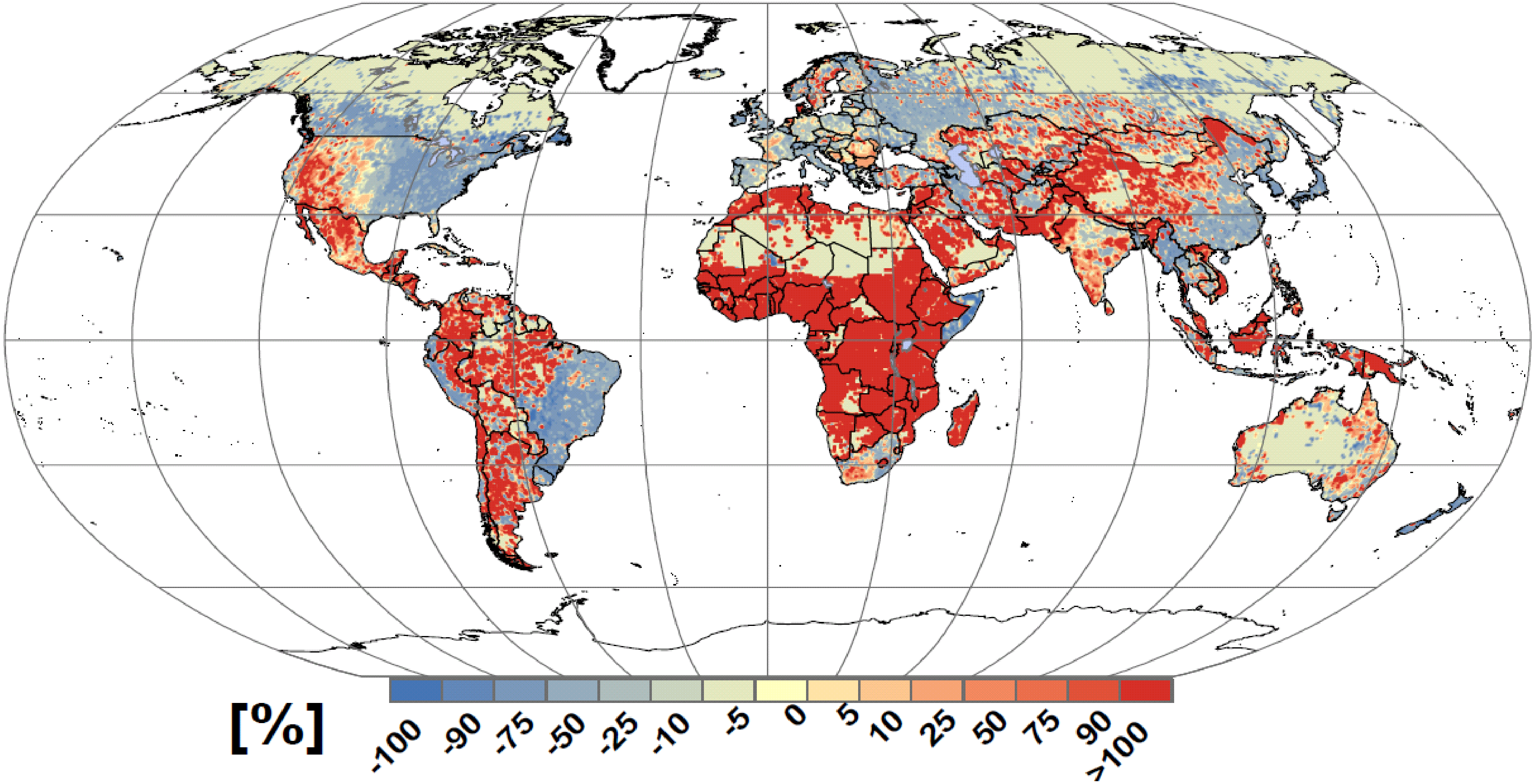
Three socio-economic and climatic scenarios:

1/ Middle of the Road (***MoR***): SSP2-RCP6.0

2/ Regional Rivalry **(*RR*)**: Water demand increases over time in all water sectors and water availability decreases, compared to *MoR.*

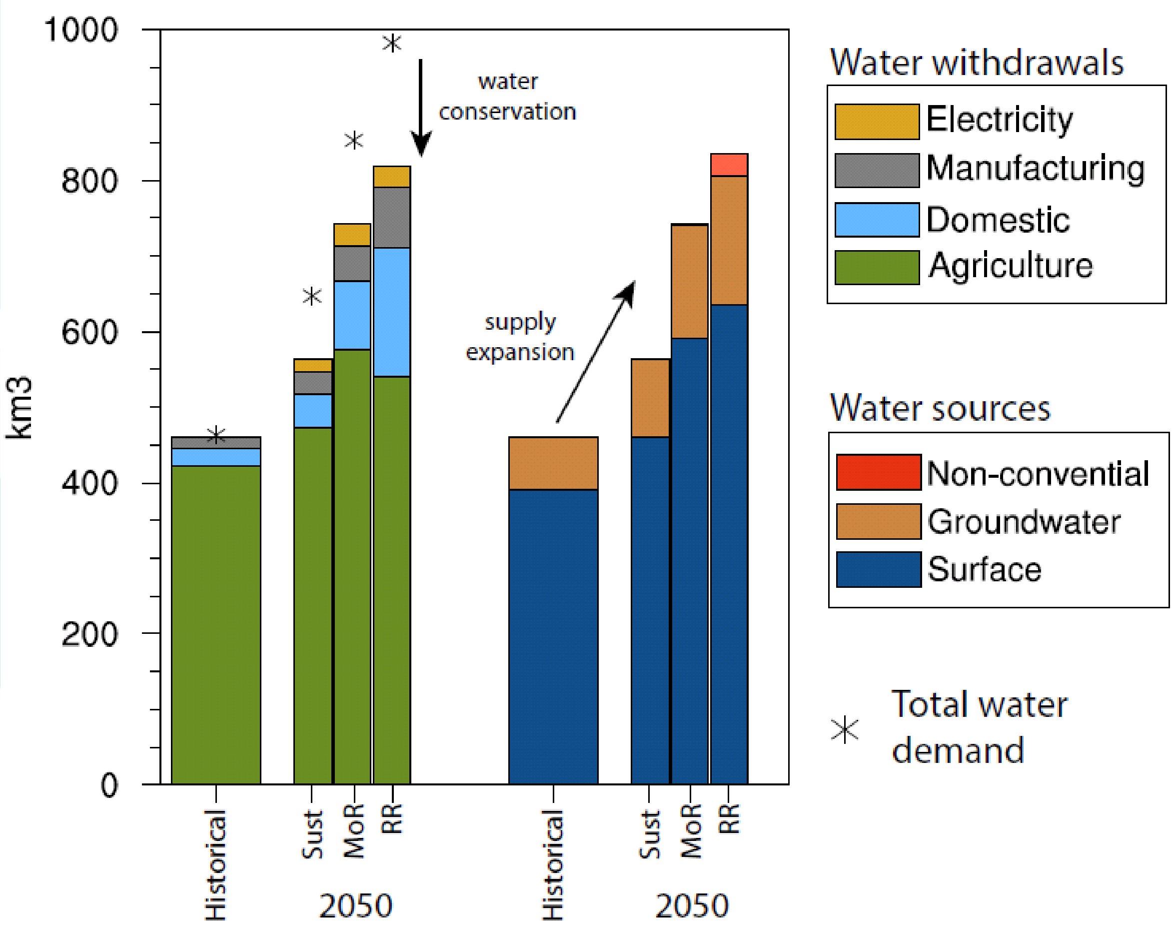
3/ Sustainability **(Sust)**: Water demand decreases over time in all water sectors and water availability increases, compared to *MoR*.

Relative change in human water use (SSP2)



2100 – 2010

Results: Water demand and withdrawals
Water supply

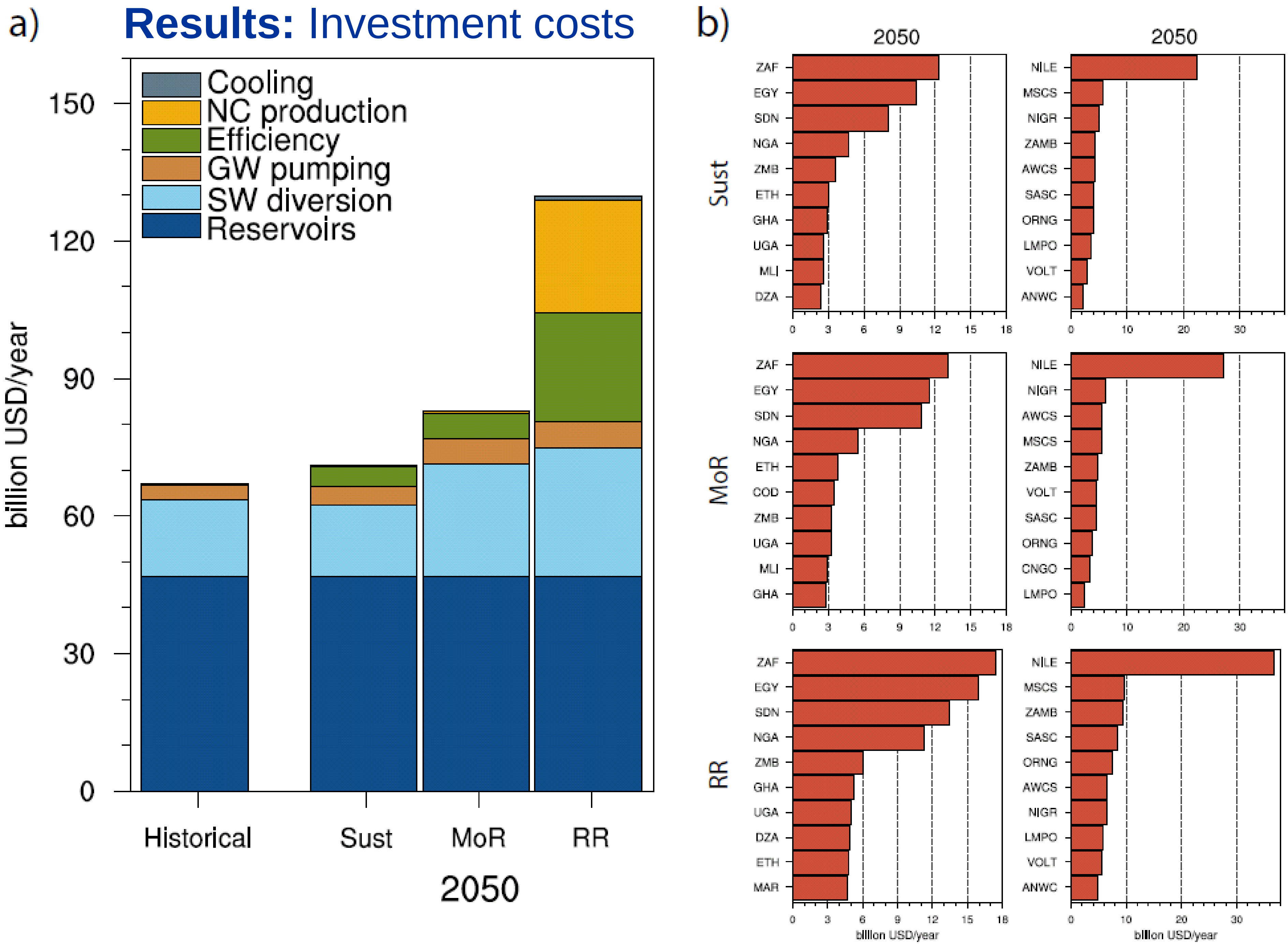


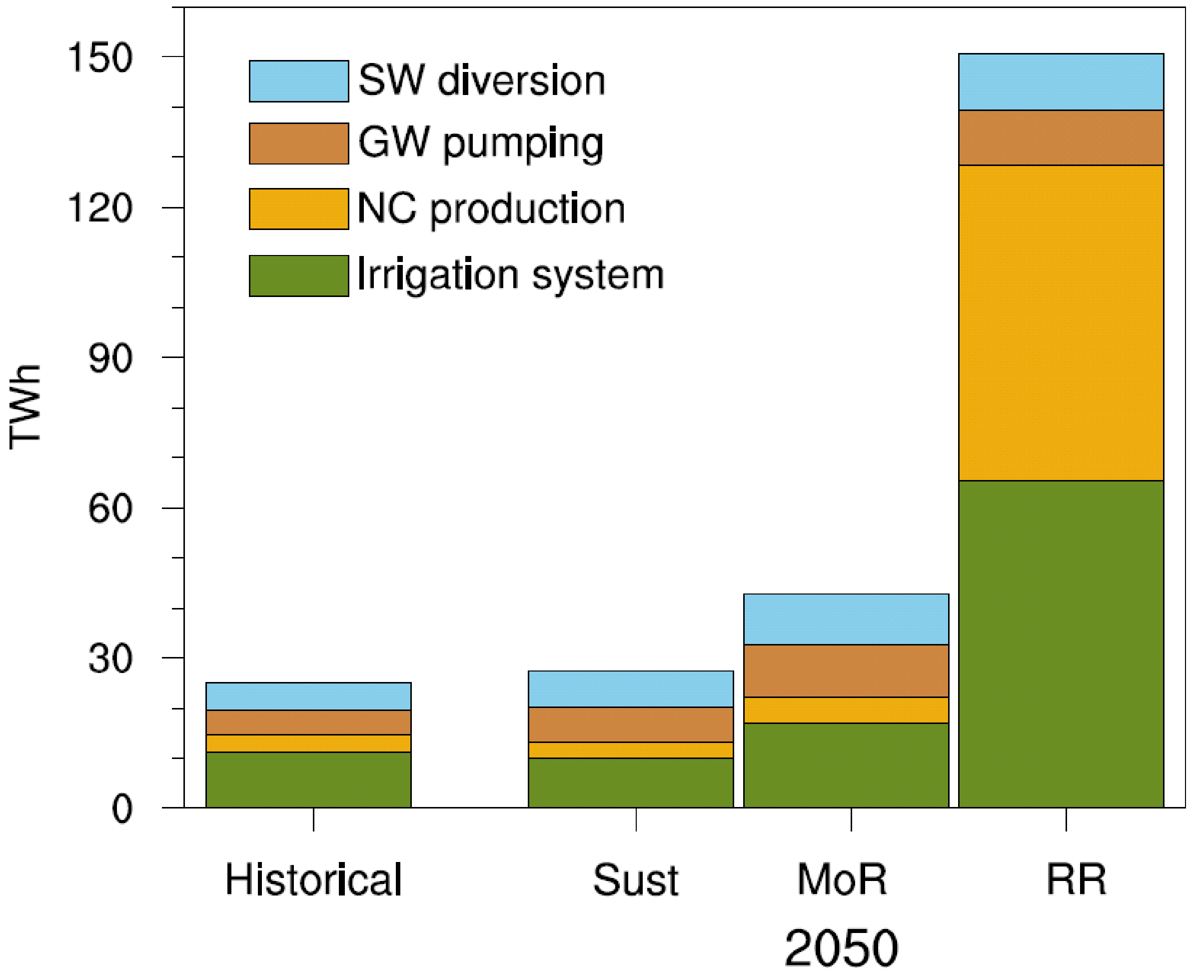
Total water demand increases in 2050 by 190-520 Km^3 (40-110%) compared to historical demand

This increase requires the implementation of demand and supply management options to balance available supply and demand

After implementing demand management options, withdrawals increase in 2050 by 100-360 Km^3 compared to historical withdrawals

Results: Investment costs





Adaptation of the water resource system to future socio-economic and climatic changes may involve tradeoffs among various environmental and economic objectives

Some of the identified adaptation options may be inconsistent with climate change mitigation targets because they involve high energy consumption, such as desalination, recycling, pumping, and pressurized irrigation systems

Our findings highlight that electricity use in the water sector can increase five-fold (or by 125 TWh) by 2050 compared to 2010 in the *RR scenario*

Results: Energy use intensity

Results: Cost implications

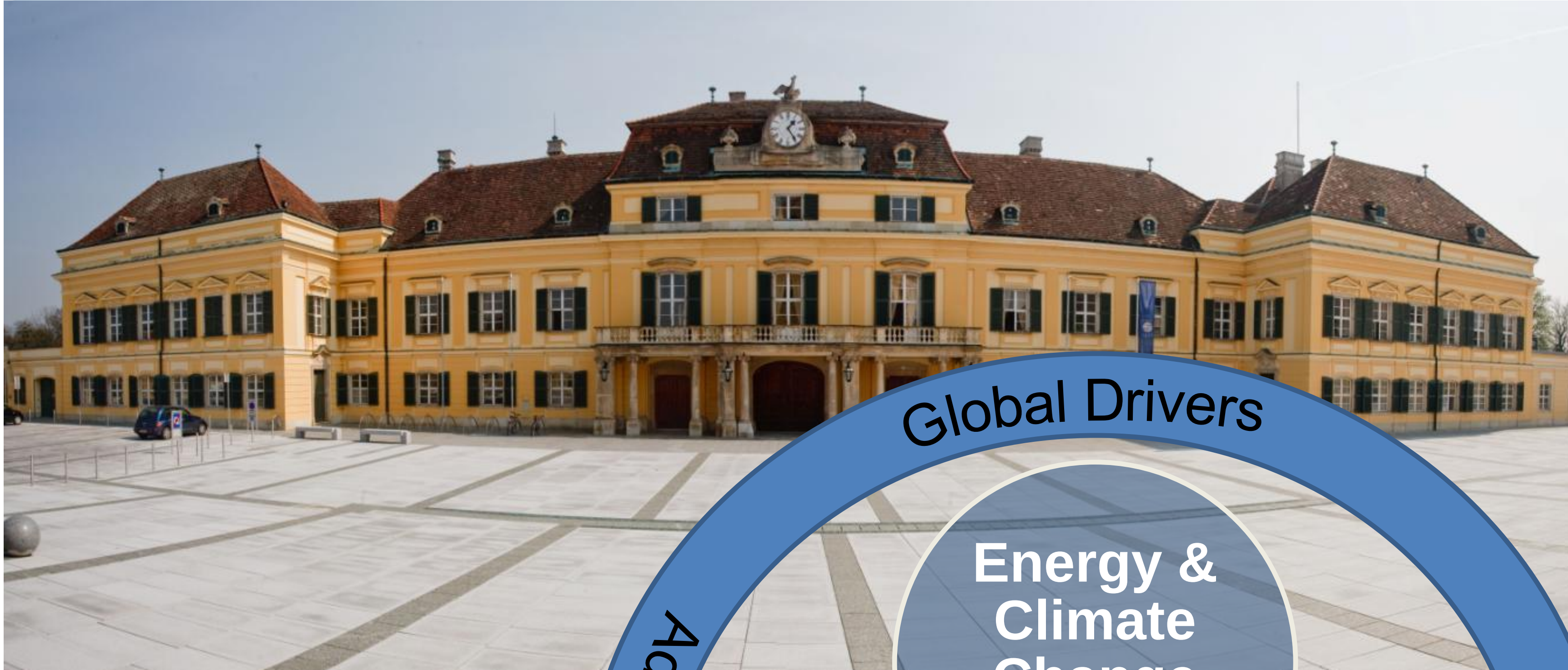
Building reservoirs is a practical solution for water supply and adapting hydrological variability but a costly option. Increase in the use of seawater cooling in coastal basins

Water system cost in Africa is expected to increase from 67 billion USD in 2010 to 70-130 billion USD in 2050 (+5 - +100% compared to 2010)

Following a sustainable pathway *(Sust scenario*) will result in a smooth increase in the water system cost while following the rocky road (RR scenario) will result in a disproportionate increase in the water system cost

The largest cost by country is in South Africa, followed by Egypt and Sudan, and by basin is in the Nile, Mediterranean South Coast, Niger and Zambezi

Adaptive strategies for hydrological variability need consideration for energy use (e.g., hydropower) and food production



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