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science for global insight

Towards Integrated Solutions for Water, Energy, and Land using an Integrated Nexus Modeling Framework

Yoshihide Wada

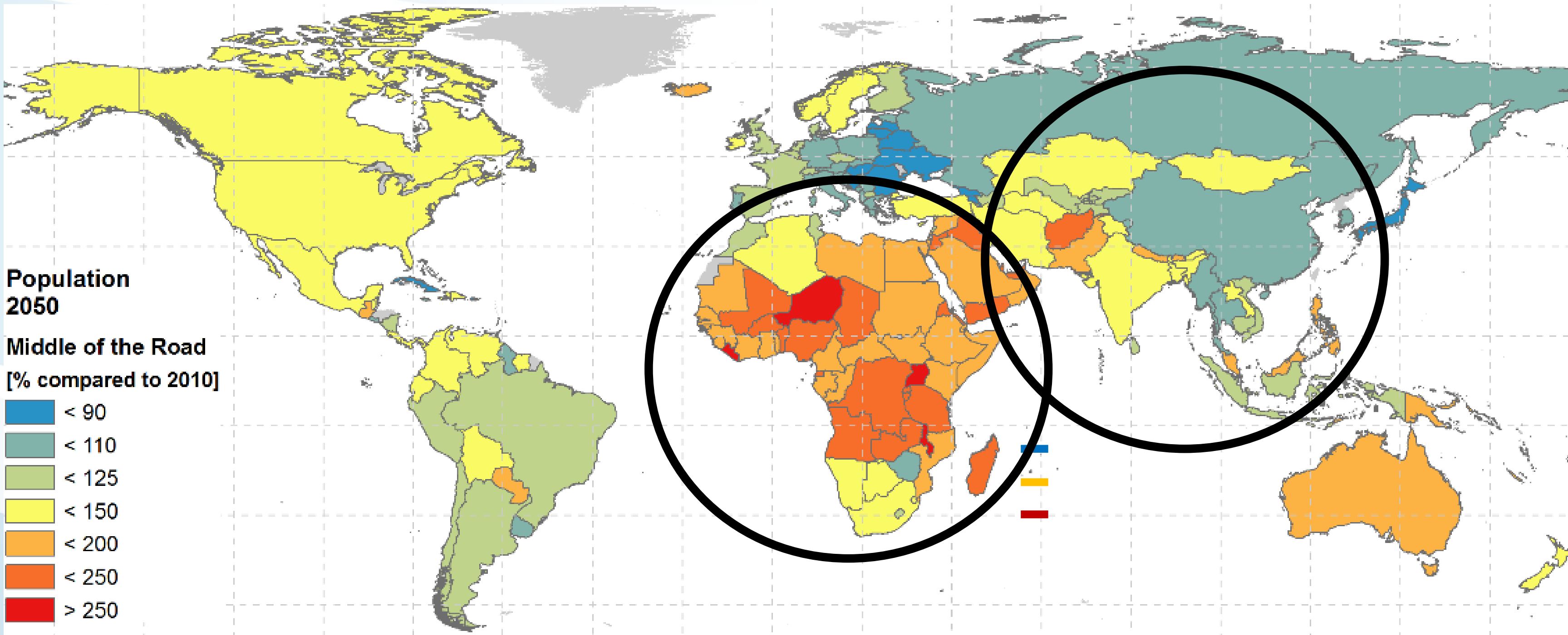
Deputy Director of Water Program, IIASA

wada@iiasa.ac.at

RIHN 12th International Symposium
Trans-scale Solutions for Sustainability

Kyoto International Conference Center, Kyoto, Japan
December 20 - 21, 2017

Population and Development Continues



Middle of the Road scenario

- 33% more people by 2050 compared to 2010 globally (6.8 billion to 9.1 billion)

Population in [billion]
GDP [1000 billion US$/yr]
GDP per cap (PPP) in [1000US$/cap/yr

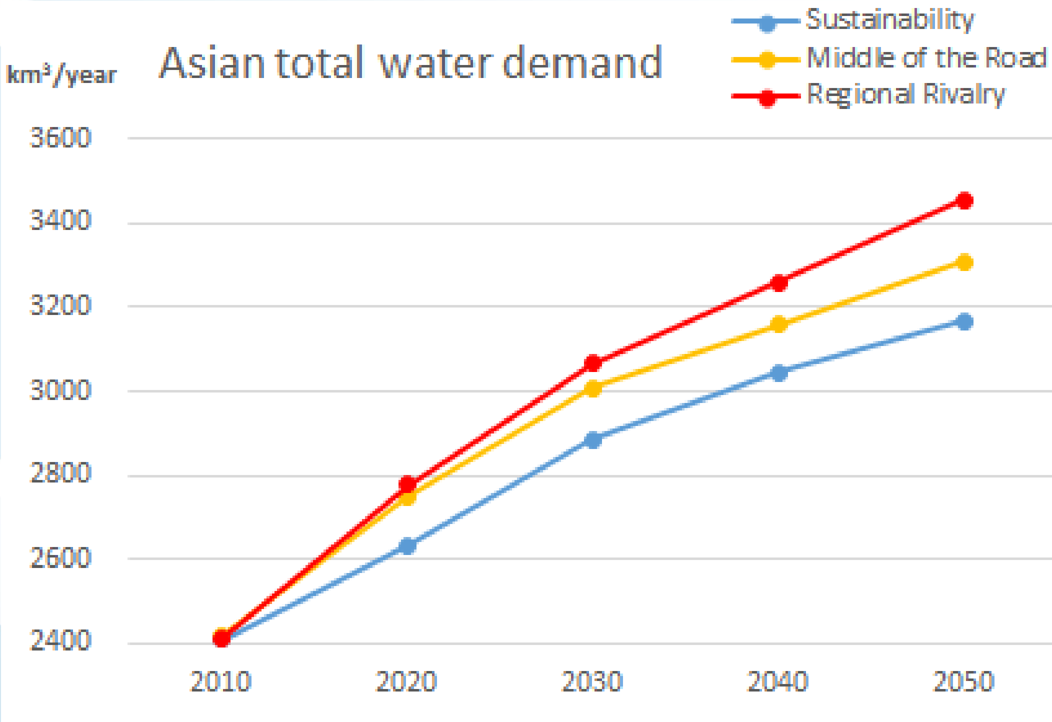
Africa

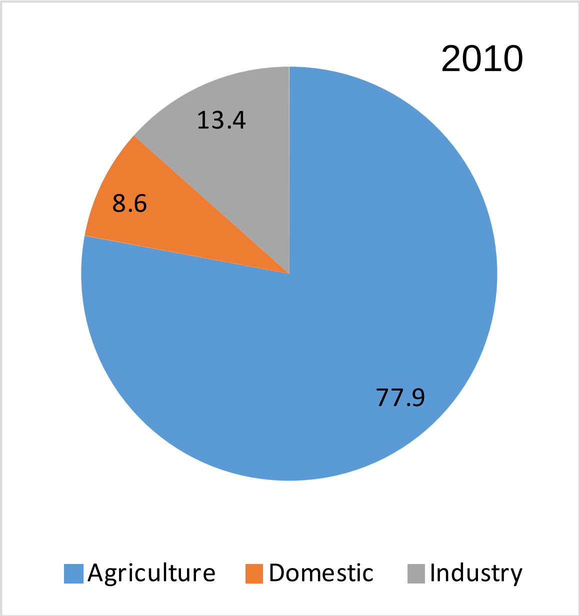
Pop:	1.0 to 2.0	2 times more
GDP:	2.8 to 19.2	7 times more
GDP pc:	2.7 to 9.5	3.5 times more

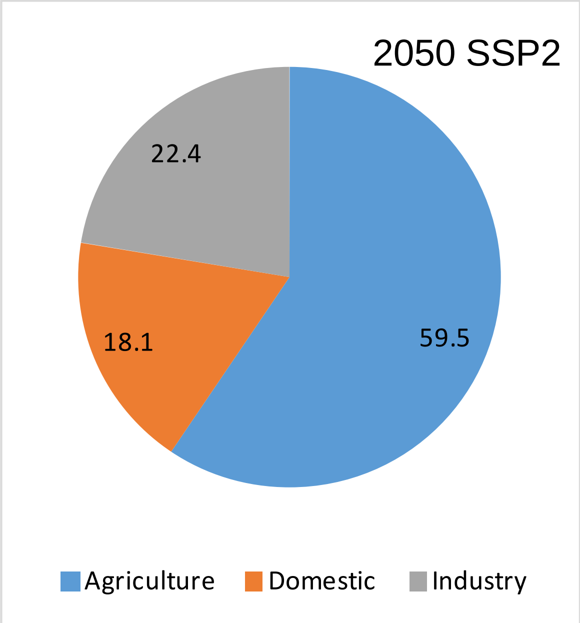
Asia

Pop:	4.1 to 5.1	1.3 times more
GDP:	26 to 123	5 times more
GDP pc:	6.2 to 24.1	4 times more

Water Demand - Asia





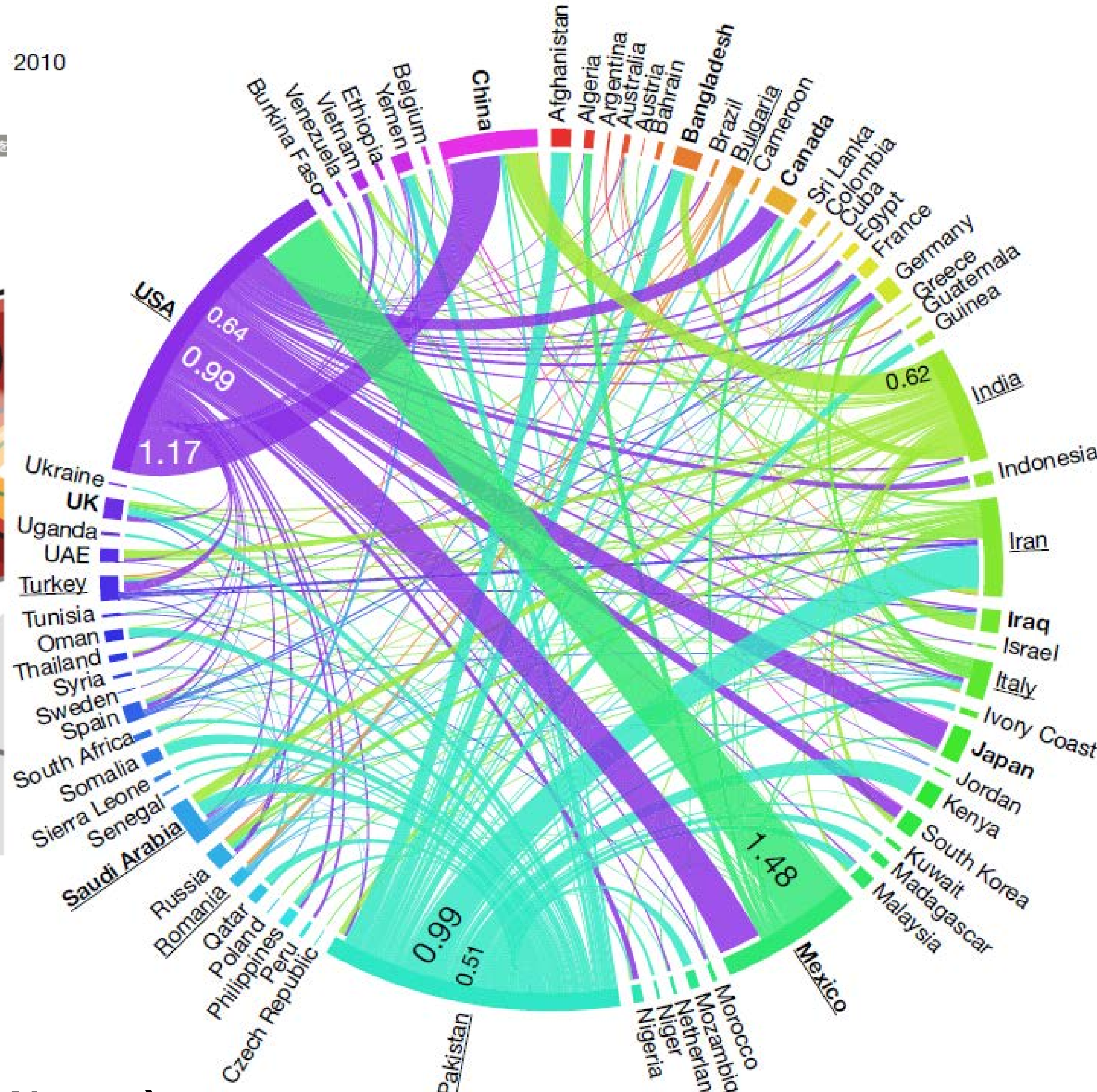


Water demand in Asia region, by sector (km^3/yr).

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

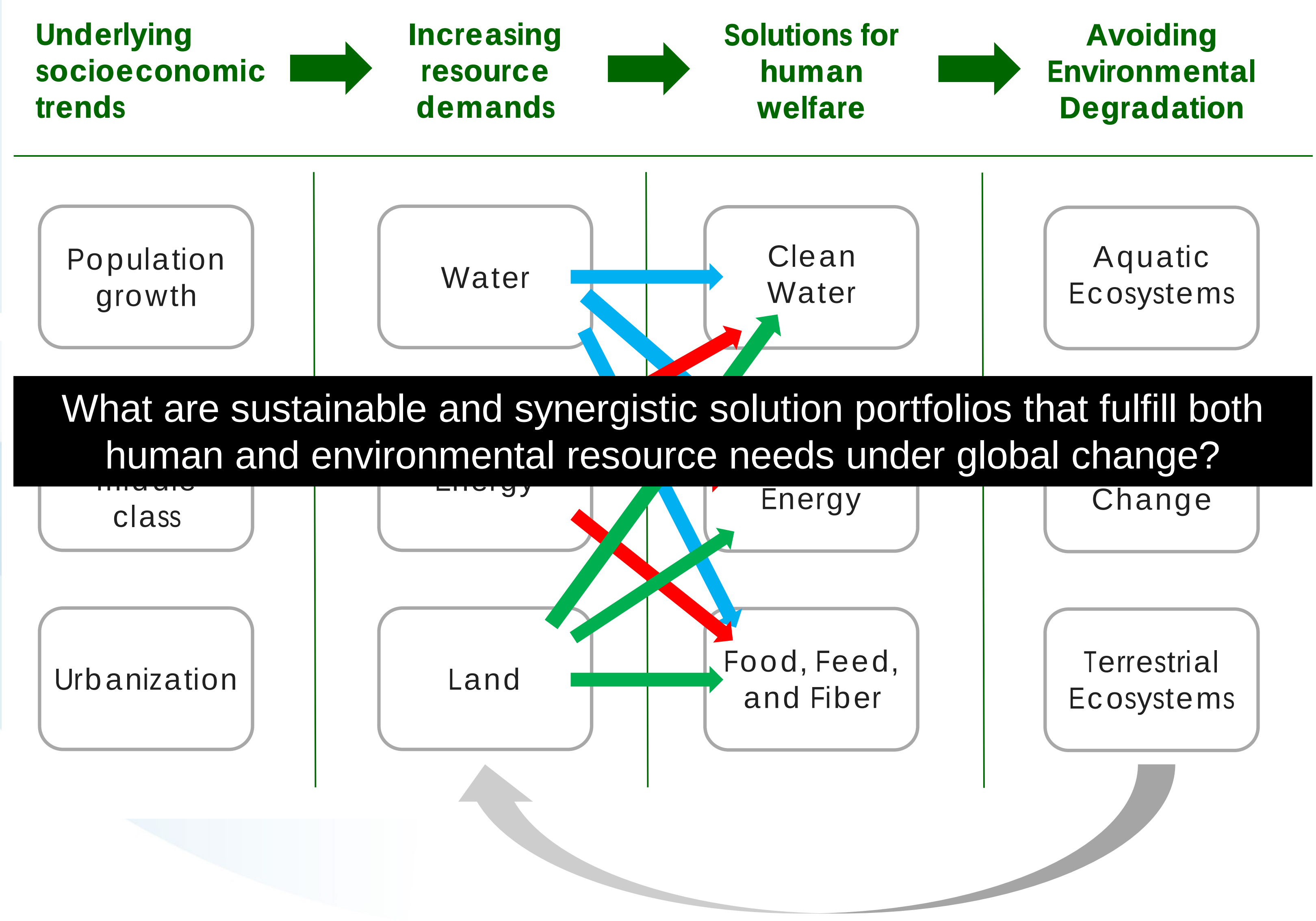
Satoh et al. (2017; Earth's Future)

UN SDGs and Water-Food-Energy Nexus

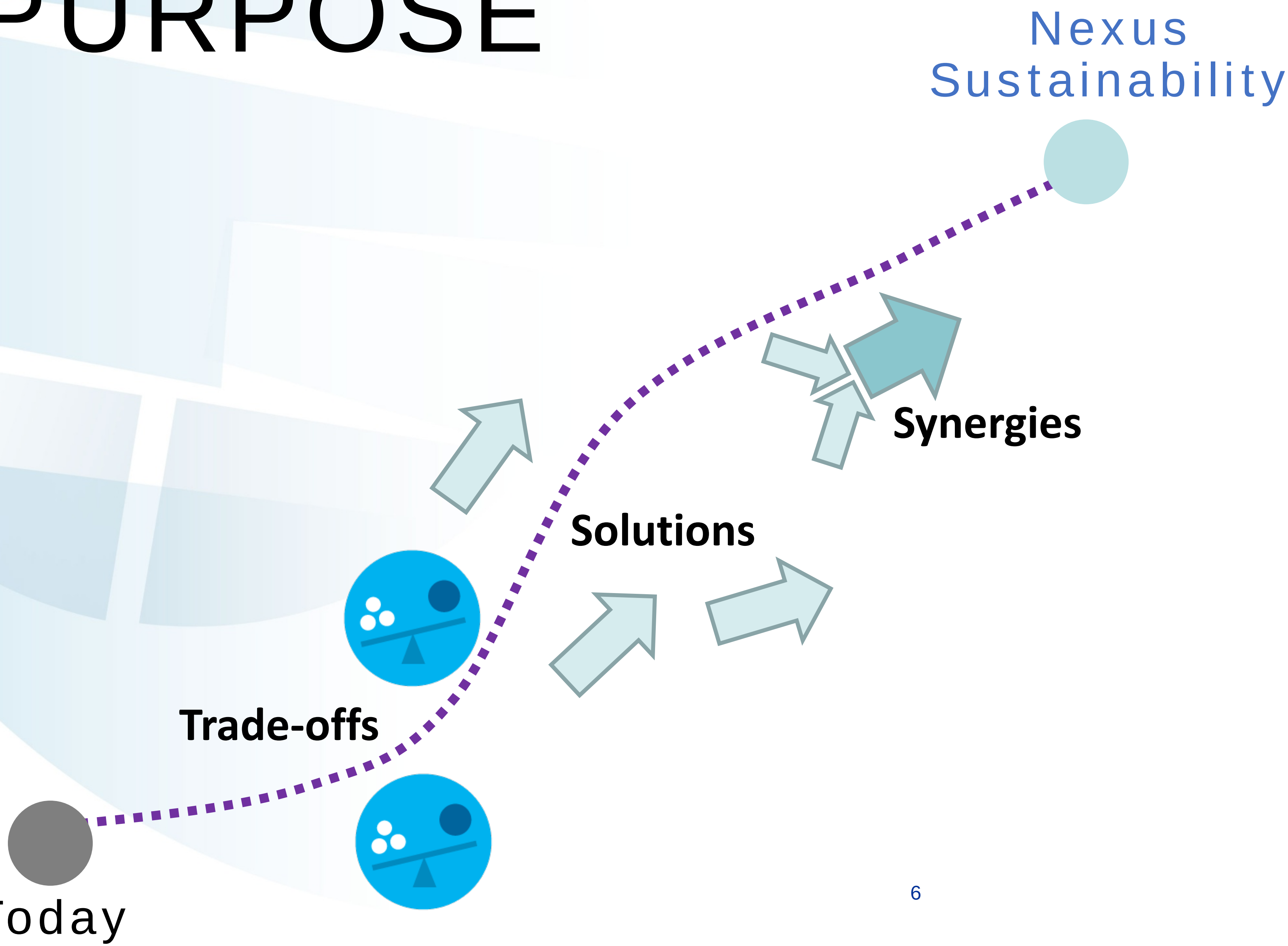


Dalin, Wada et al. (2017; Nature)

The Nexus Challenge

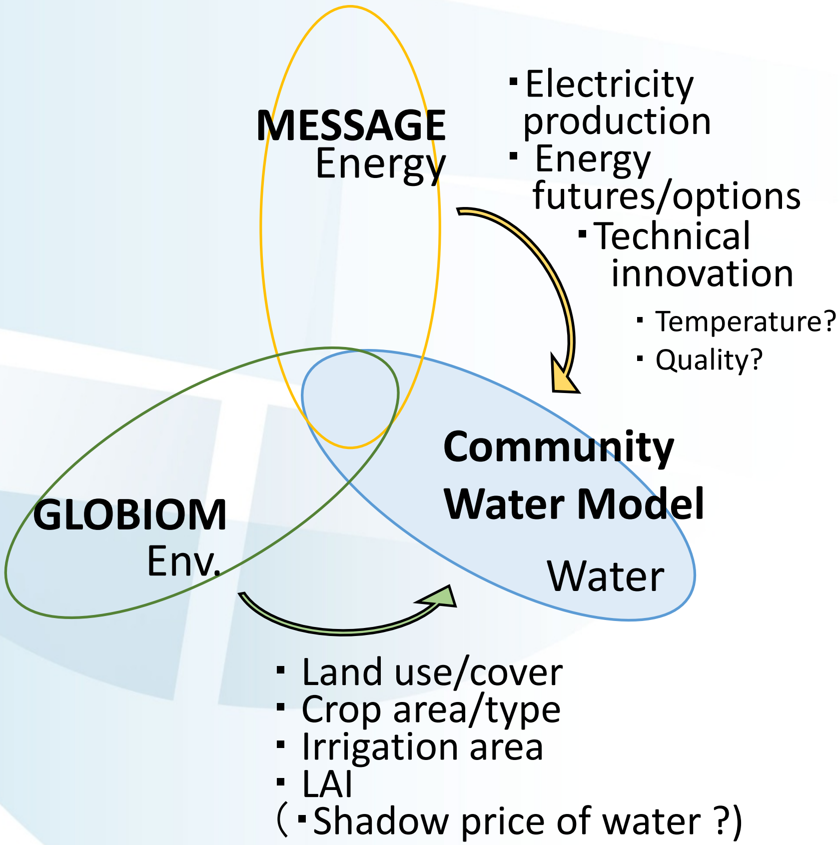


PURPOSE

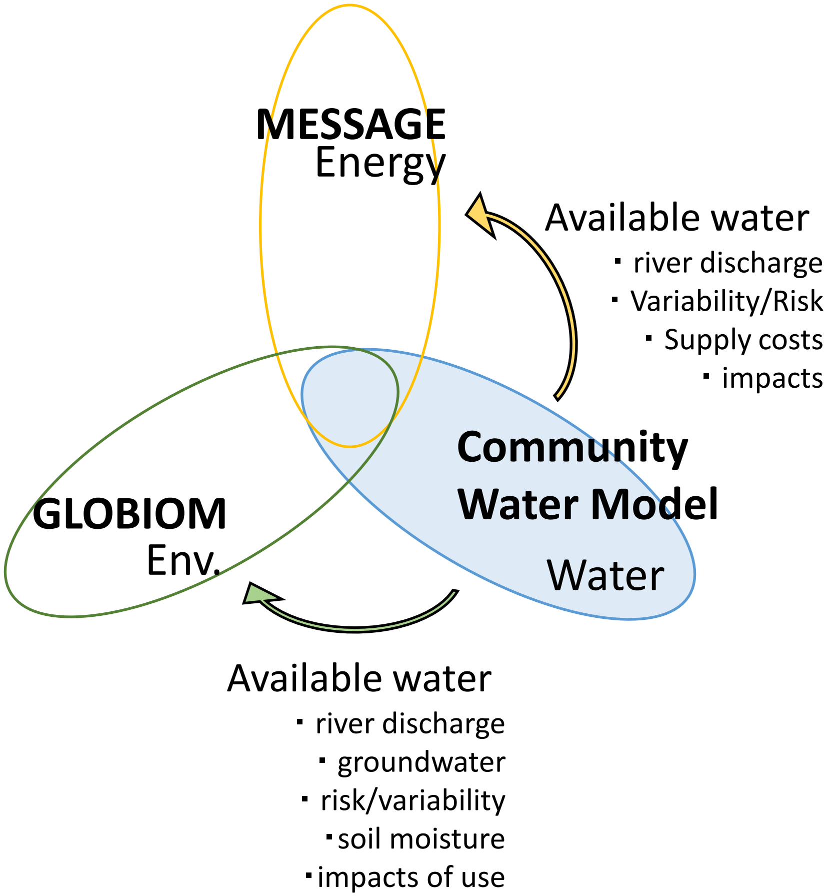

Nexus
Sustainability
Synergies
Solutions
Trade-offs
Today

Nexus Integration towards SDGs

Enhanced water assessments

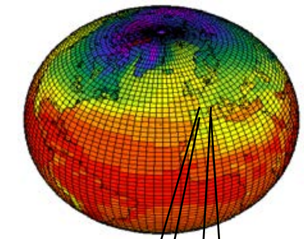


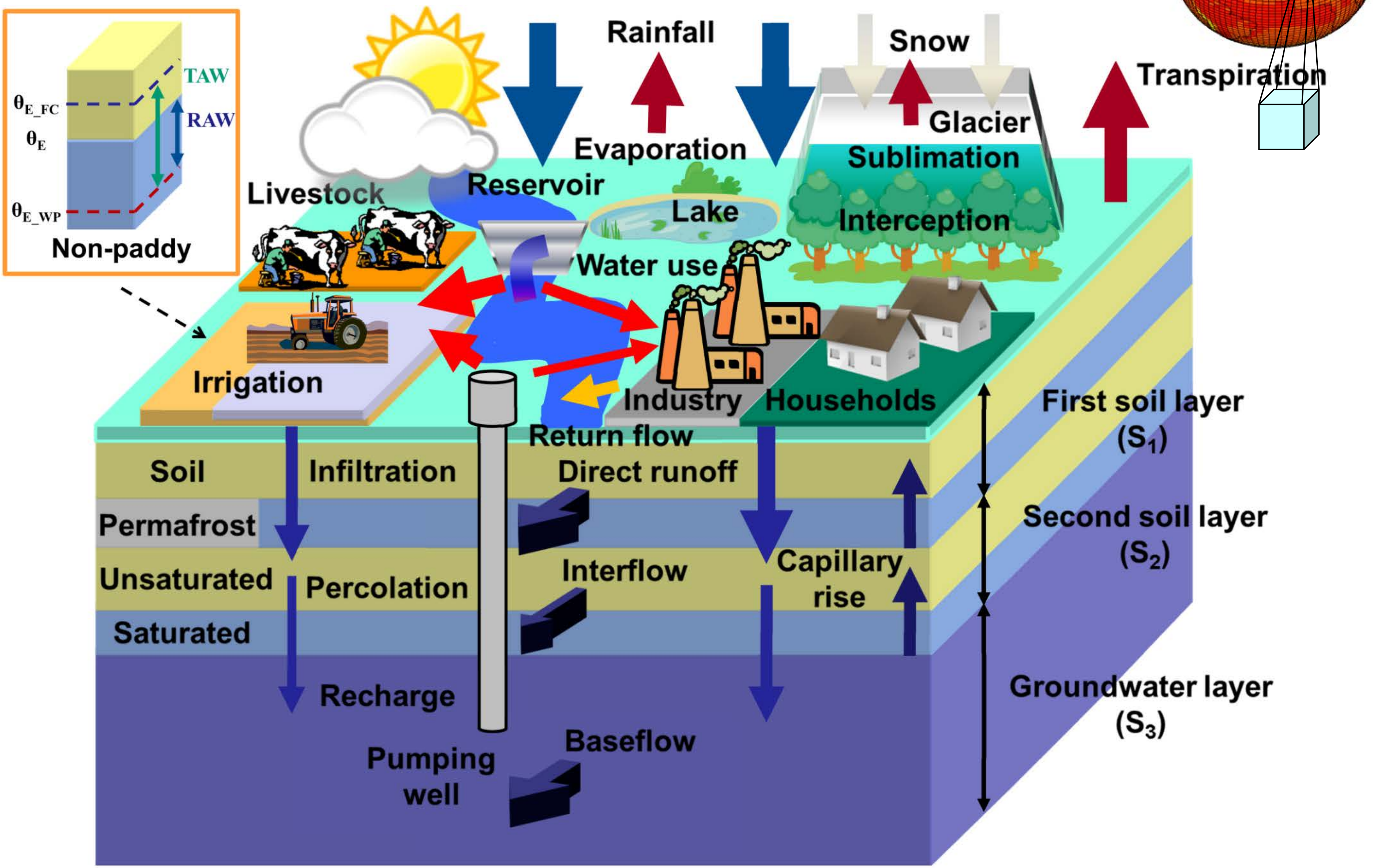
Improved analysis feedbacks



Innovative Resource Analysis

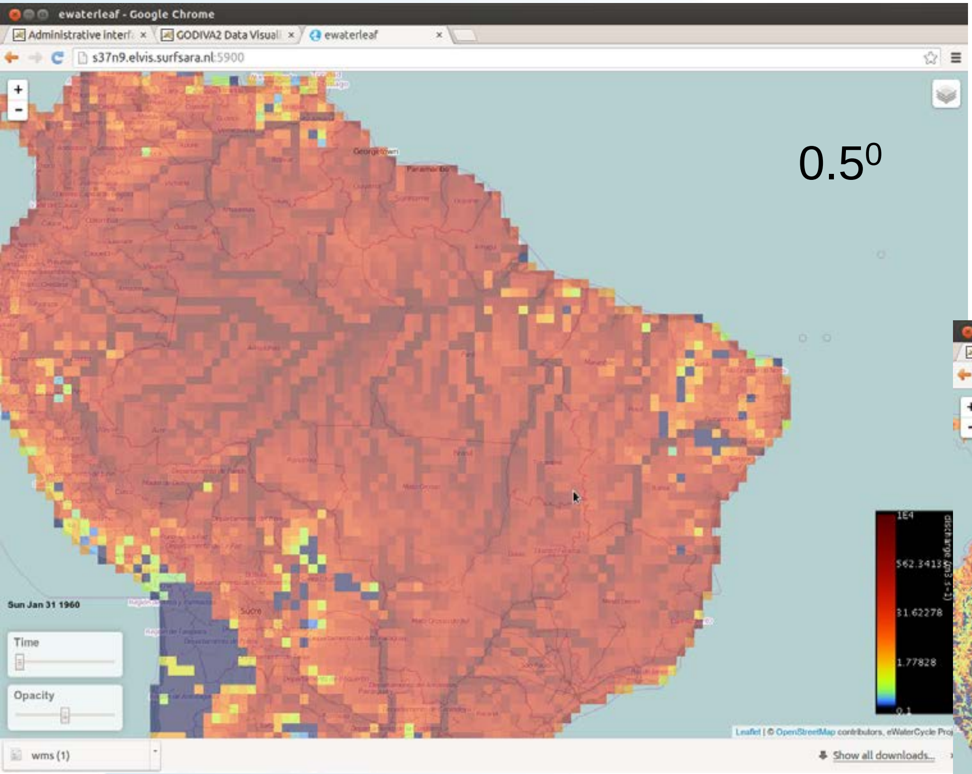
IIASA Community Water Model



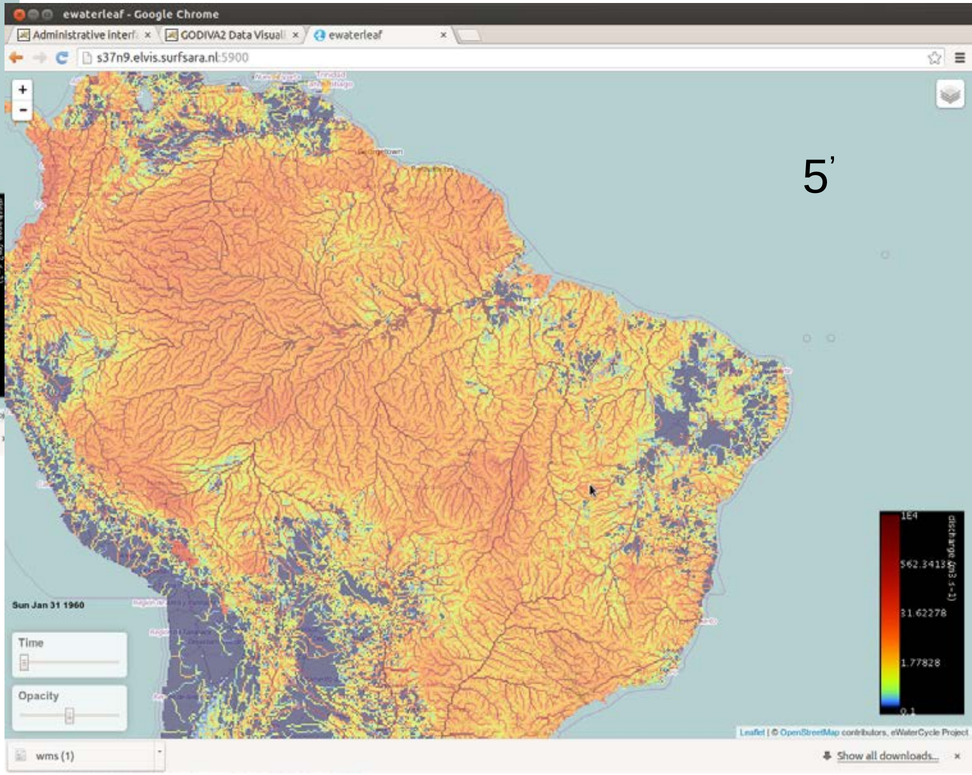


Innovative water supply analysis

High resolution hydrological modeling with local calibration

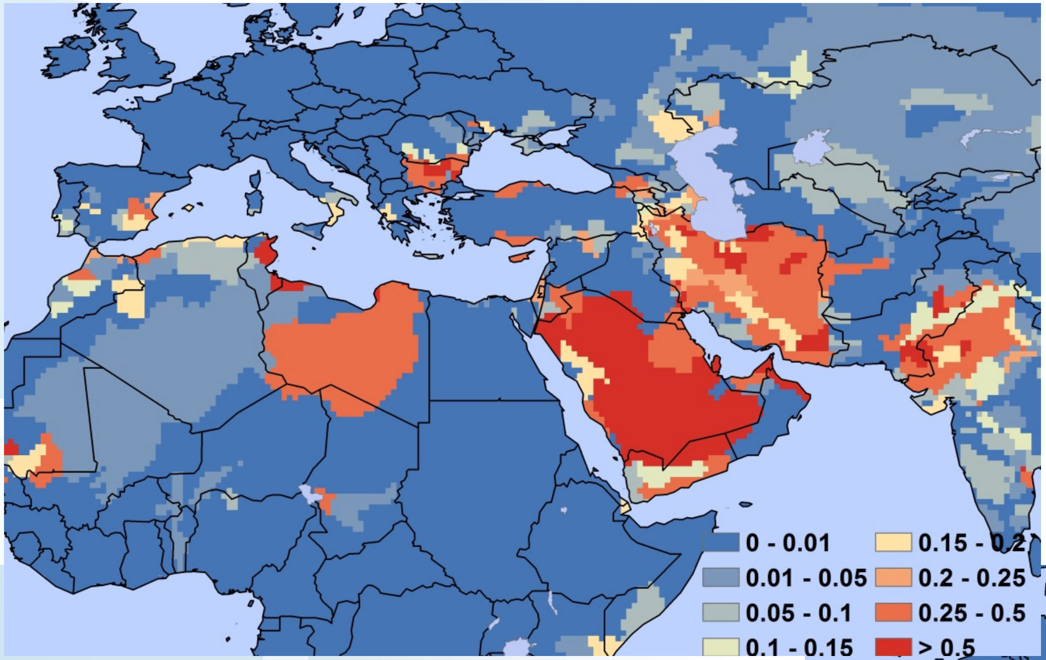


0.5⁰

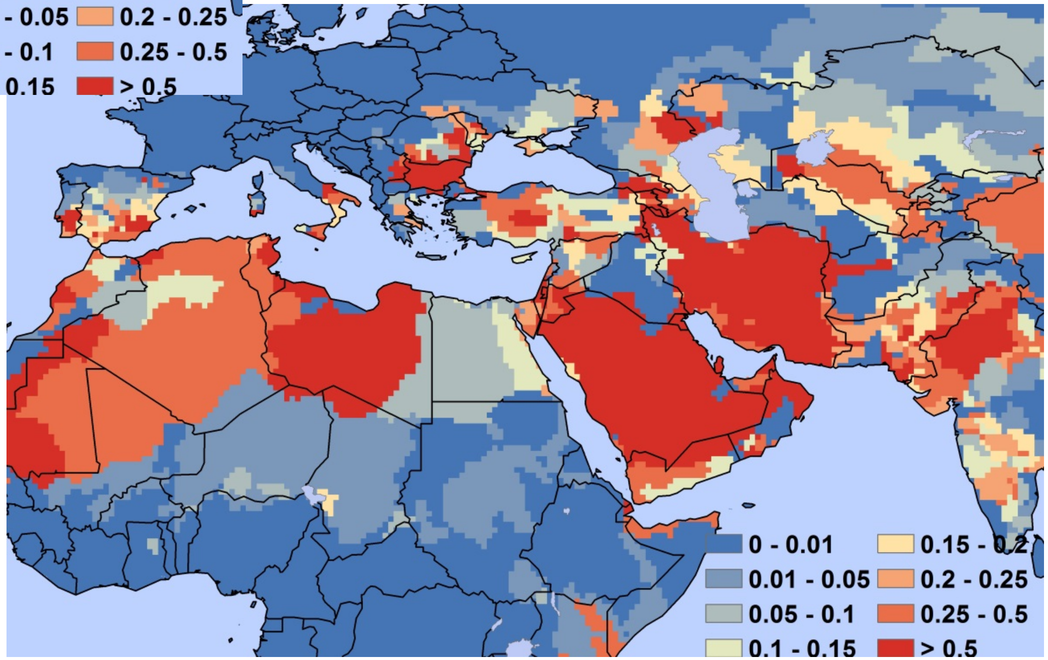


5'

Future Groundwater Sustainability – how much pumping unsustainable [Fraction; 0.5 = 50%]



Current (left)
vs
Future SSP2 with Climate Change (below)



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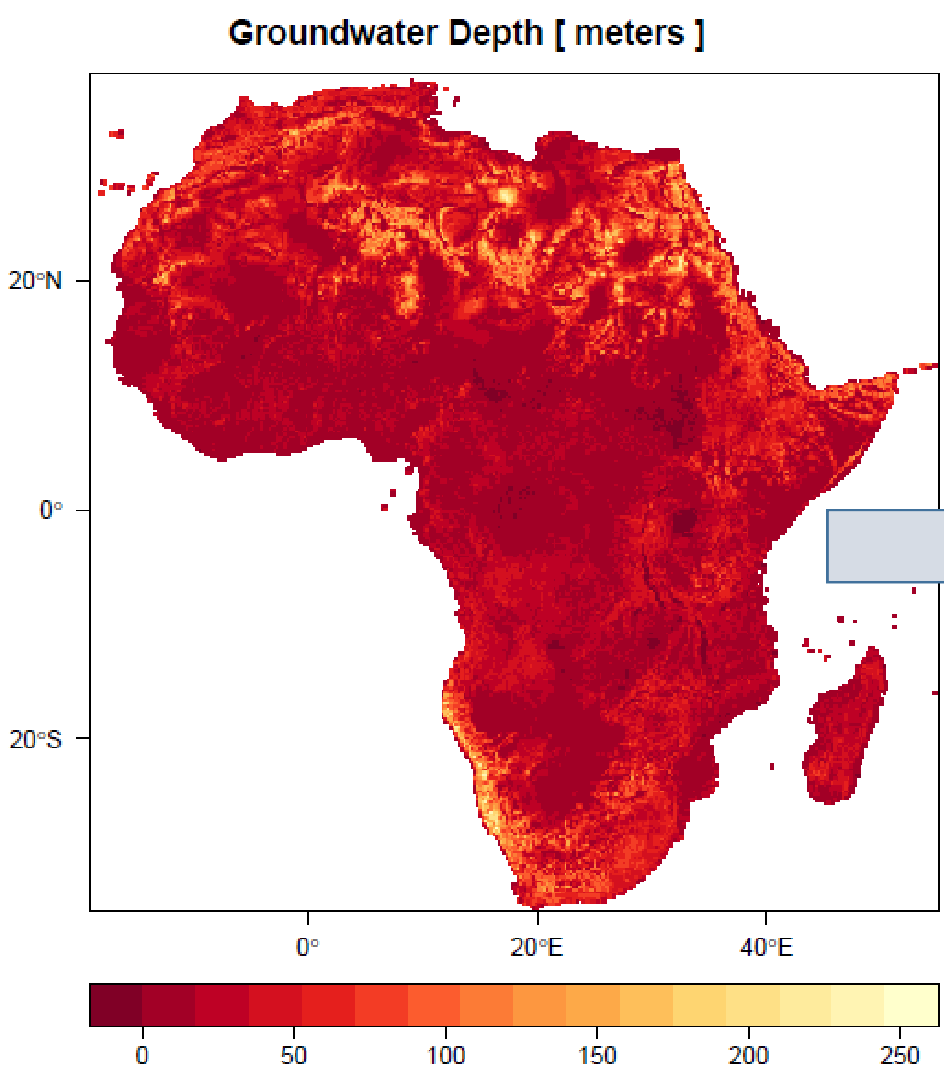
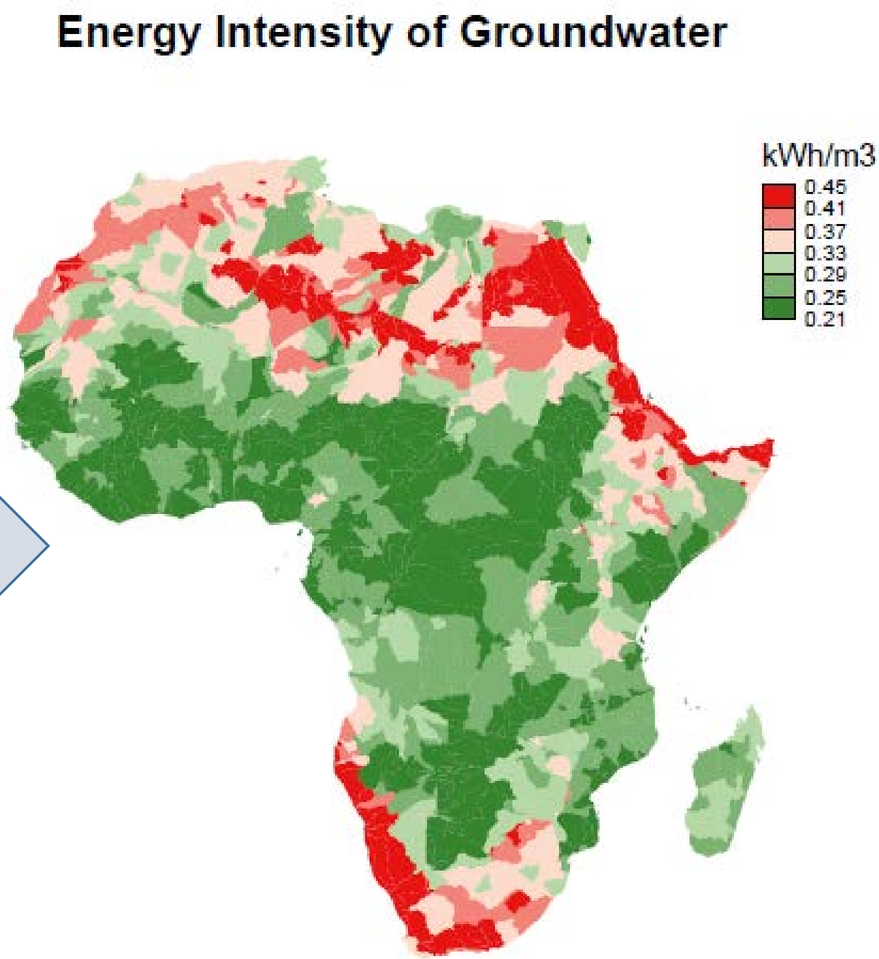
Energy intensity of water supply options

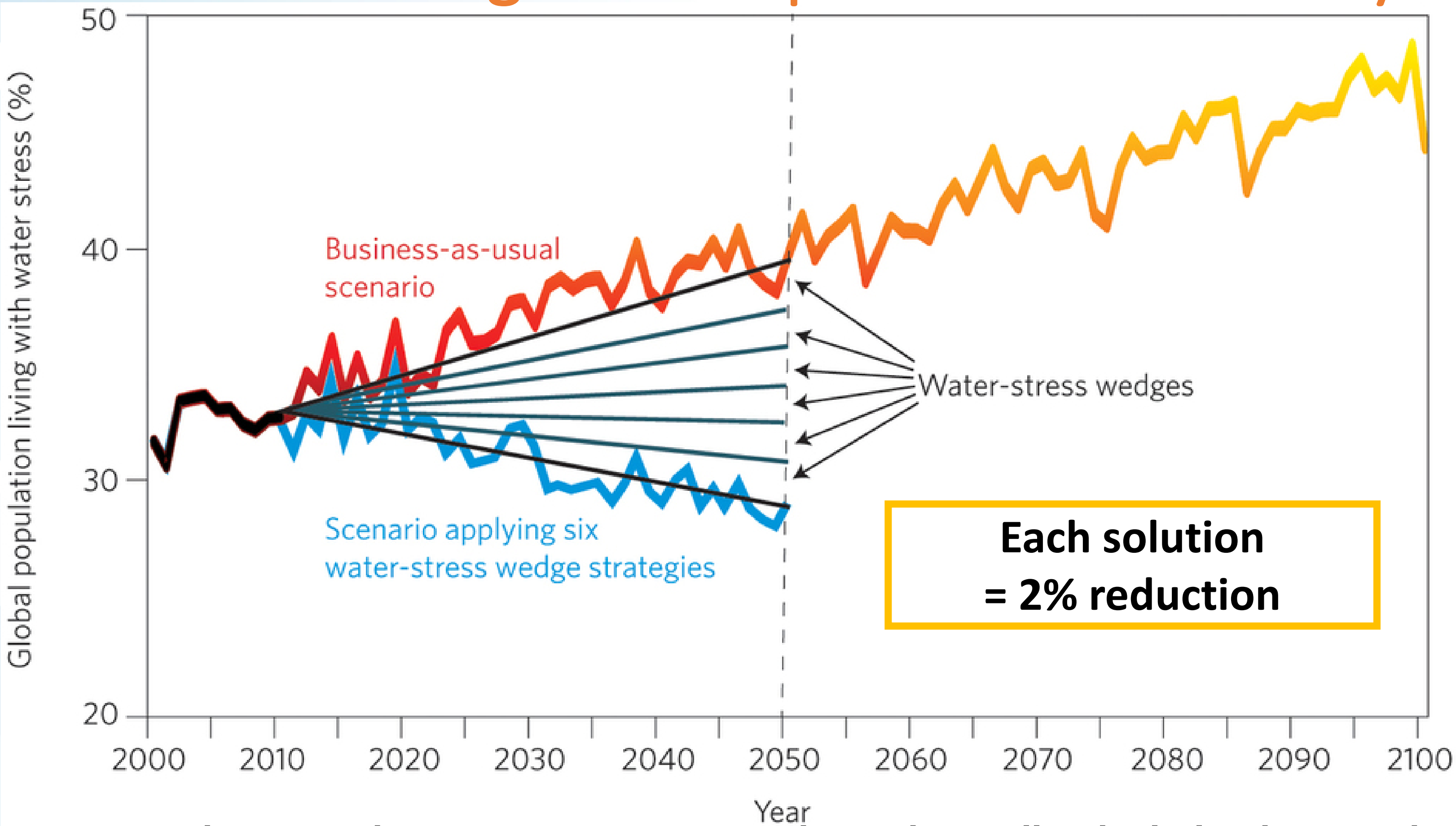




Preliminary results

Data sources: Fan et al. (2013); Wada et al. 2014; hydroBASINS (2015).

Water Management Options and Economy?



Each solution
= 2% reduction

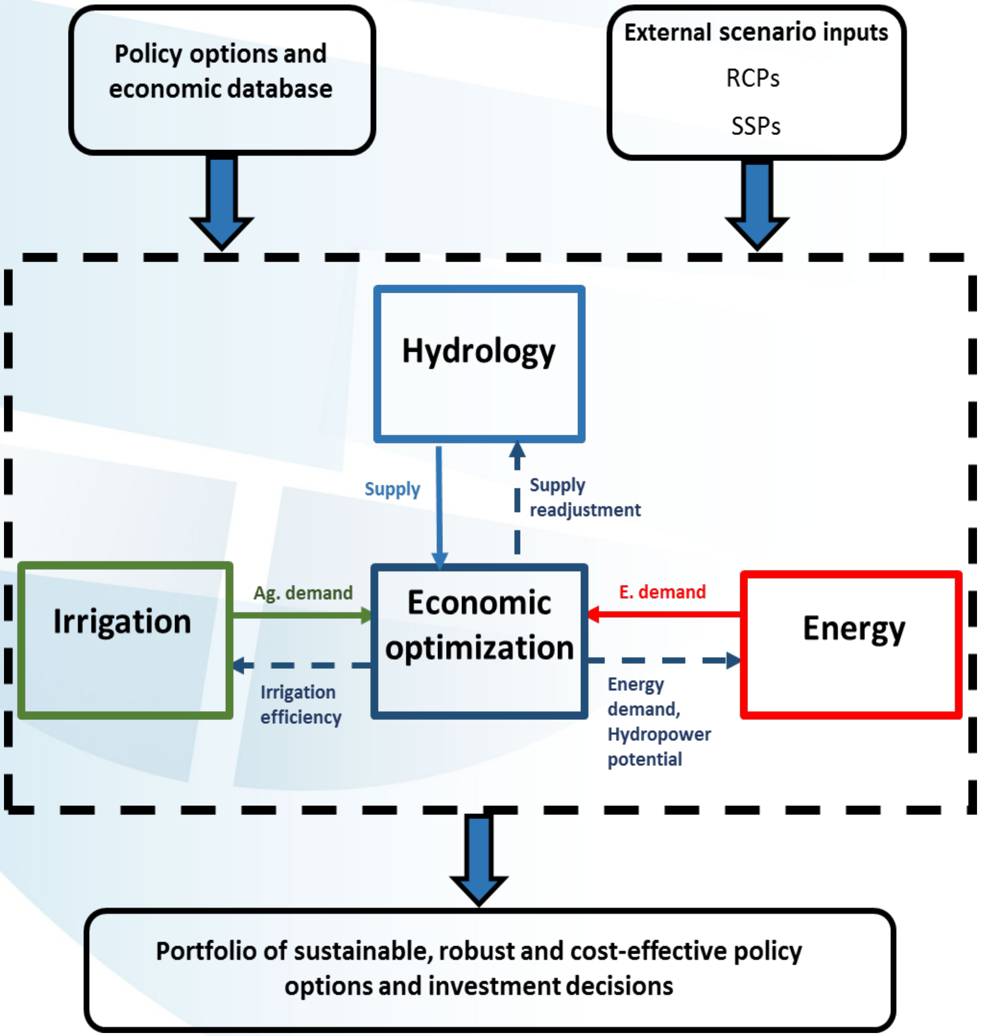
We present six strategies, or water-stress wedges, that collectively lead to a reduction in the population affected by water stress by 2050, despite an increasing population.

- **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.

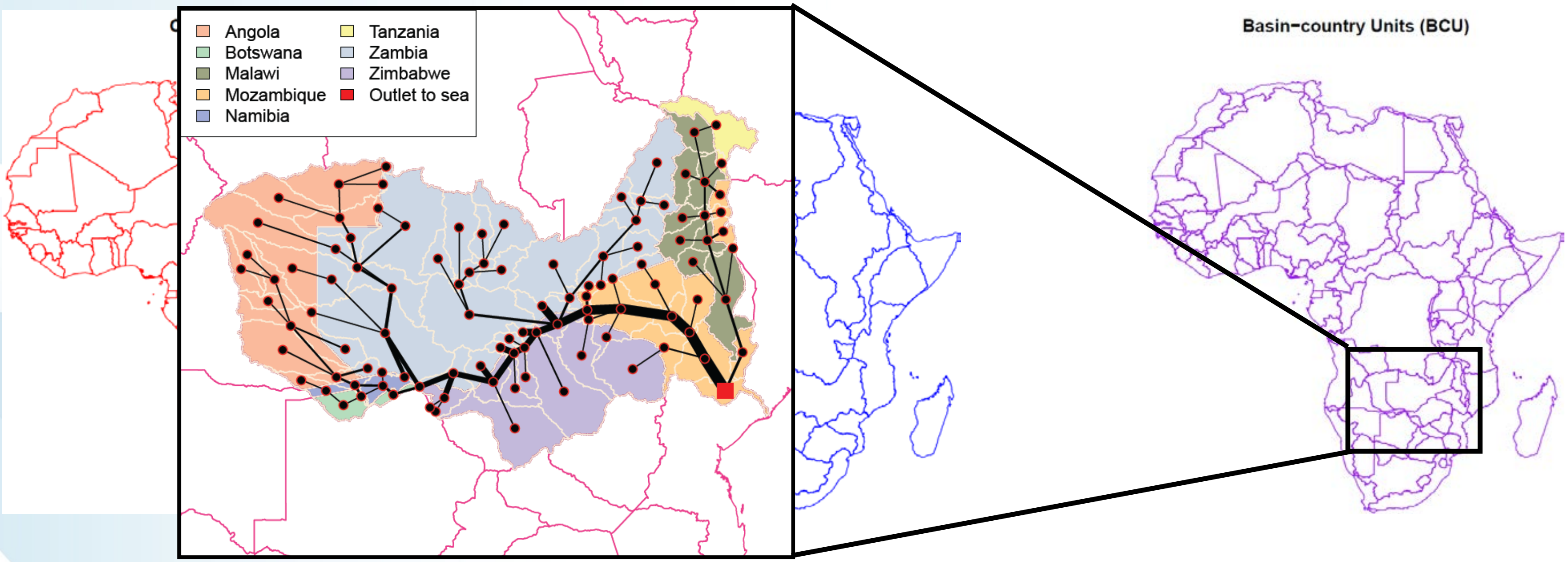
Impacts: Prices; Demands; Emissions; Water quality; Environmental flow; Groundwater depletion; Resource security; etc.

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

Innovation

Multi-scale modeling incorporating basin-level decision making

Catchment-scale w/ reduced form network



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:

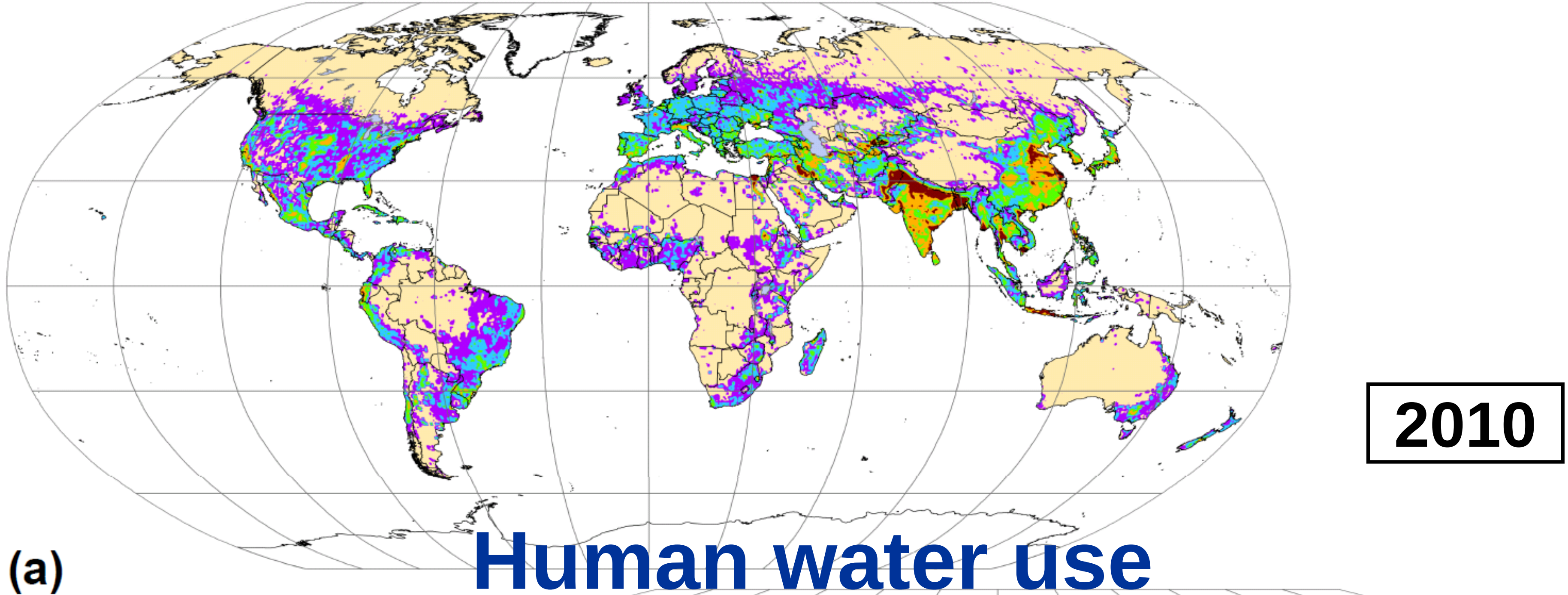
1/ Middle of the Road (***MoR***): SSP2-RCP6.0

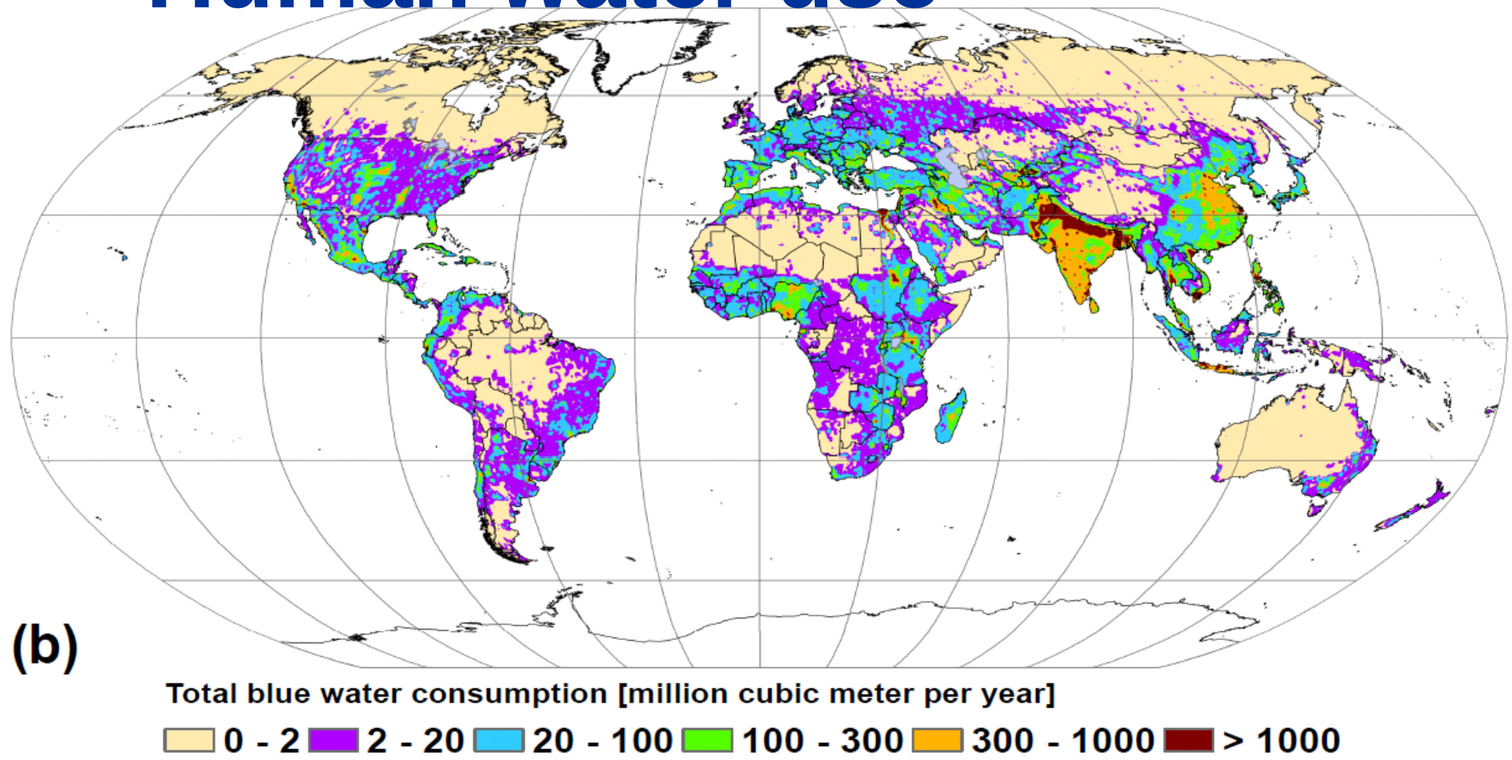
2/ Regional Rivalry **(*RR*)**: Water demand increases over time in all water sectors and water availability decreases, compared to *MoR.*

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

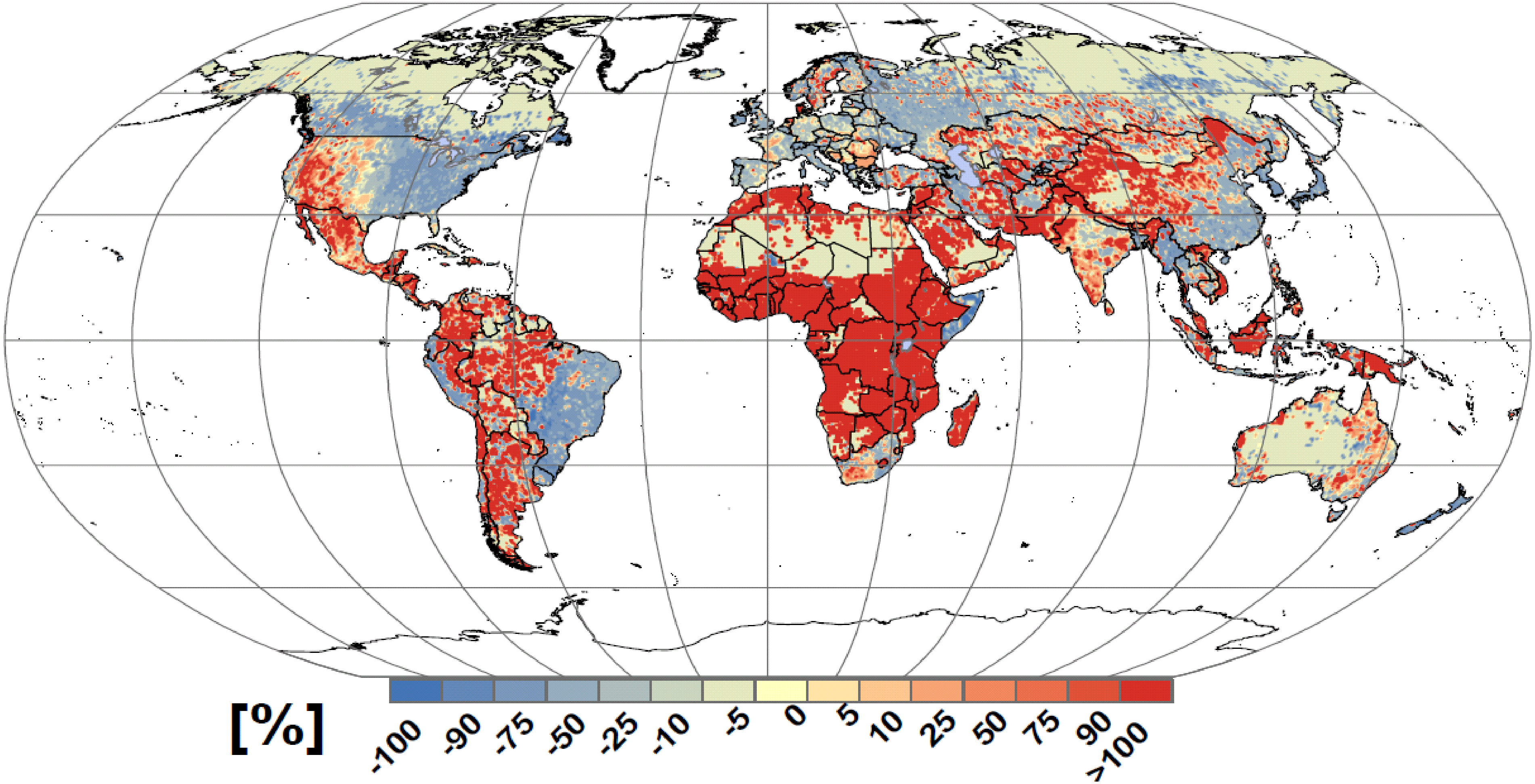
150 BCUs

Human water use



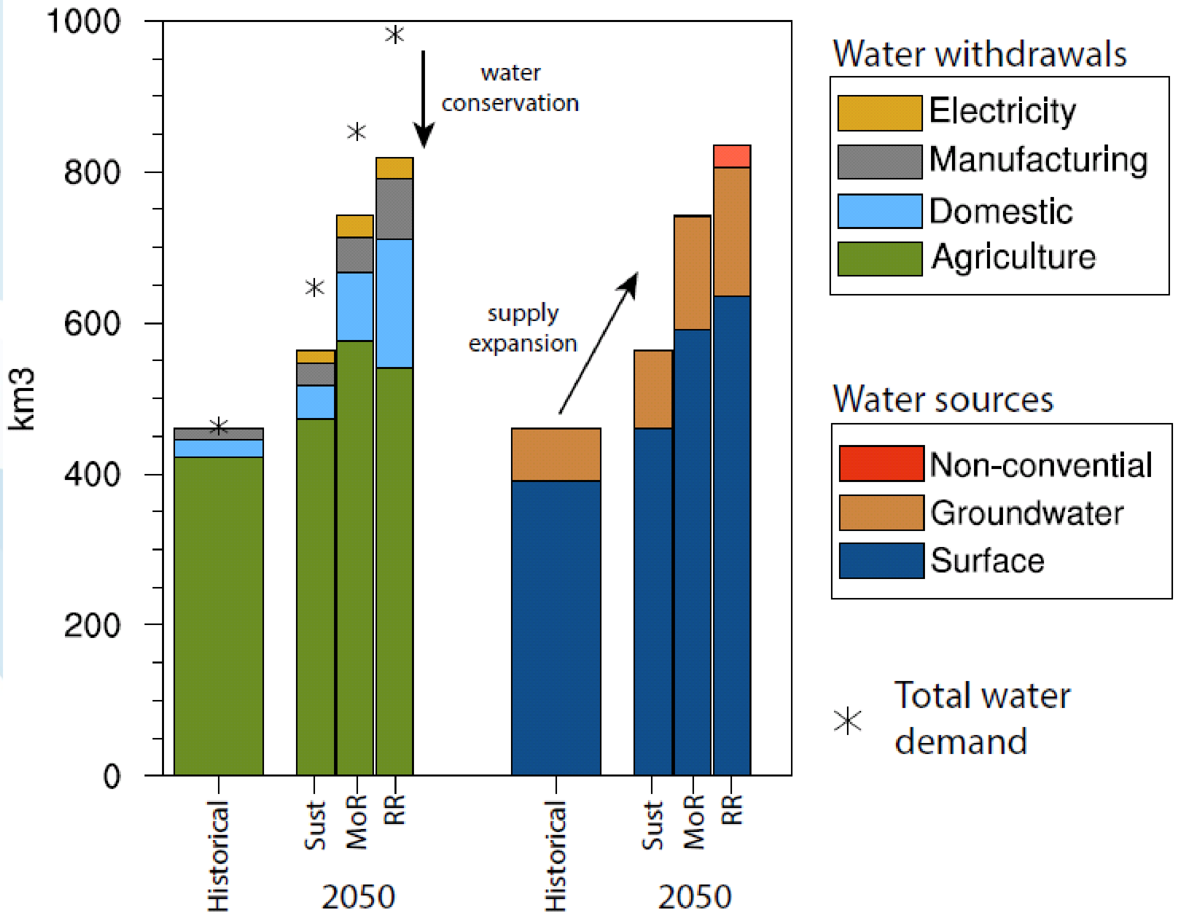


Relative change in human water use



2100 – 2010

Results: Water demand and withdrawals
Water supply

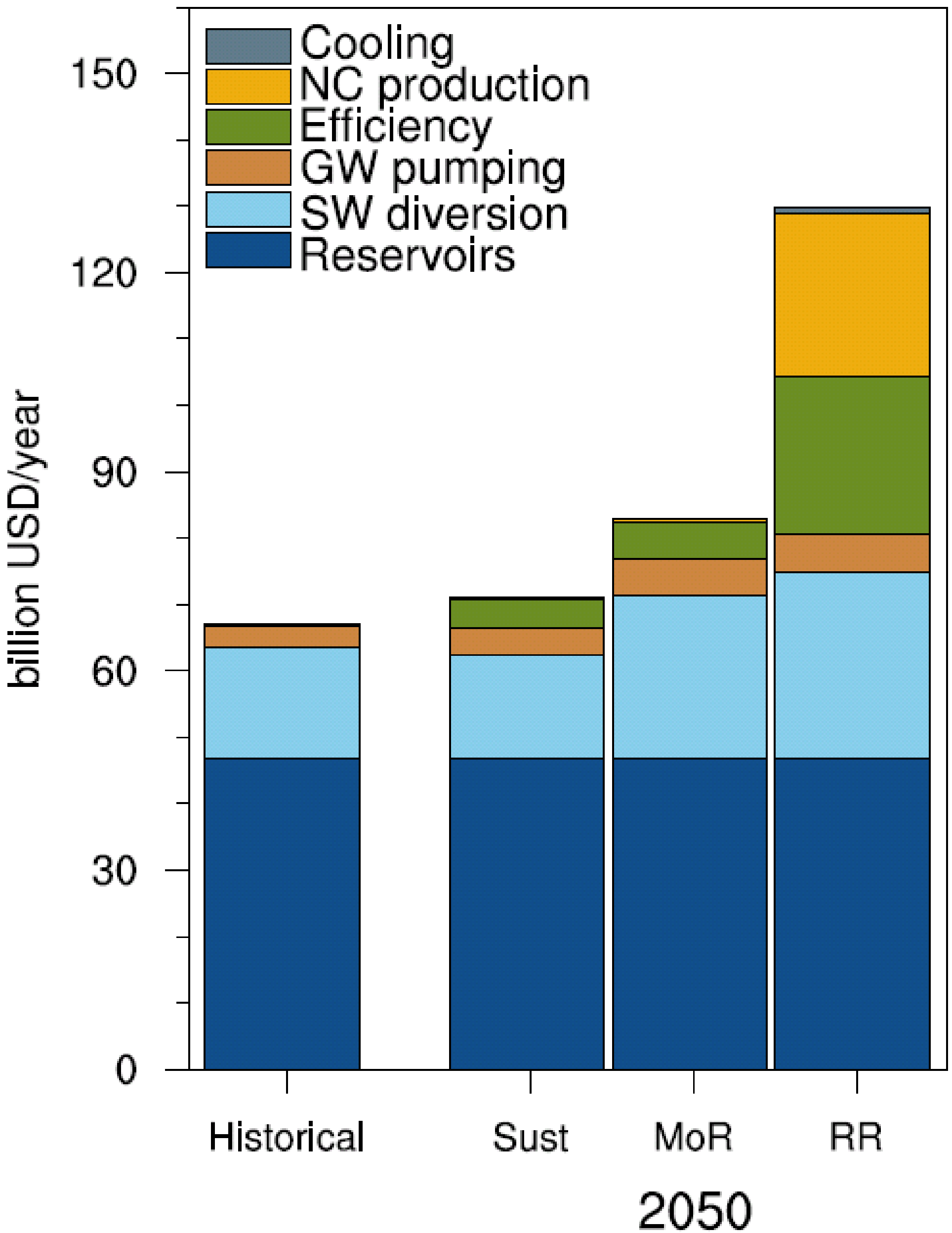


Total water demand increases in 2050 by 190-520 Km^3 (40-110%) compared to historical demand

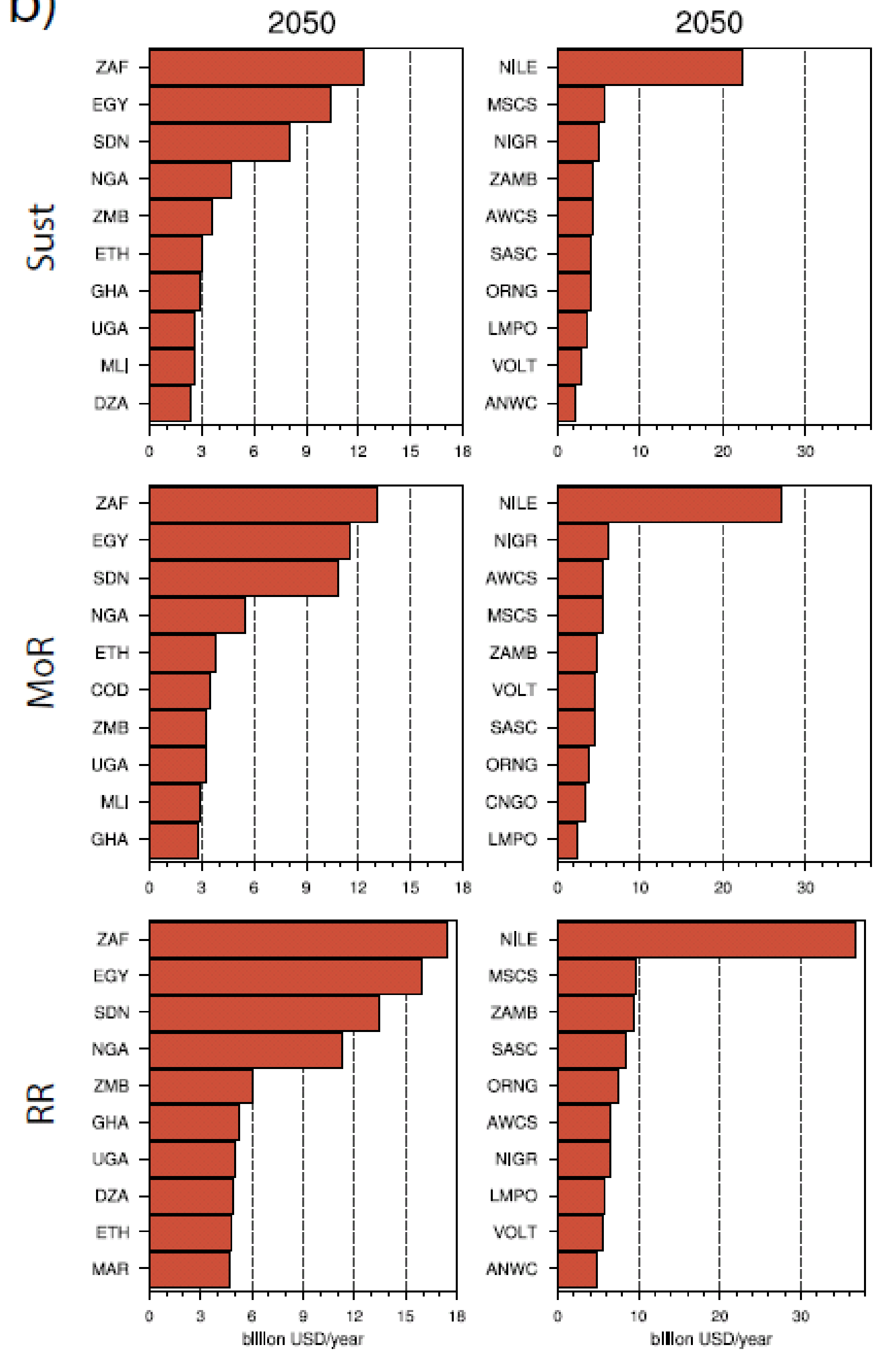
This increase requires the implementation of demand and supply management options to balance available supply and demand

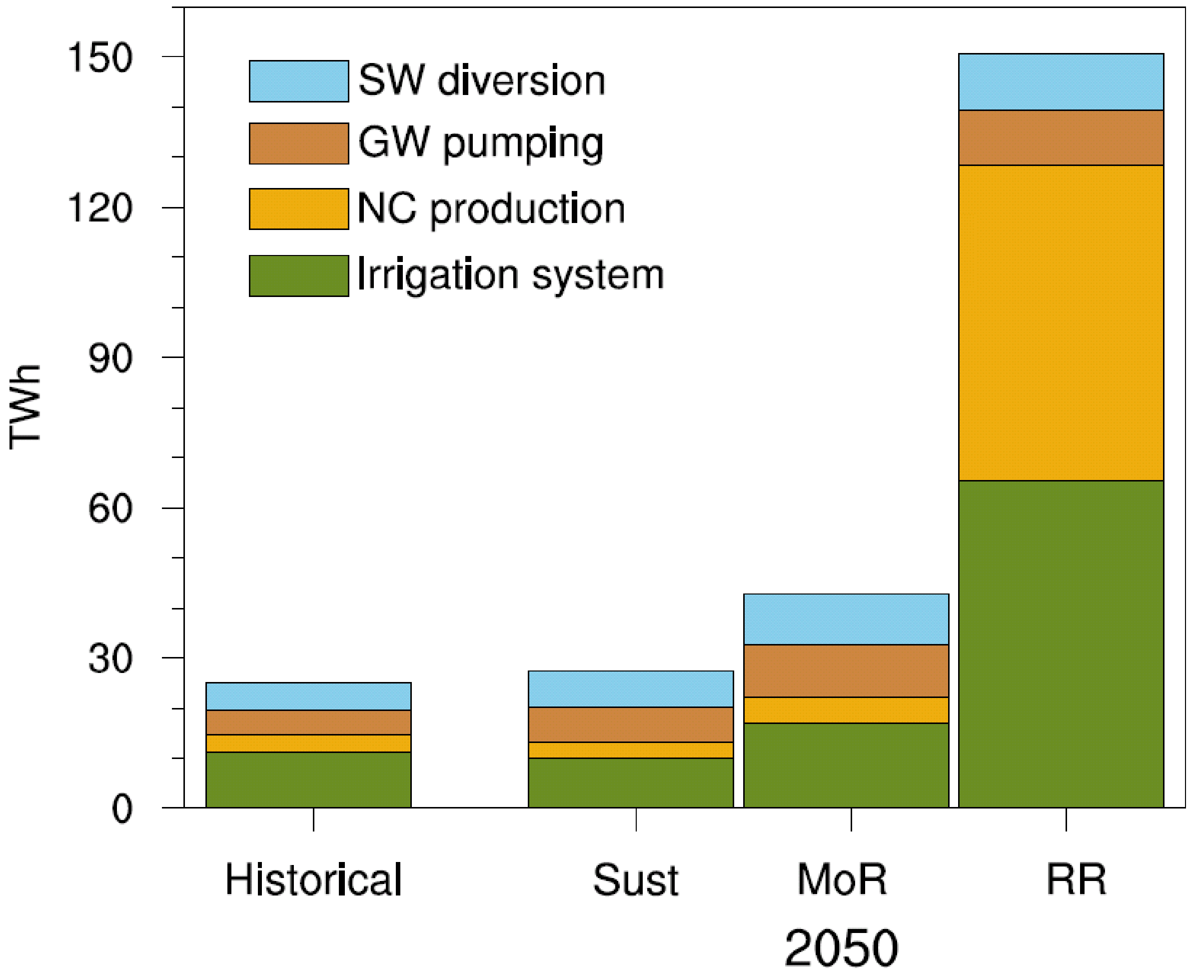
After implementing demand management options, withdrawals increase in 2050 by 100-360 Km^3 compared to historical withdrawals a)

Results: Investment costs



b)





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

Increase in the use of seawater cooling in coastal basins

Increase in the use of once-though and closed-loop in inland basins (depending on scenarios)

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

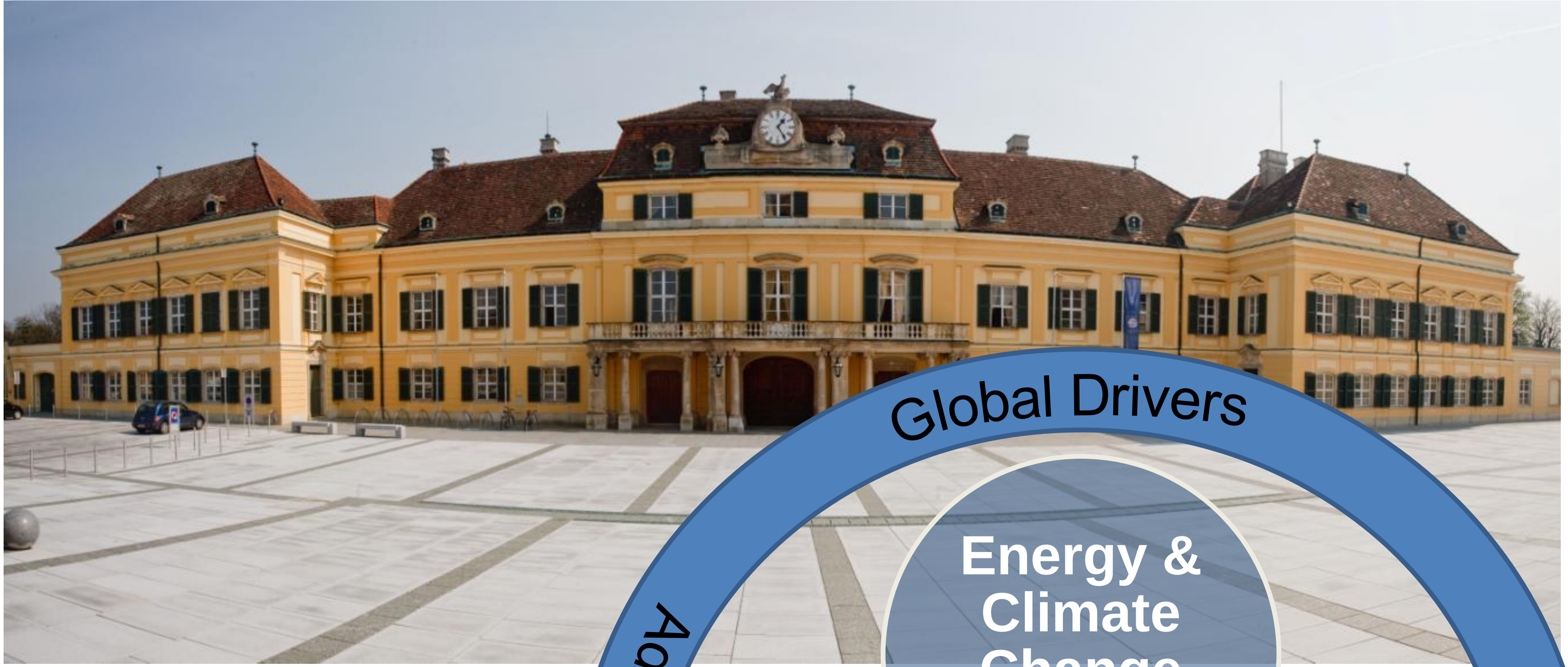
Half our planet's population still suffer from water insecurity

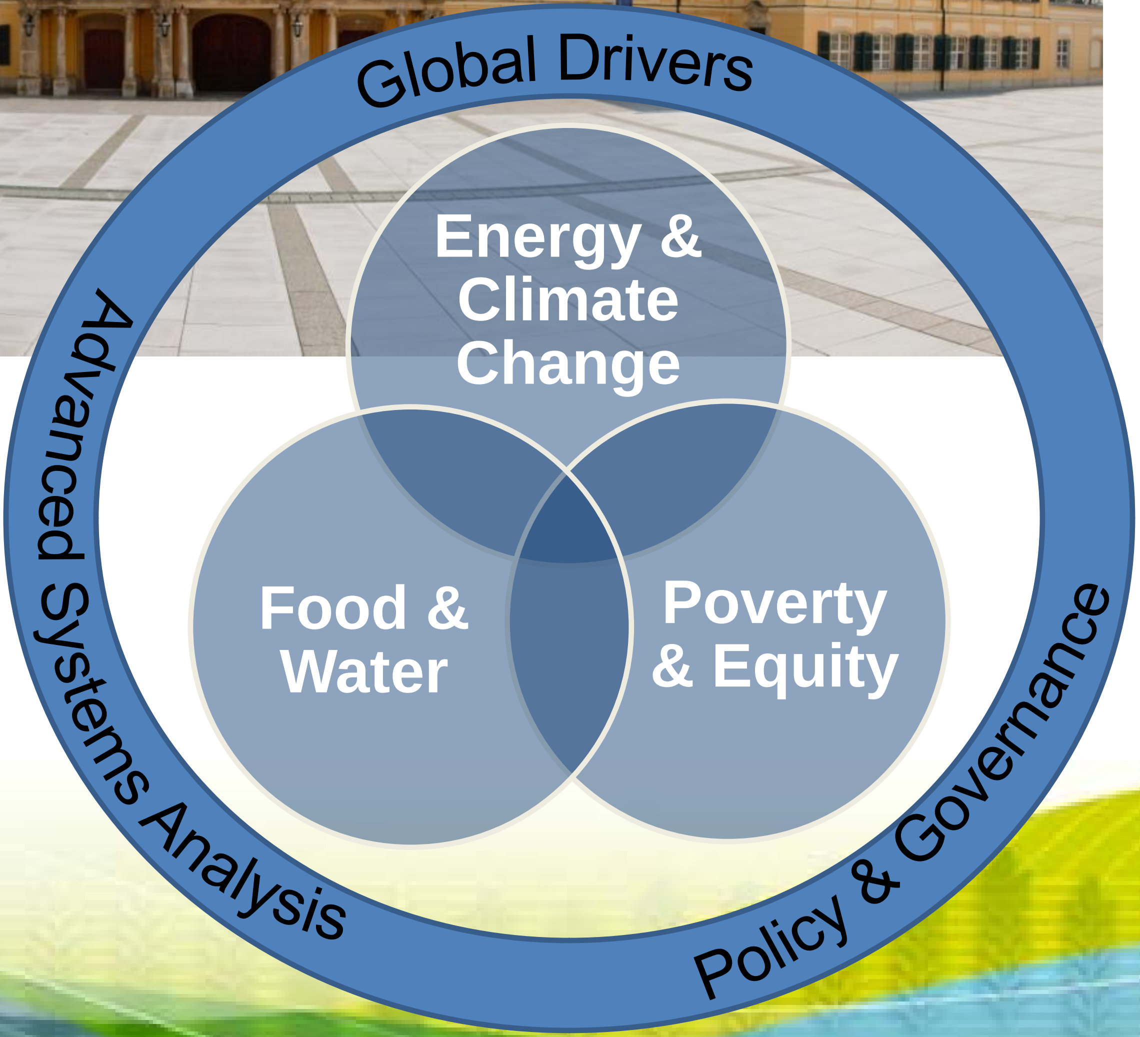
Absent/unreliable water supply

Poor sanitation

Floods & droughts

Poor irrigation and food production





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