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Mit der Natur für den Menschen – seit mehr als 185 Jahren.

Earth System Analysis & Stewardship

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Outline

Monday Nov. 18

- The water cycle: From hydrological processes to observations,
- presentation of topics, groupwork

Tuesday Nov. 19

- The nexus water – energy – food. Water as a basic need, water as a threat:
- Selection of topics, groupwork

- ## Wednesday Nov. 20

- Eco-hydrological modelling,
- Groupwork

Thursday Nov. 21

- Groupwork

Friday Nov. 22

- Presentation of selected tasks, visiting PIK

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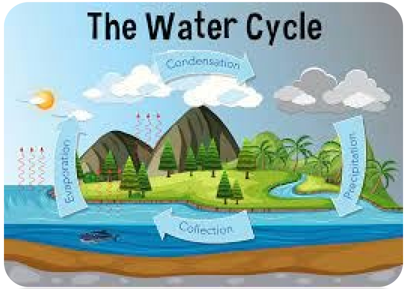
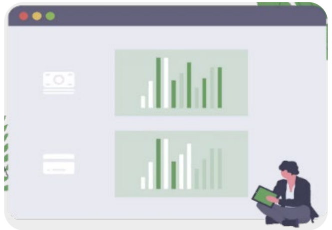
What we will do

Theory
Background and conceptualization



Examples
Modelling and interpretation

Application
Presentation of selected topics



Groupwork

Problem/ Pressure	Solution*	Adaptation measure	Remarks

*A problem may have more than one solution etc.

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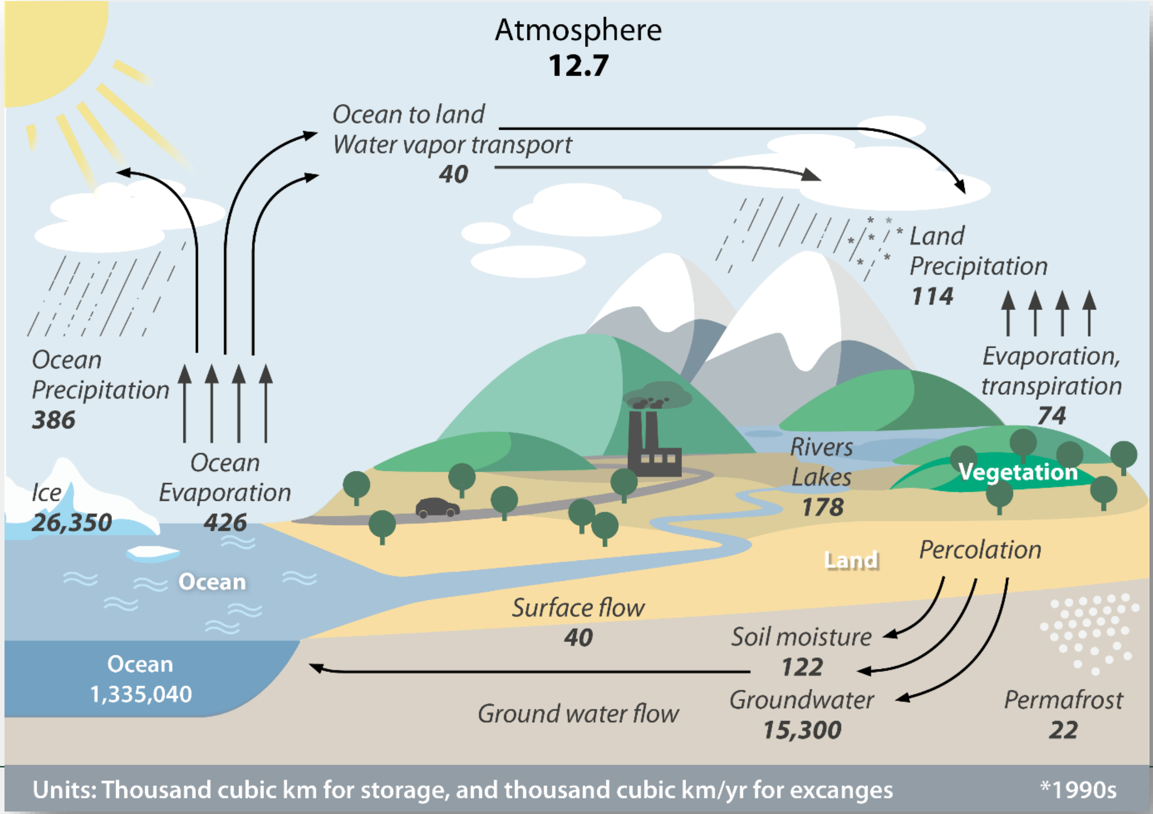
Water cycle, global



Water reservoirs

- Oceans, inland waters, glaciers, groundwater, atmosphere, soil water, organisms ...

Processes

- Precipitation,
- evaporation,
- seepage,
- Runoff

The global water cycle. Illustration: GIZ (2020) with data from Trenberth et al. (2011).

The Nexus Water – Food – Energy – Health

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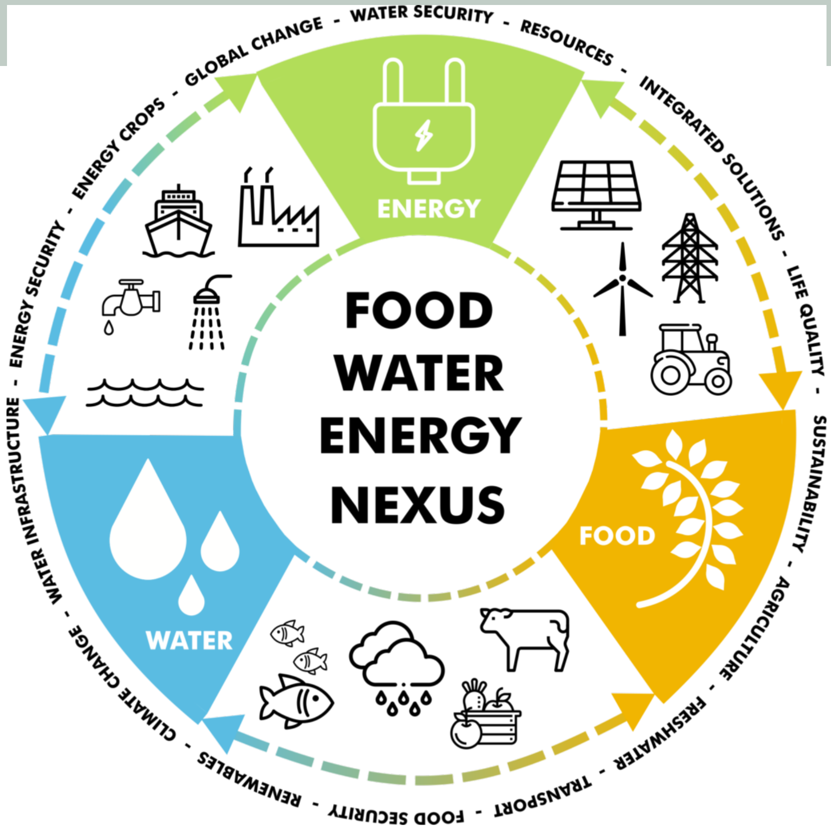
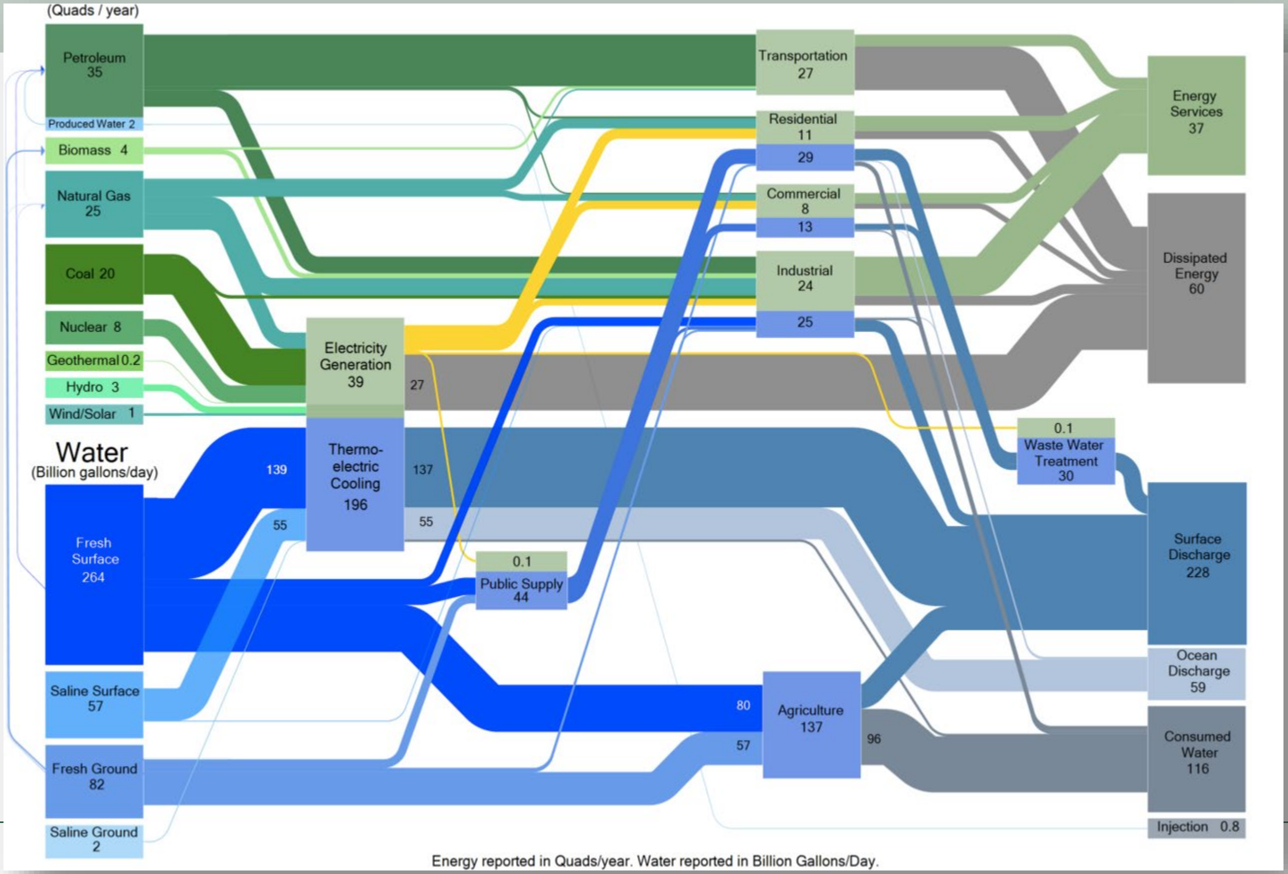
The WEF NEXUS

- **Food, Water and Energy** are elements that are inevitably linked with each other.
- **Impacts on one part might also cause changes in the other ones.**
- To provide a sustainable development on a global scale, solutions concerning food, water and energy challenges have to be created and established

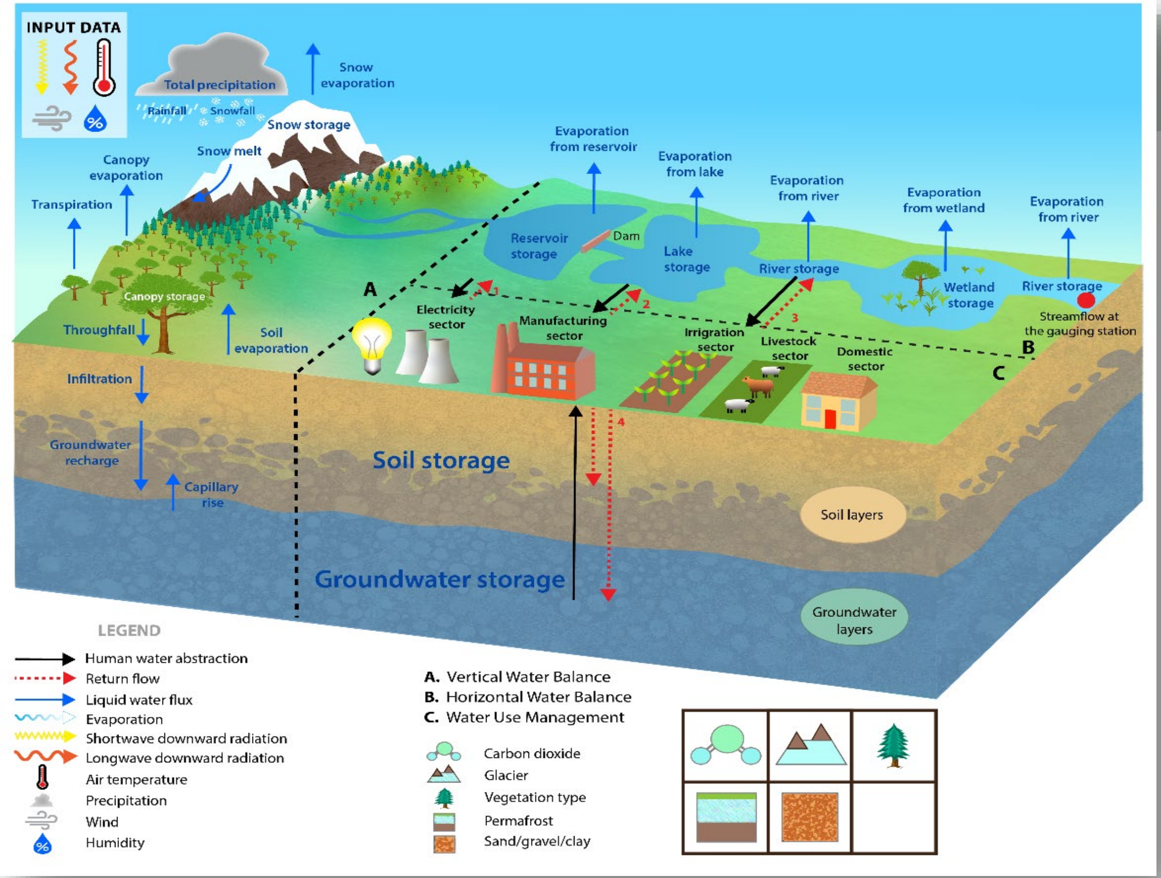


The Nexus and the SDGs

Interlinkages Water Energy

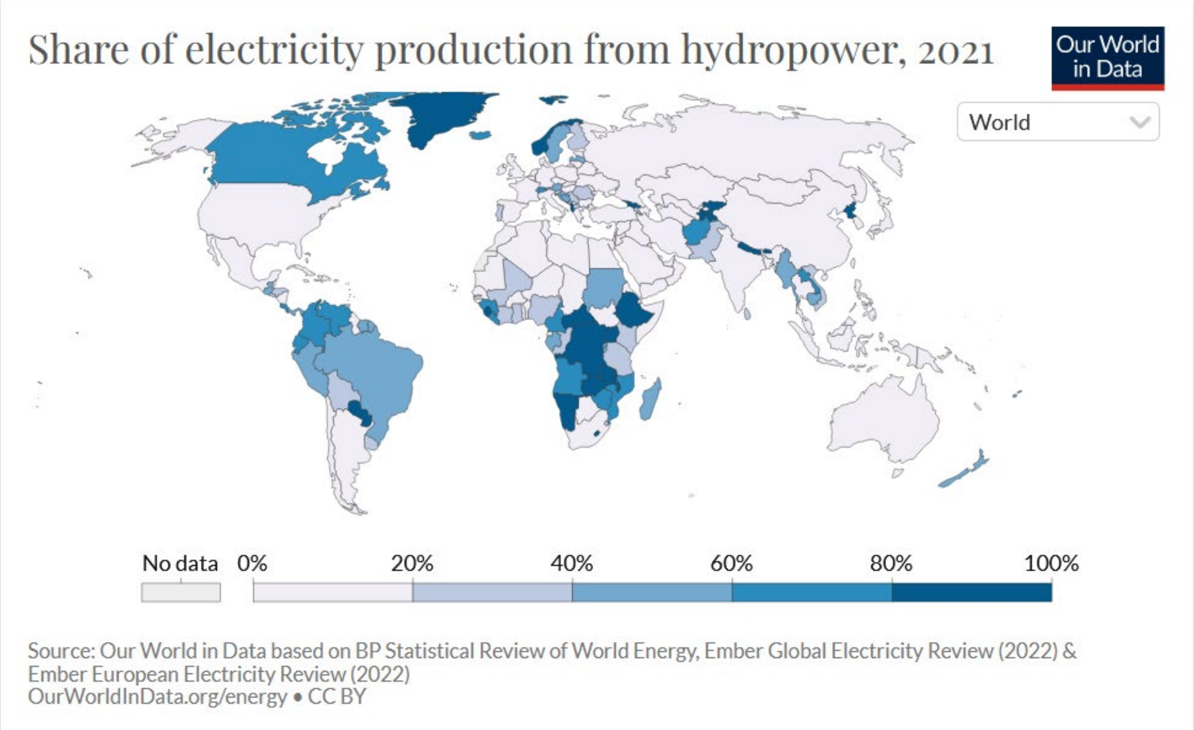


A complex system of interlinkages

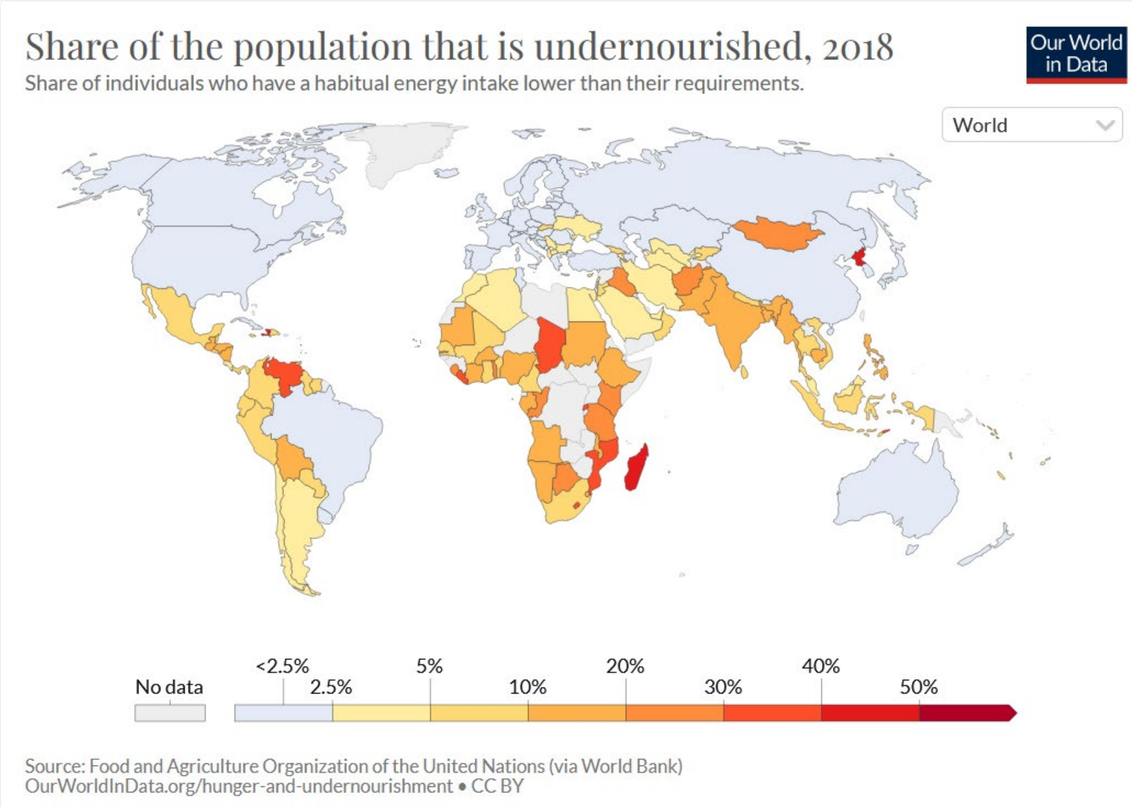


Source: Camelia Telteu (Universität Frankfurt)

Share of hydropower per capita

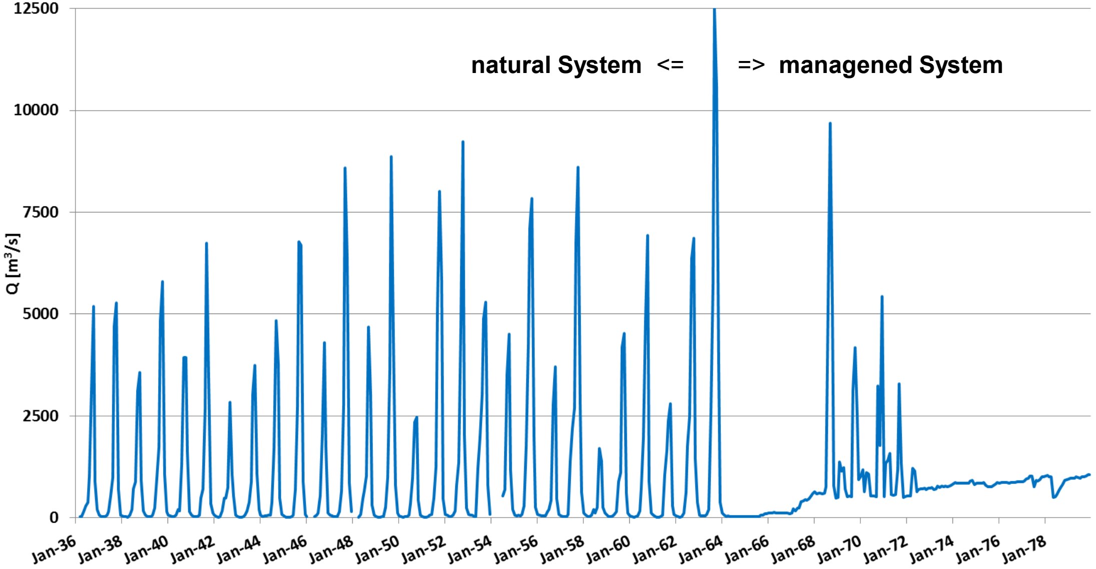


Undernurishment



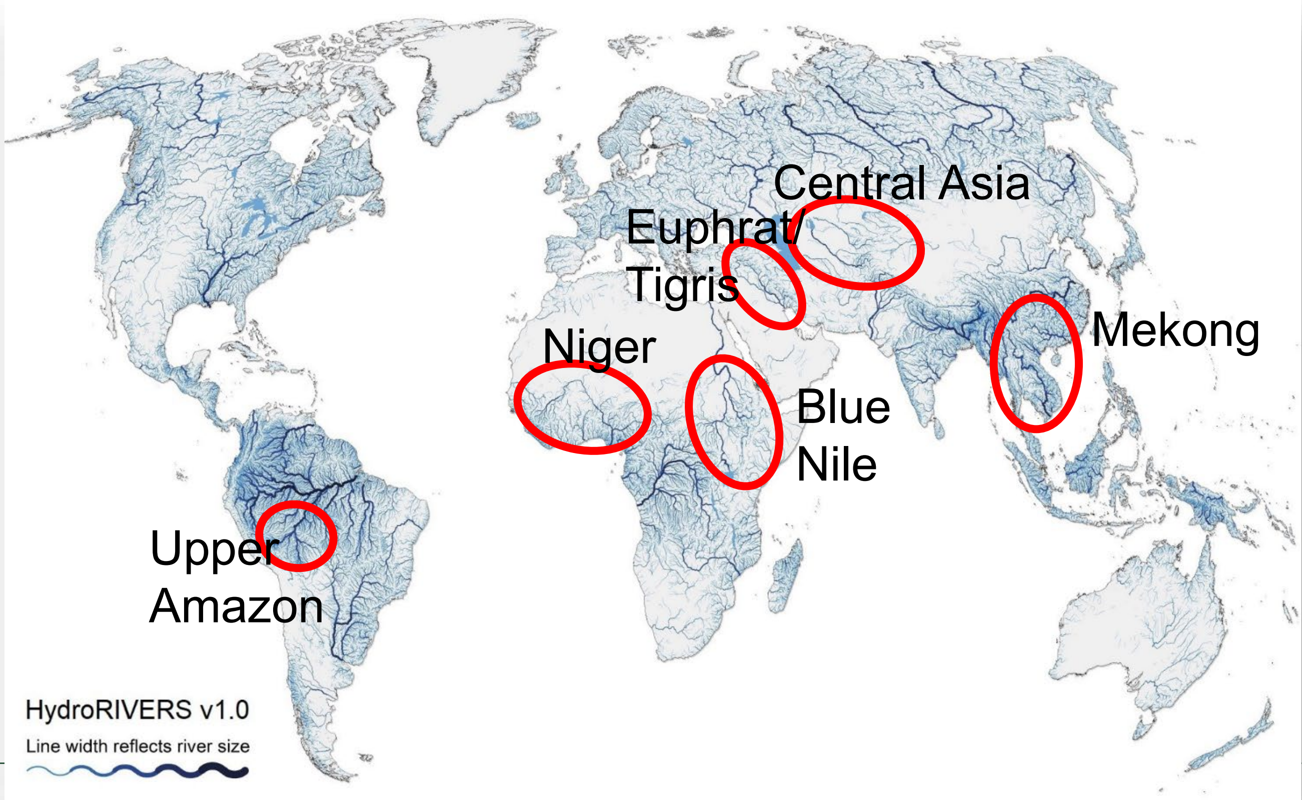
Impact of management on river discharge and ecosystems

Discharge at gauge Senchi / Volta (Ghana, uh. Lake Volta)

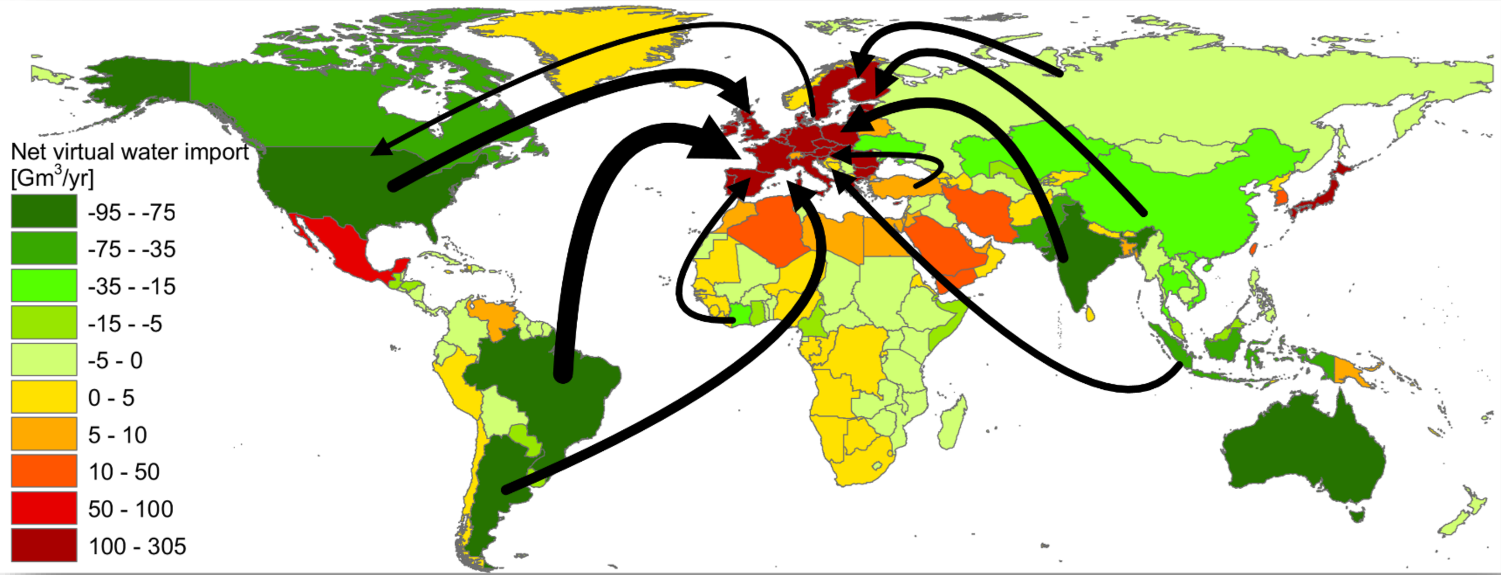


Daten: GRDC, Koch 2020

Transboundary river systems with upstream-downstream water conflicts



Virtual water import



Mekonnen, M.M. and Hoekstra, A.Y. (2011)

Groupwork

Problem/ Pressure	Solution*	Adaptation measure	Remarks

*A problem may have more than one solution etc.

Some background

Definition water management

DIN 4049:

Water management: Control and operation of water management systems for

- water supply,
- wastewater disposal,
- irrigation and drainage,
- canal and flood protection and
- hydraulic engineering facilities (dams, navigation channels)

with the aim of protecting water resources and the water ecosystem and balancing the interests of different uses.

Rurtalsperre (Eifel)

Integrated water management

Integrated water resources management:

- Integrated water resources management (IWRM) has been defined by the Global Water Partnership (GWP) as "**a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems**".

Integrated river basin management:

- Integrated River Basin Management (IRBM) **emphasises cross-disciplinary coordination of water, land and related resources in a river basin**, watershed or catchment to achieve long-term sustainability.
- **IRBM highlights the importance of ecosystem function in the long term**, and reminds us that an integration of policies, decisions and costs are necessary across a multitude of sectors.

The European Water Framework Directive (WFD)

Since Sept. 14, 2001, the EU Water Framework Directive has been in effect in the states of the European Union:

- Directive establishing a framework for Community action in the field of water policy - Water Framework Directive (WFD)
- **Management plans for entire river basins**
- **Focus on the protection and improvement of aquatic ecosystems**
- The promotion of sustainable use of water resources
- Reduction of water pollution by hazardous substances in accordance with marine protection agreements
- **Reduction of the ecological impact of floods and droughts**

WFD

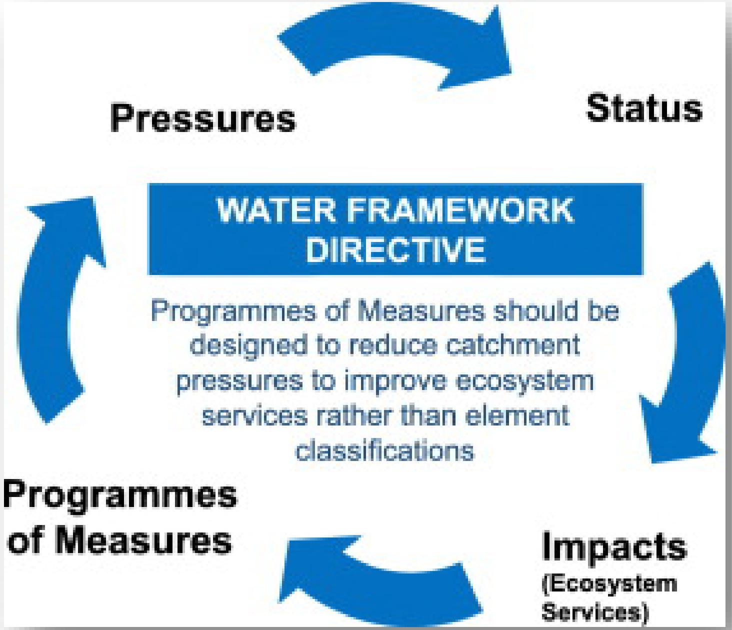
The Directive aims for 'good status' for all ground and surface waters (rivers, lakes, transitional waters, and coastal waters) in the EU.

The ecological and chemical status of surface waters are assessed according to the following criteria (see also: freshwater environmental quality parameters):

- Biological quality (fish, benthic invertebrates, aquatic flora)
- Hydromorphological quality such as river bank structure, river continuity or substrate of the river bed
- Physical-chemical quality such as temperature, oxygenation and nutrient conditions
- Chemical quality that refers to environmental quality standards for river basin specific pollutants.

These standards specify maximum concentrations for specific water pollutants. If even one such concentration is exceeded, the water body will not be classed as having a “good ecological status”.

The European Water Framework Directive



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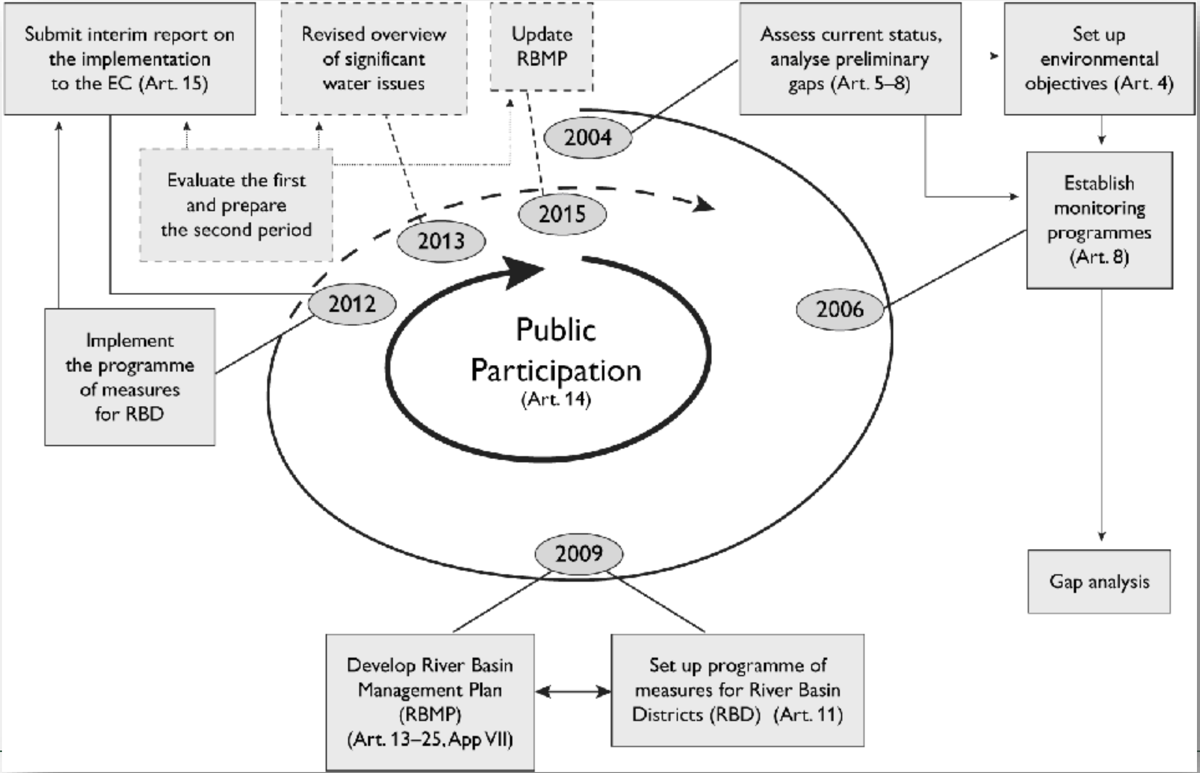
The European Water Framework Directive



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WEF Nexus Examples

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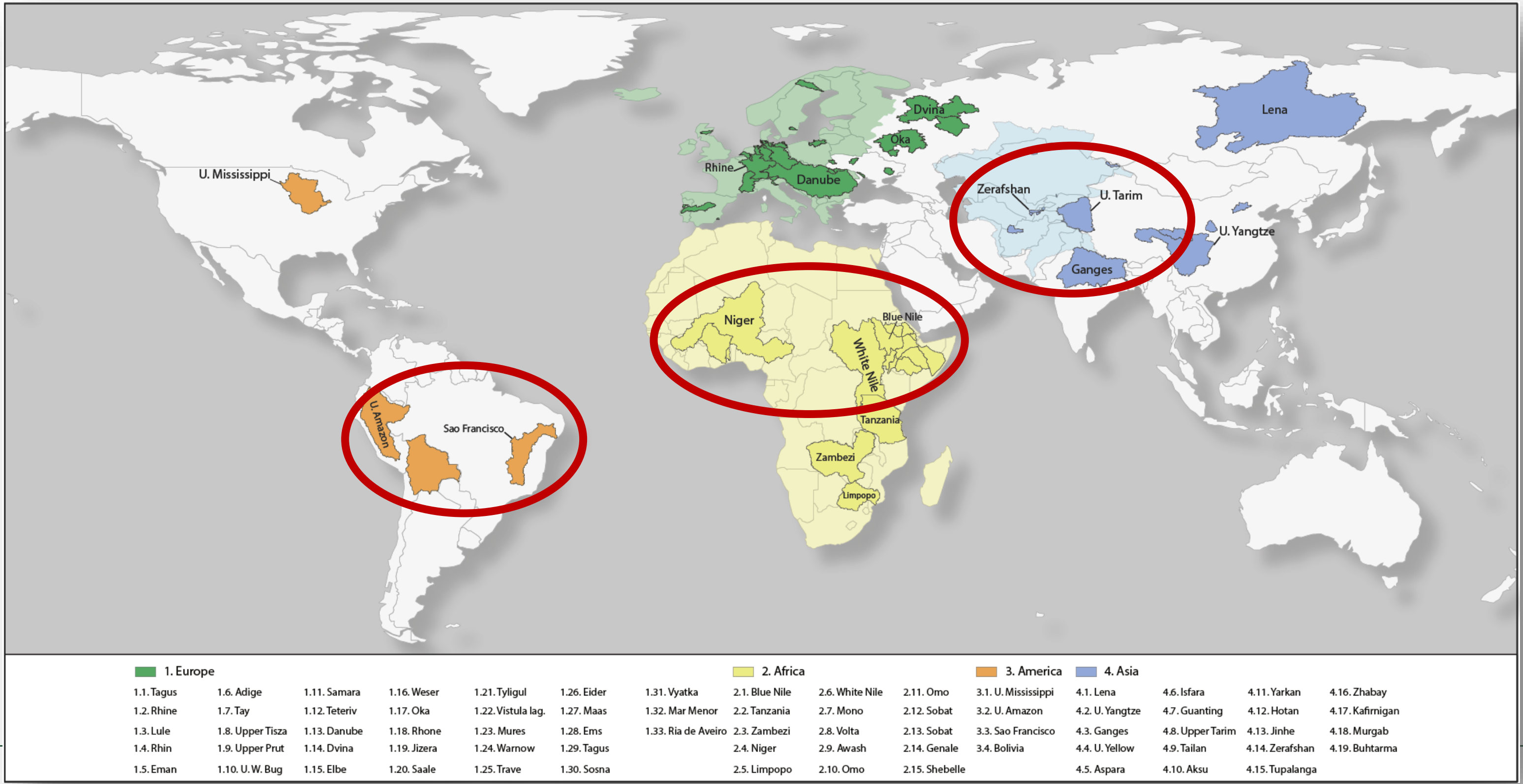
Ongoing projects: focus regions



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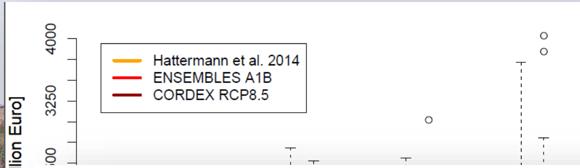

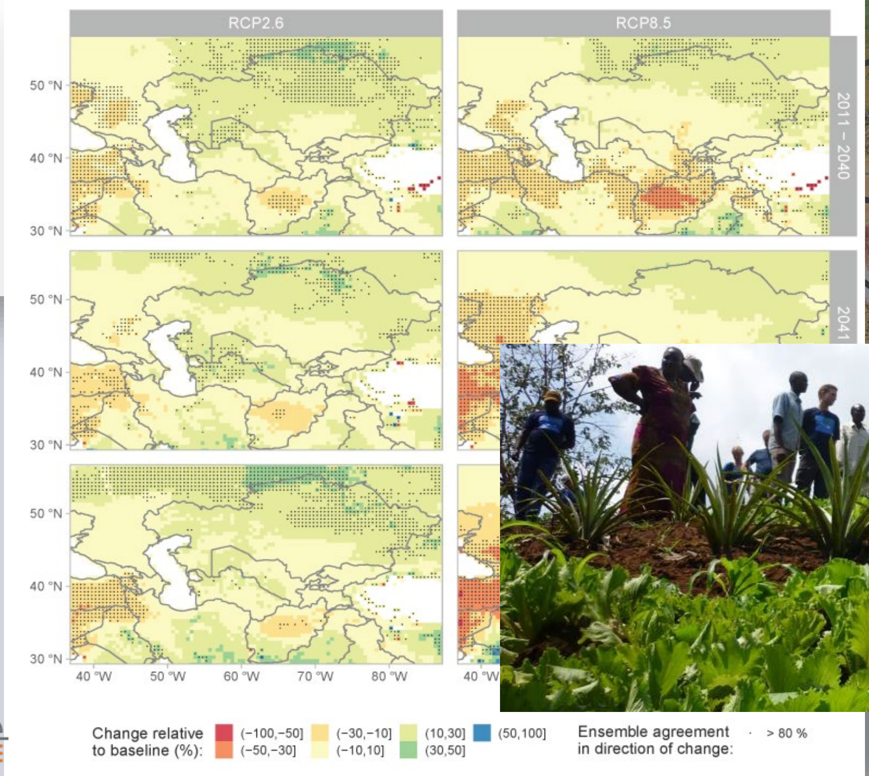

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WEF Nexus Examples

1 The Grand Ethiopian Renaissance Dam (GERD)

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The Grand Ethiopian Renaissance Dam (GERD)

- **Africa's largest hydropower project:**
- **Installed capacity:** ~6000 MW, 16 turbines

  (~4 nuclear power plants)

- **Storage:** 74 billion m^3

  (~1.5 years Blue Nile flows)

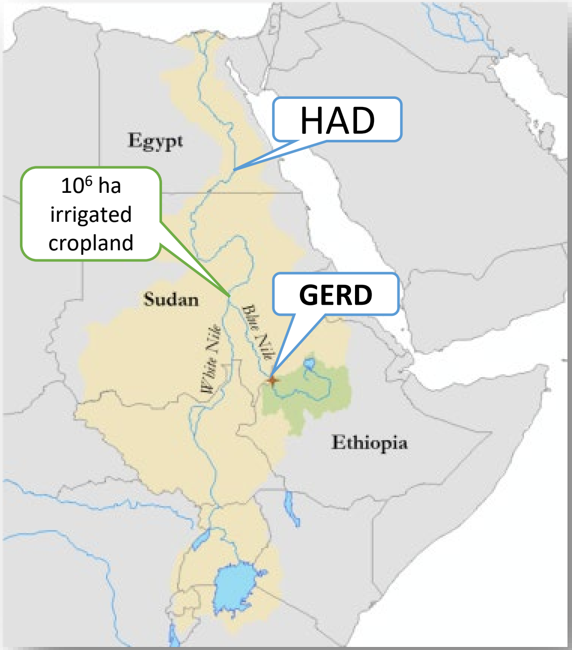
- **Lake area:** 1874 km^2

  (>2 times Berlin area)

Source: www.brusselstimes.com

Political tension

- Blue Nile contributes **60-80% of flows to Egypt**
  - Ethiopia controls the major source of Egypt's lifeline
  - Water & energy shortage during filling and operation
  - Lack of transparency
    - No environmental / social impact assessment conducted
  - Lack of willingness to cooperate (all parties)
  - Construction began in 2011 without consent
  - Filling of dead storage started in rainy season 2020
    - Without agreed filling timetable



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The Upper Blue Nile SWIM

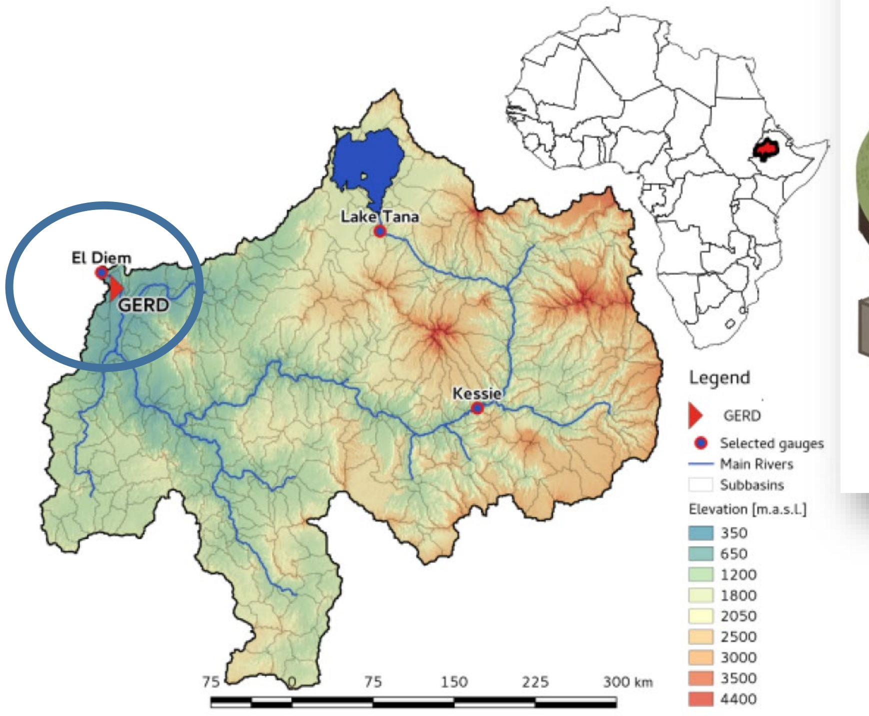
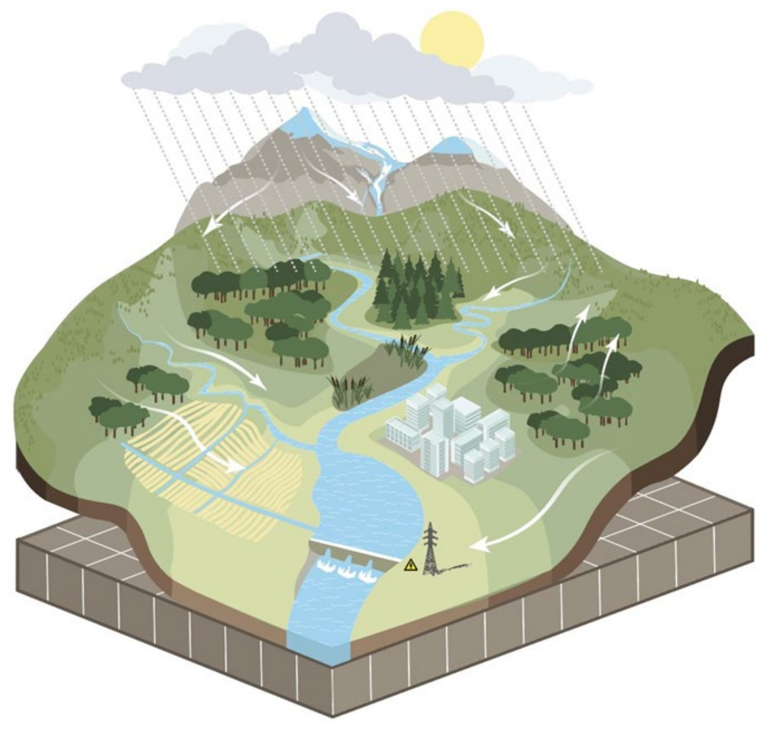


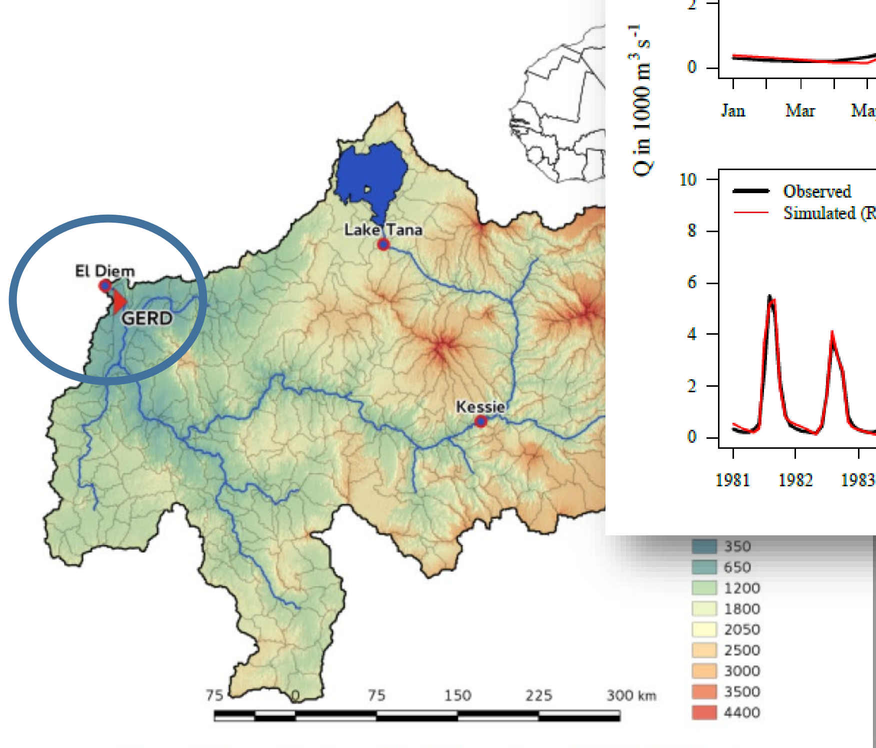
Figure 1. Map of the Upper Blue Nile catchment (UBN) in Ethiopia.



- The basin and calibration/ validation

Liersch et al. 2018

The Upper Blue Nile SWIM



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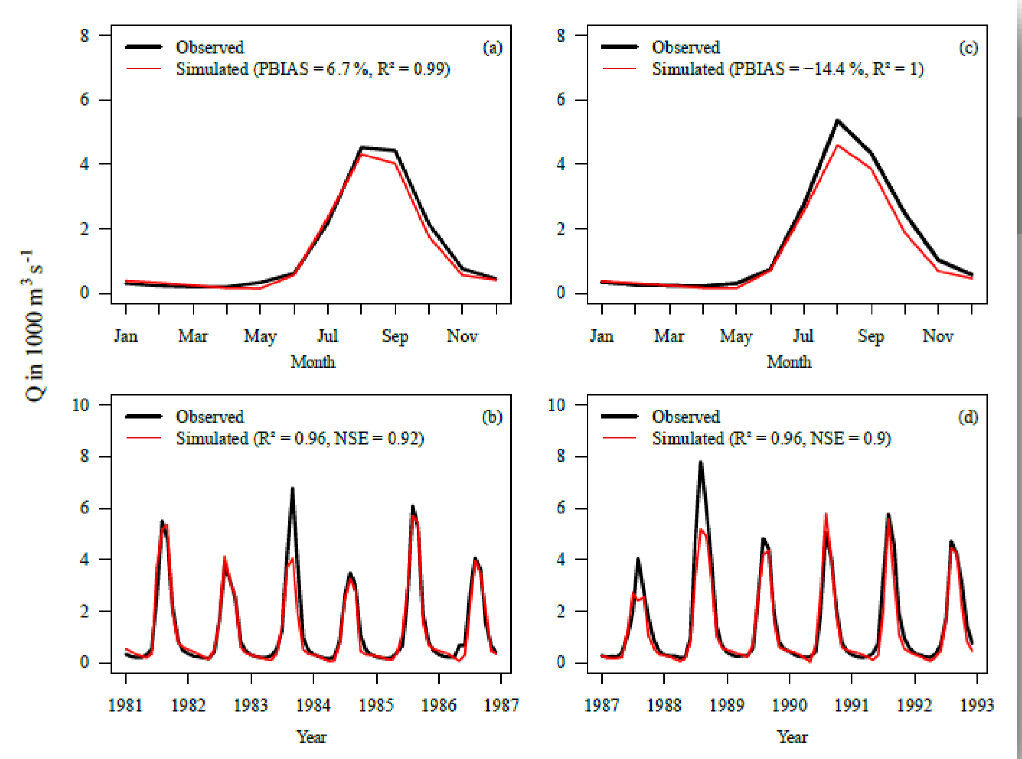
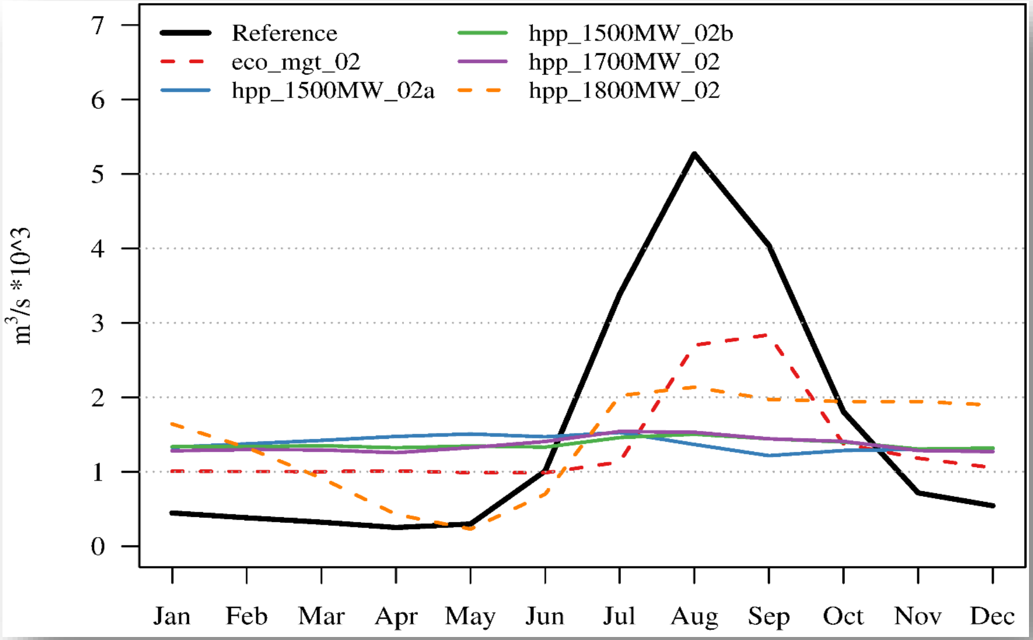


- The basin and calibration/ validation

Liersch et al. 2018

GERD in operation (SWIM simulation)

- Hydropower targets
  - 1500 MW
  - 1700 MW
  - 1800 MW
- Environmental flows
  - eco_mgt



Average 1961-1999

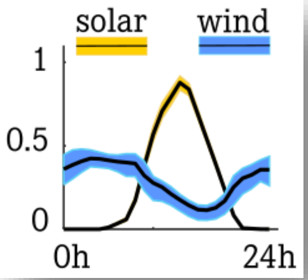
Liersch, S., Koch, H., Hattermann, F. (2017). Management Scenarios of the Grand Ethiopian Renaissance Dam and Their Impacts under Recent and Future Climates. Water, 2017, 9. DOI:10.3390/w9100728

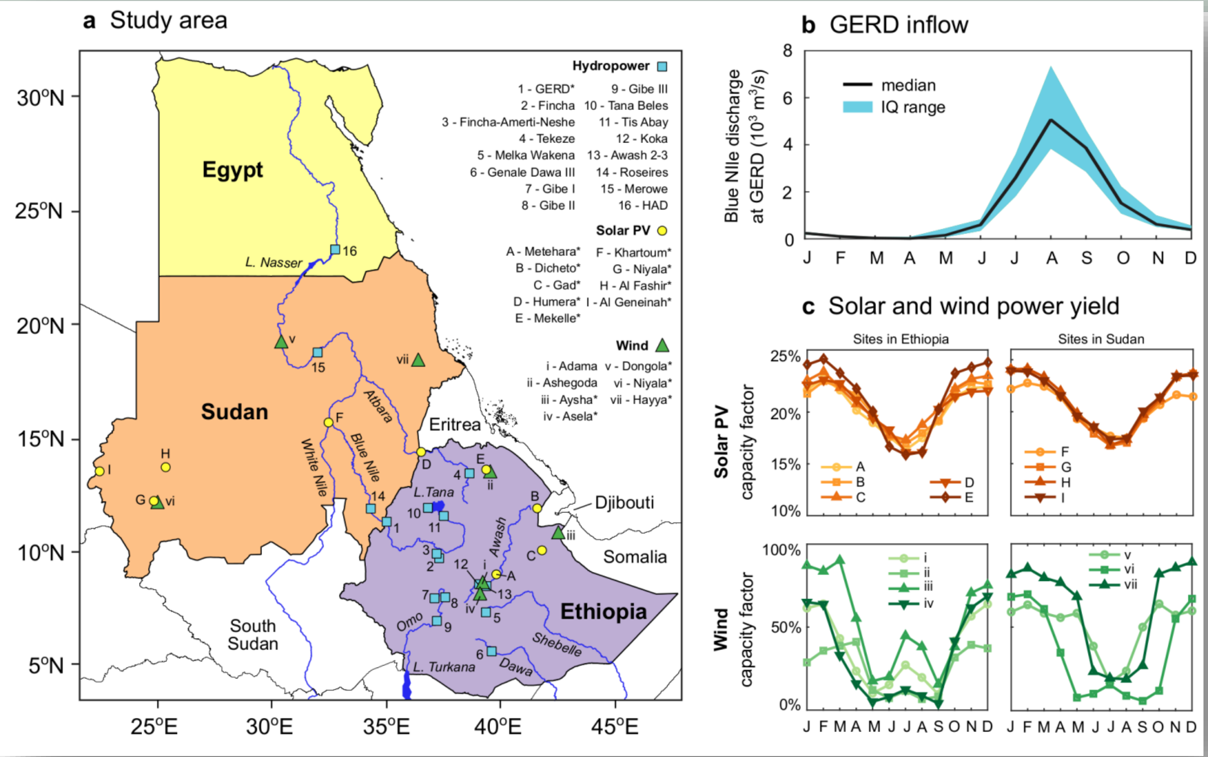
Goals

- Investigate functioning of GERD under climate change conditions
- Support water management to mediate upstream downstream conflicts
- Support integration of renewable energies to stabilize energy generation and natural flow regime

Improving management by integration of solar & wind

- Complementarity of RE sources at diurnal and seasonal time scales





Sterl, S., Fadly, D., Liersch, S., Koch, H., Thiery, W. (2021). Linking solar and wind power in eastern Africa with operation of the Grand Ethiopian Renaissance Dam. Nature Energy (currently with Editor after 2nd submission)

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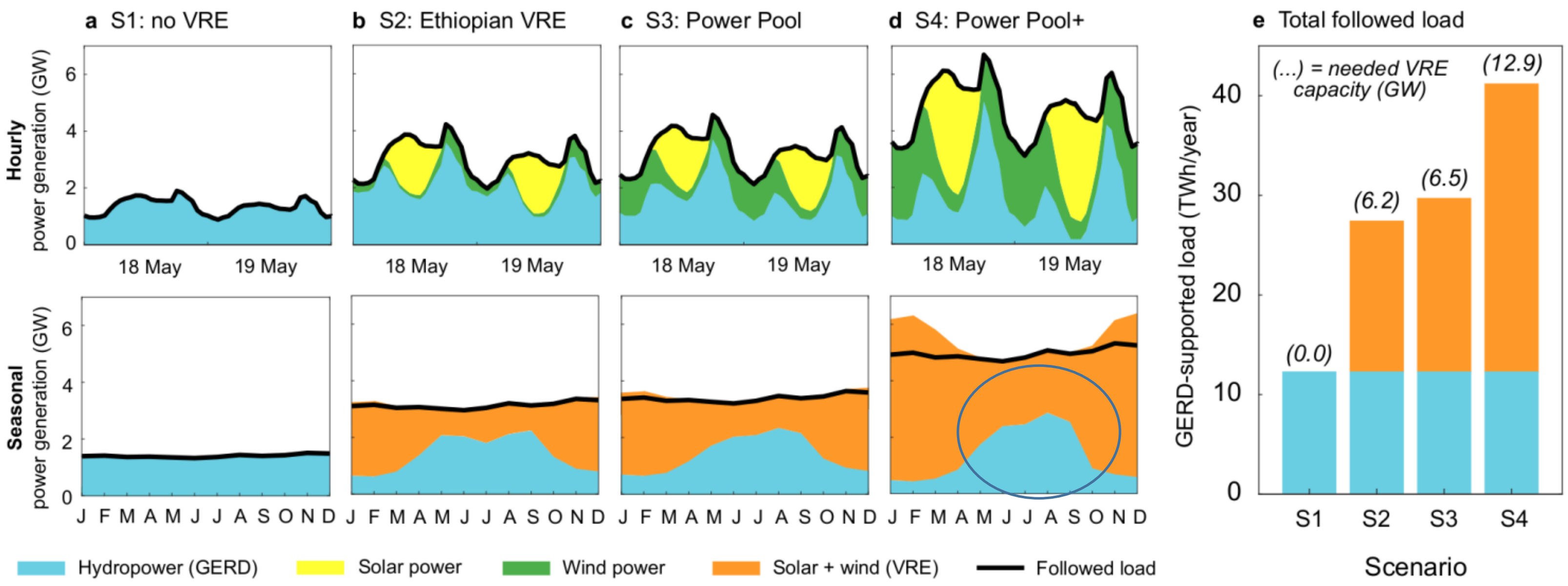
Supporting the integration of hydro, solar & wind



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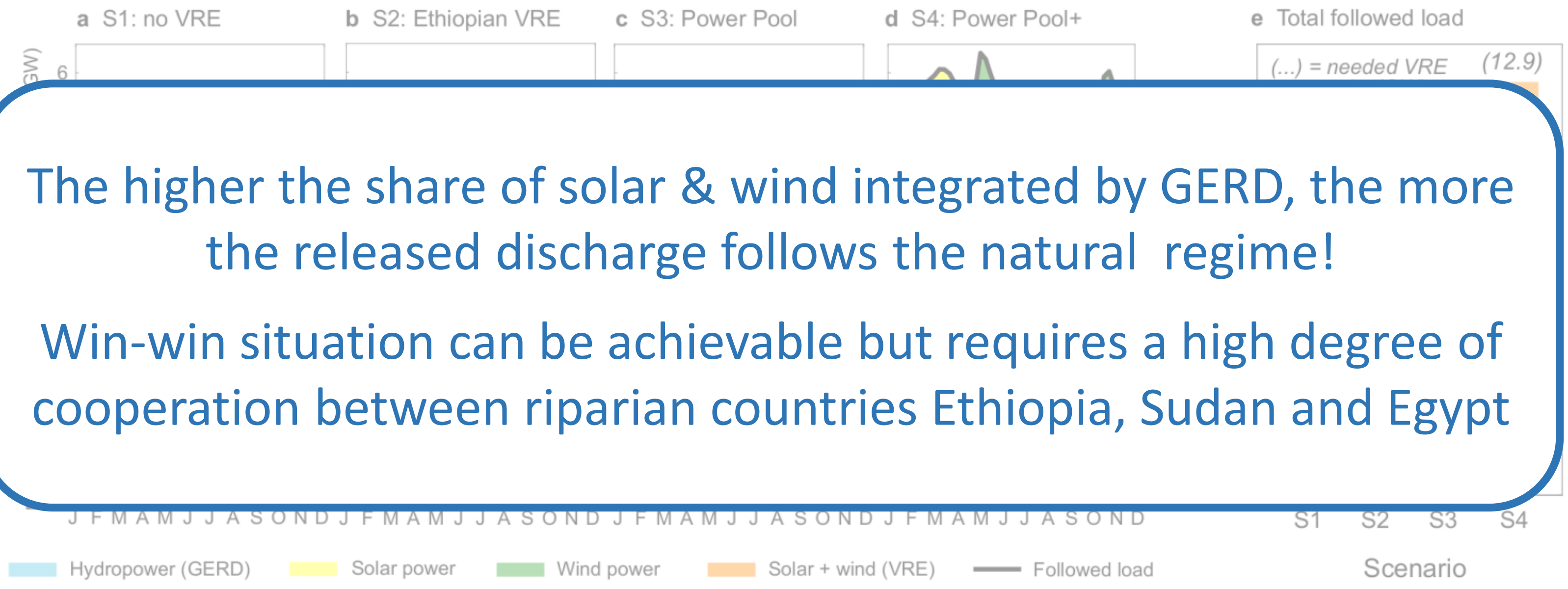
Supporting the integration of solar & wind



The higher the share of solar & wind integrated by GERD, the more the released discharge follows the natural regime!

Win-win situation can be achievable but requires a high degree of cooperation between riparian countries Ethiopia, Sudan and Egypt

Sterl, S., Fadly, D., Liersch, S., Koch, H., Thiery, W. (2021). Linking solar and wind power in eastern Africa with operation of the Grand Ethiopian Renaissance Dam. Nature Energy (currently with Editor after 2nd submission)

Groupwork

Problem/ Pressure	Solution*	Adaptation measure	Remarks

*A problem may have more than one solution etc.

WEF Nexus Examples
2 Assessment of climate impacts on land and water management and adaptation options in Bolivia

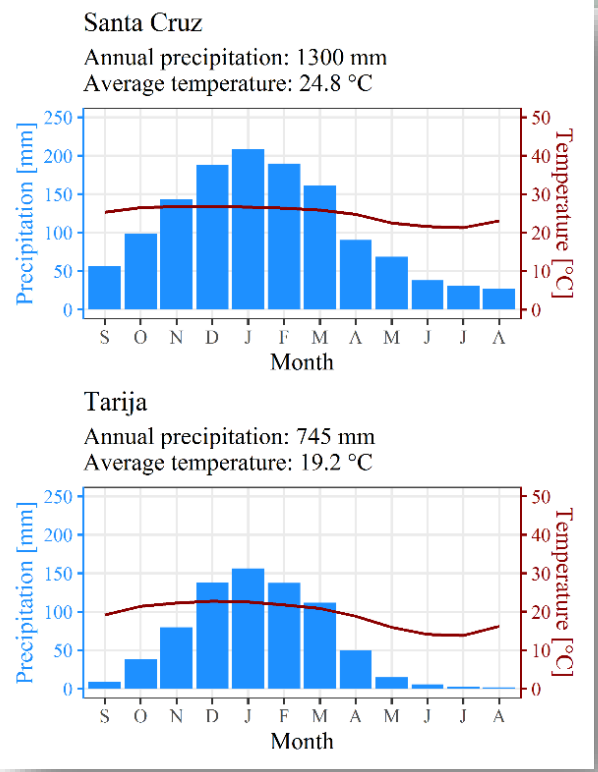
Overview and goals

Target: Climate impact and adaptation study in the water - food - energy nexus

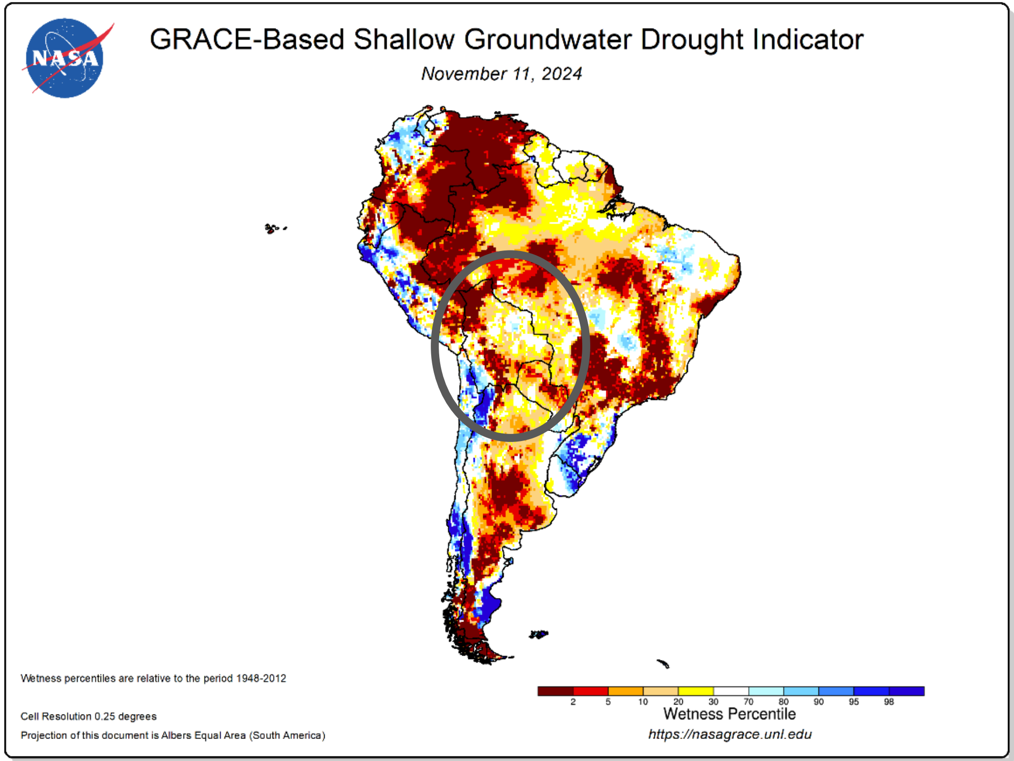
Target group: Lokal water experts, farmers and energy suppliers

Methods: Data analysis, workshops, integrated modelling, economical evaluation

Target region and climate



Trends from satellite data (Grace - Gravity Recovery and Climate Experiment)



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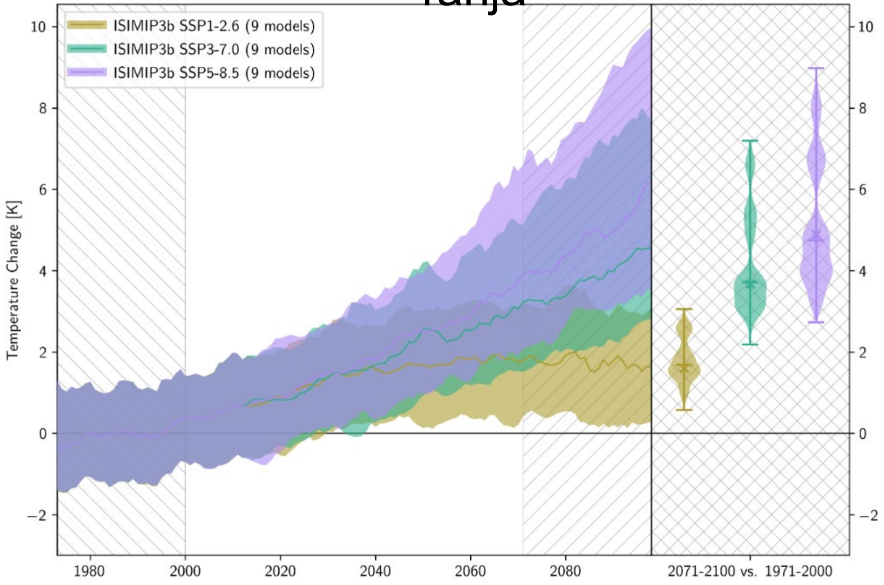
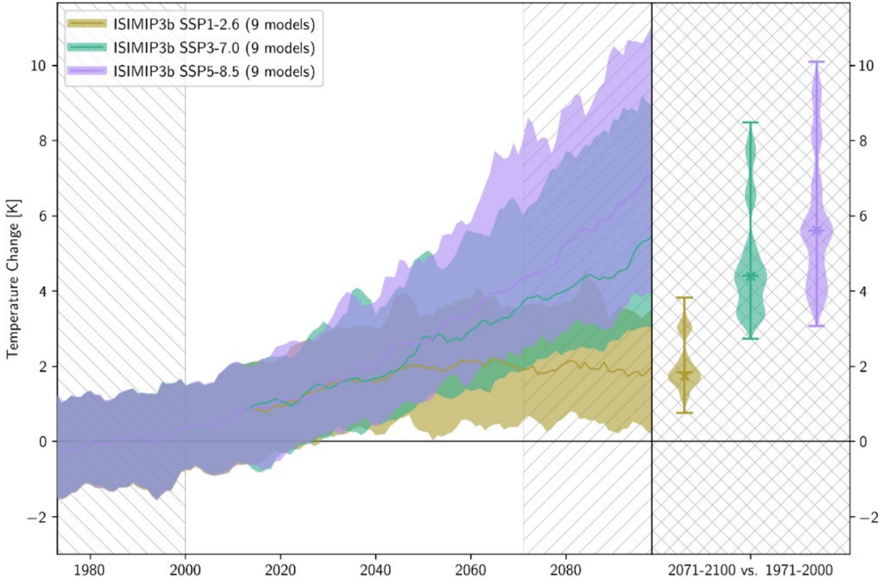
Climate change – temperature
(10 CMIP6-GCM-Läufe pro Szenario mit Downskaling und Korrektur)

Tarija

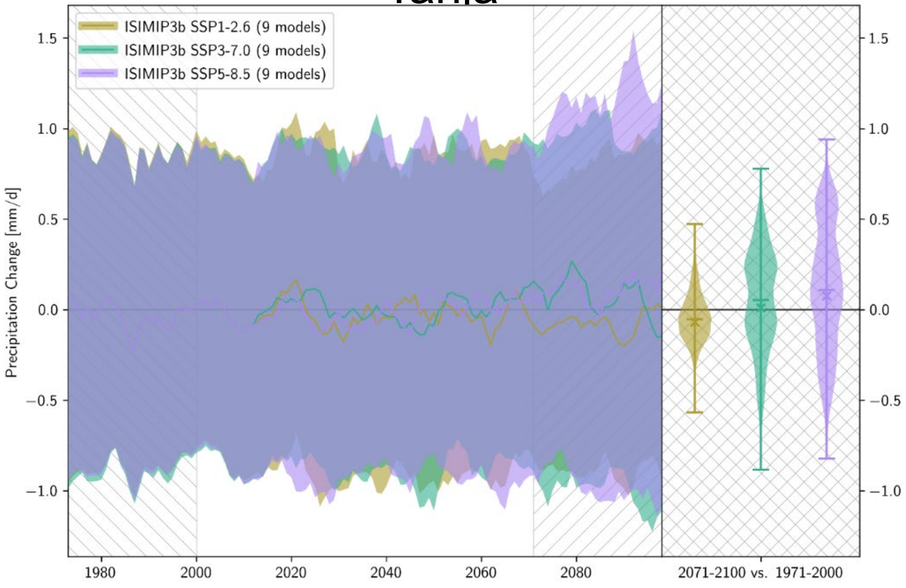


Santa Cruz

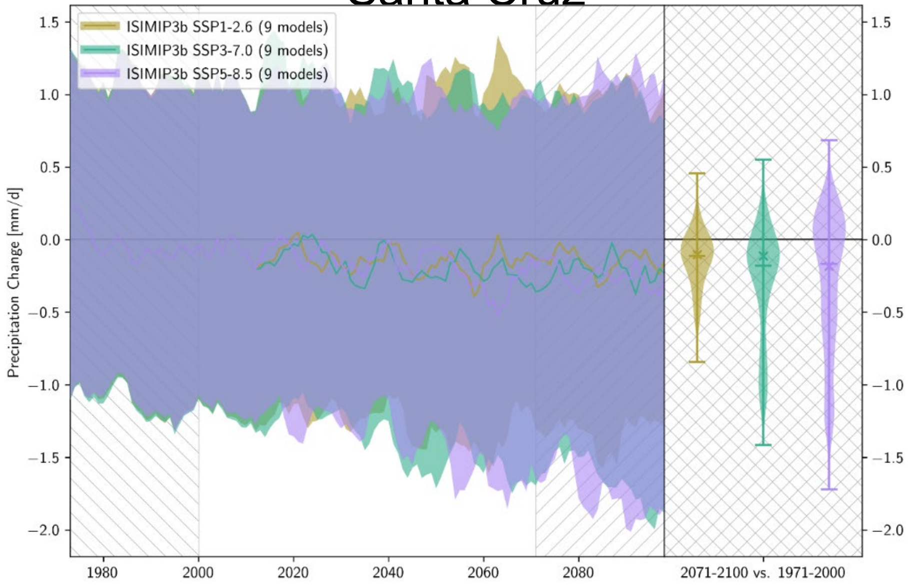


Precipitation
(10 CMIP6-GCM-Läufe pro Szenario mit Downskaling und Korrektur)

Tarija



Santa Cruz



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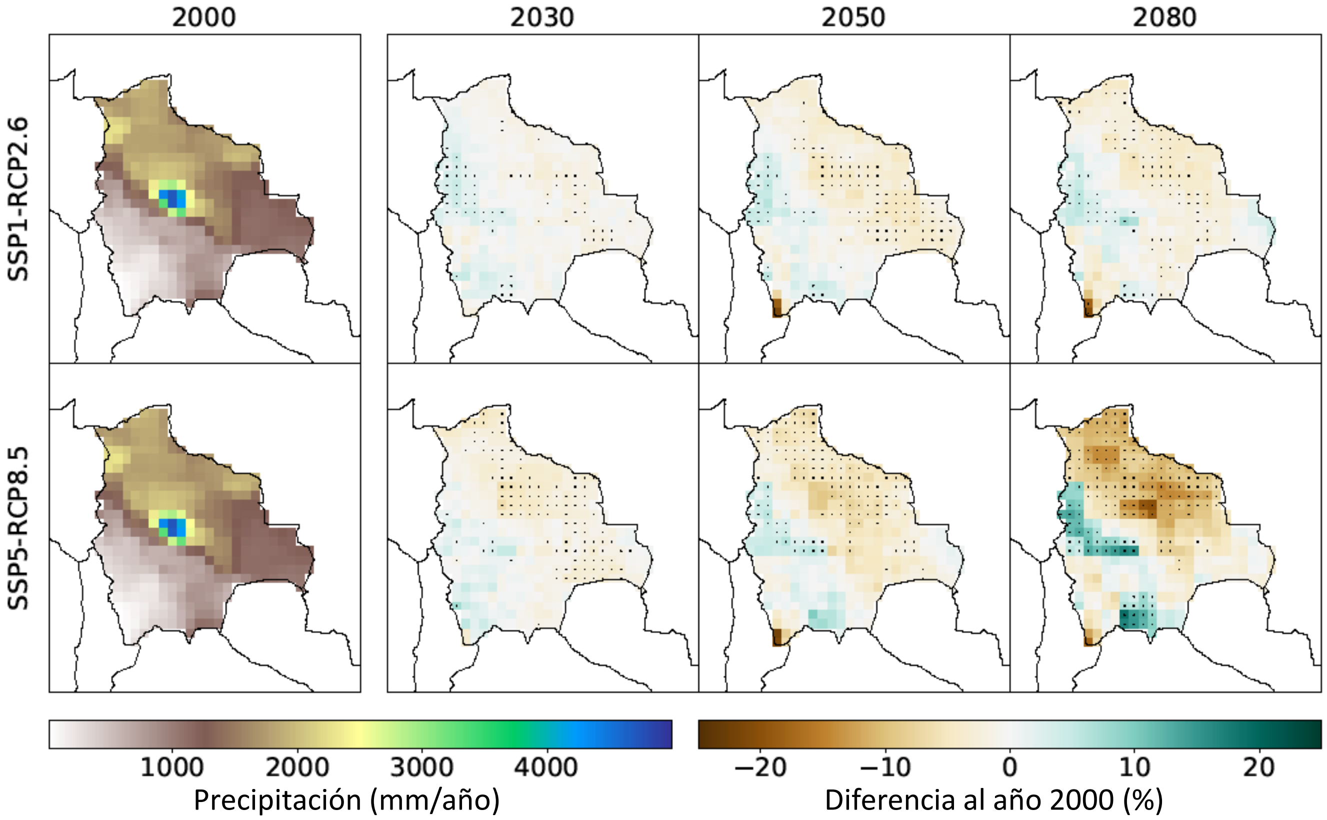

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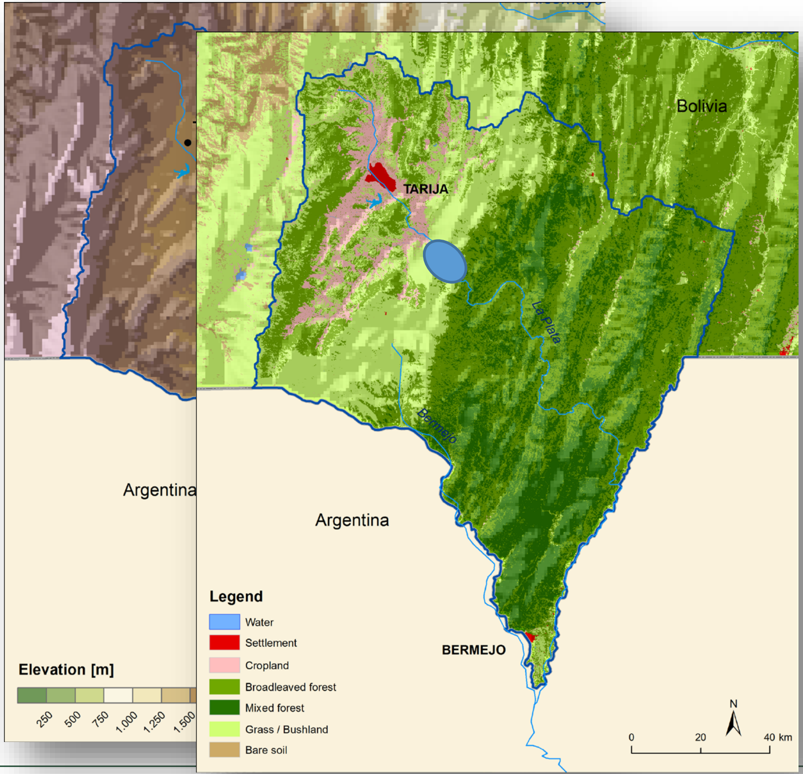
Tarija-Basin



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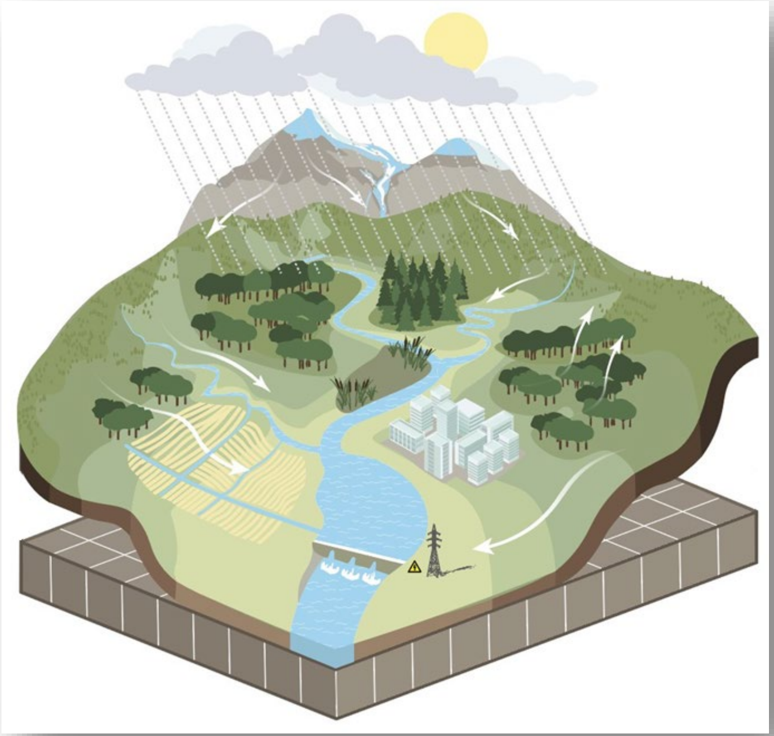
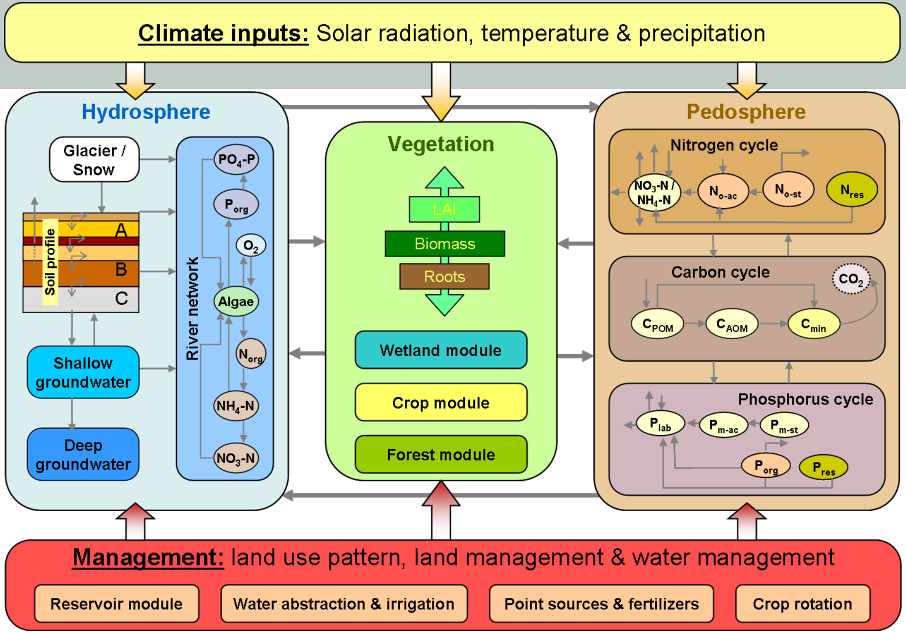
SWIM ecohydrological Model

Soil and Water Integrated Model

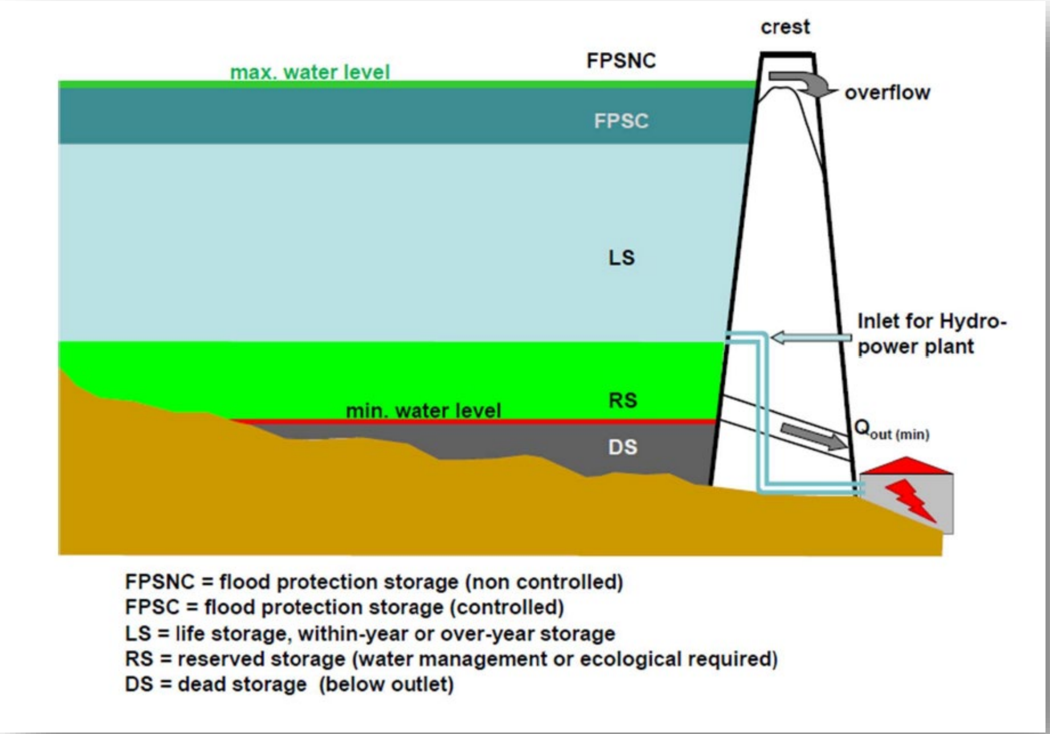




- Water and vegetation processes
- Agriculture and natural vegetation (forests, grasslands, ...)
- Water management (irrigation, dams, hydropower, ...)

Krysanova et al. 2015, Hattermann et al. 2011, 2015

The reservoir modul: Parametrization



- 63.0 million m^3 Maximum capacity of Reservoir
- 17.8 million m^3 Dead storage
- 54.15 m Maximum fall heigth of HPP

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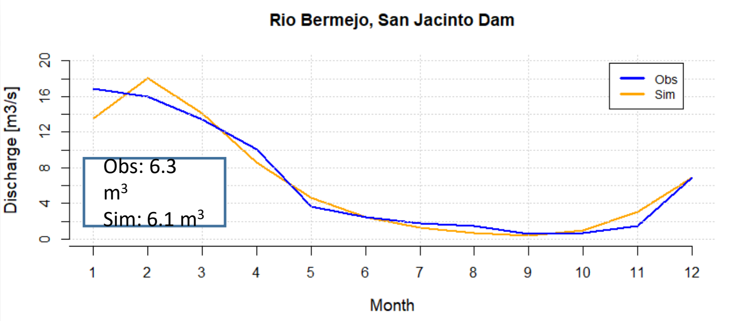
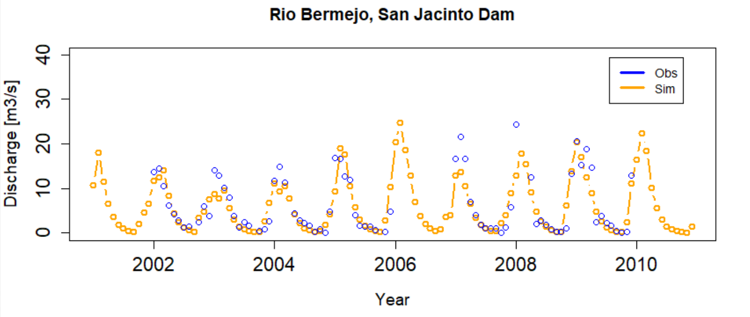
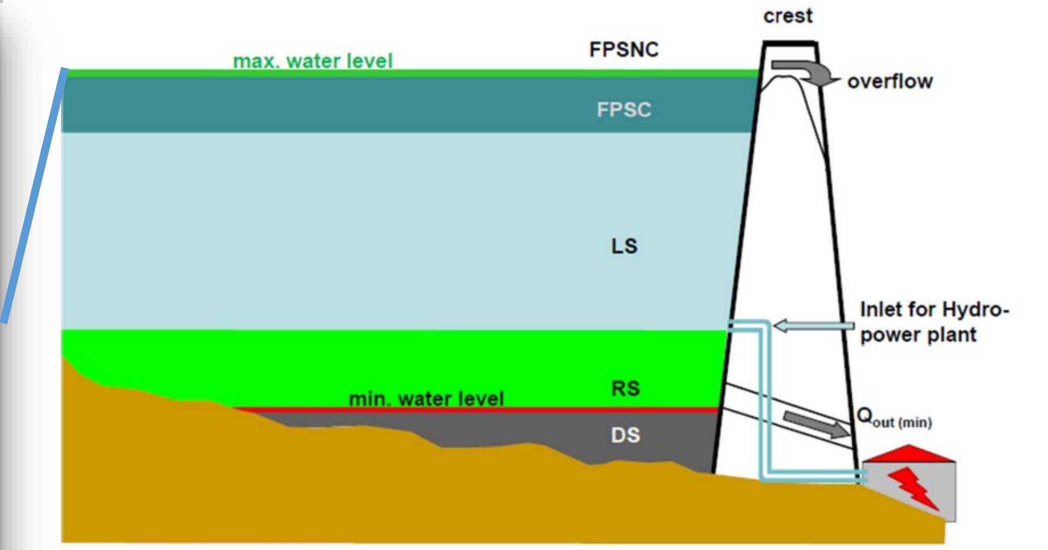
Reservoir: Discharge observed and simulated

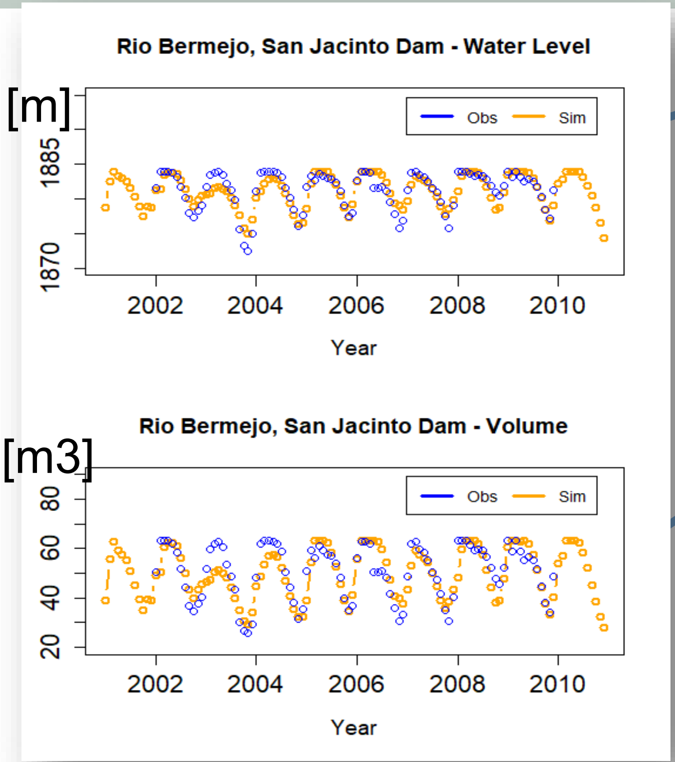


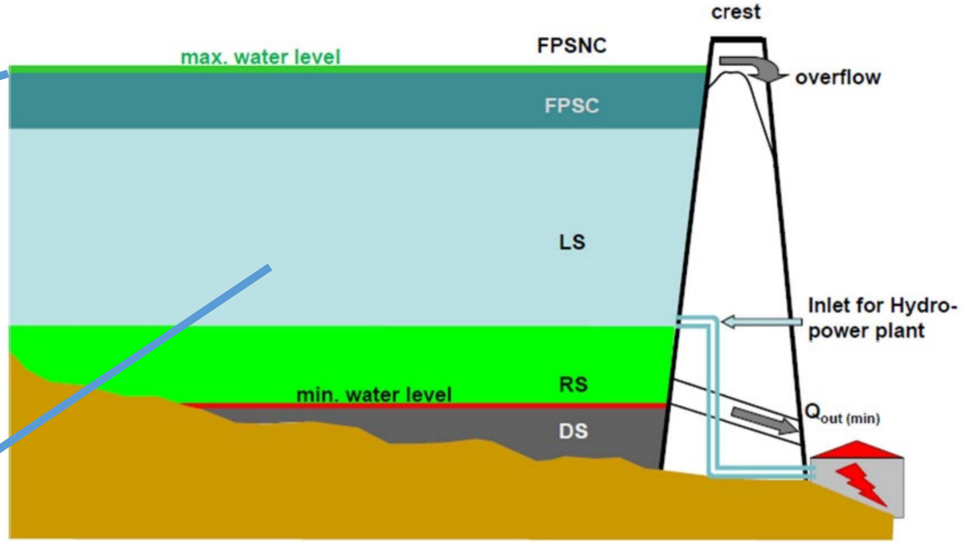




FPSNC = flood protection storage (non controlled)
FPSC = flood protection storage (controlled)
LS = life storage, within-year or over-year storage
RS = reserved storage (water management or ecological required)
DS = dead storage (below outlet)

Reservoir: Water level and volume





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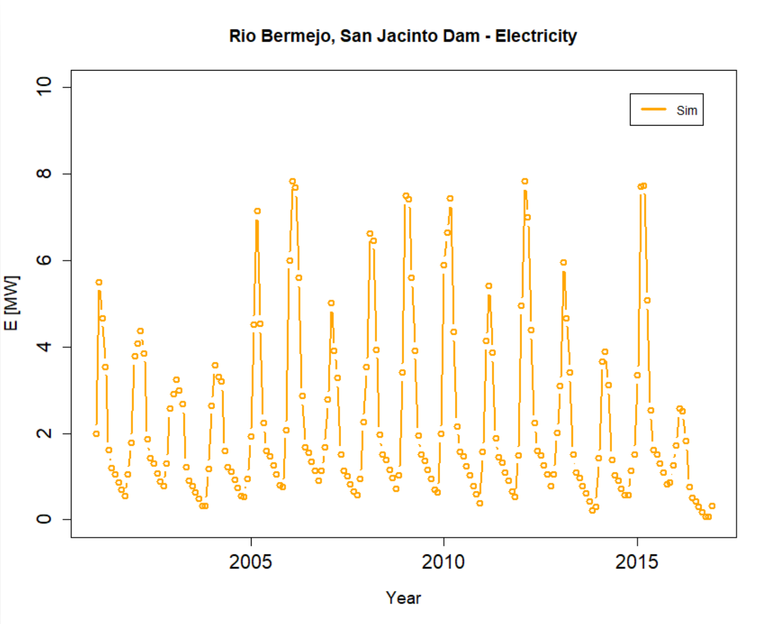
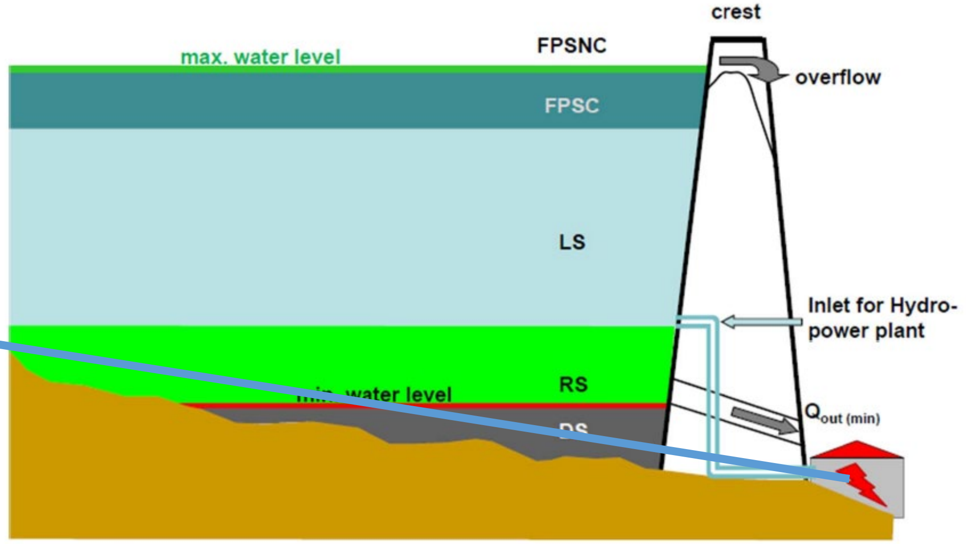
Reservoir: Hydropower





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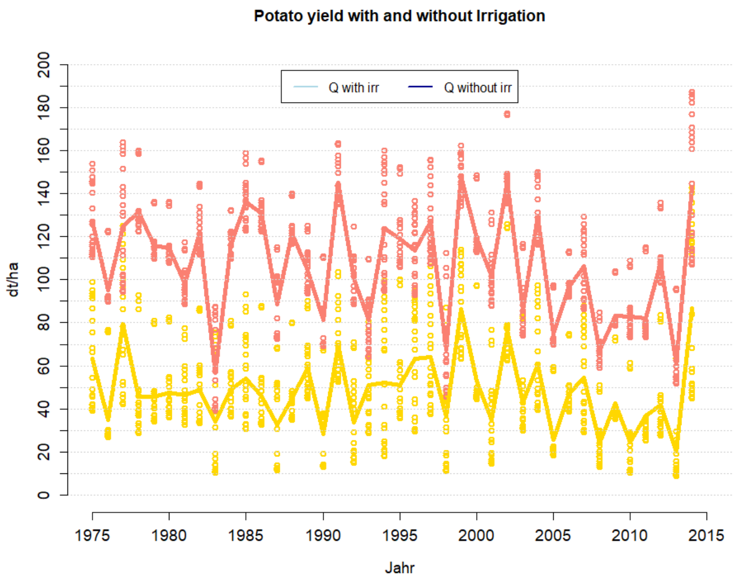
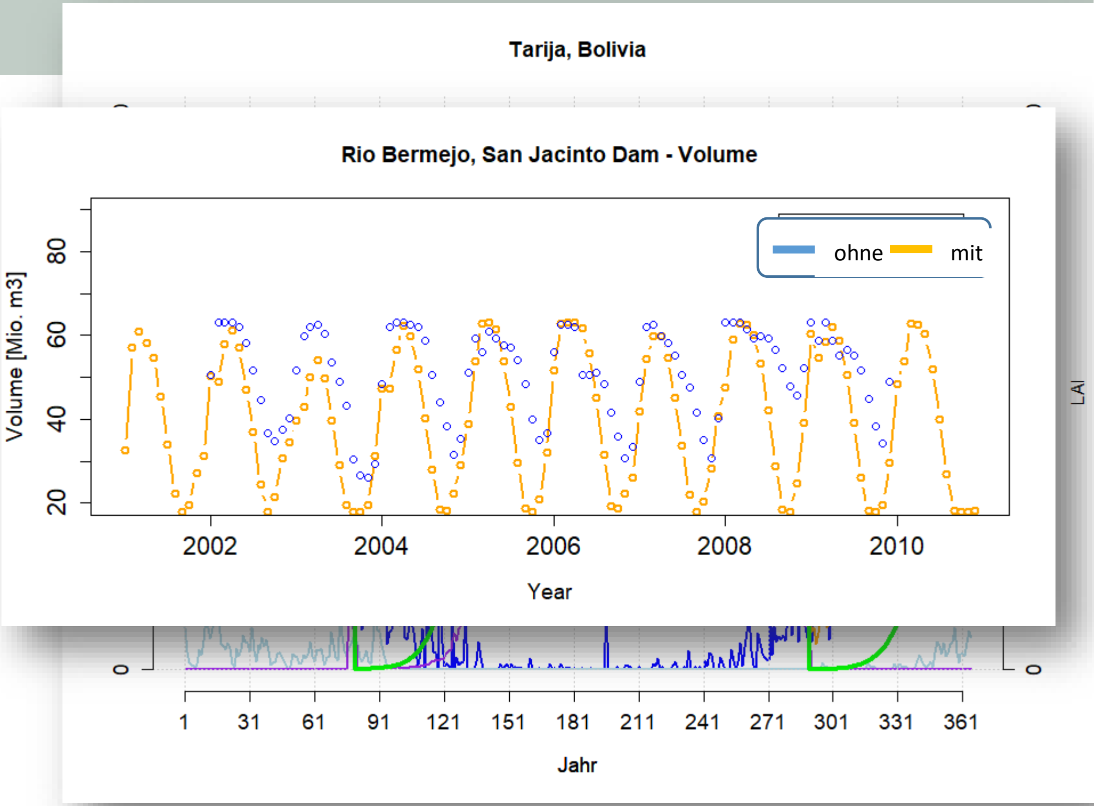
Example irrigation

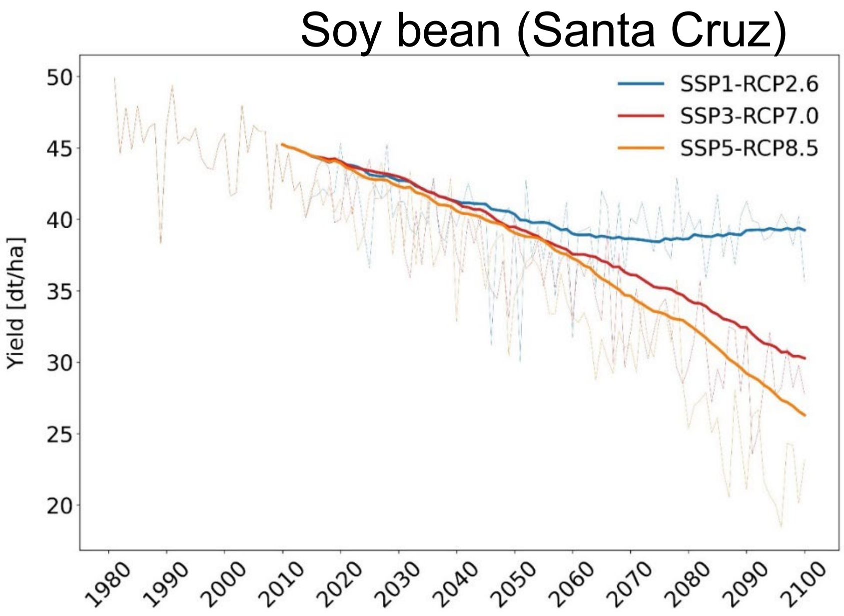


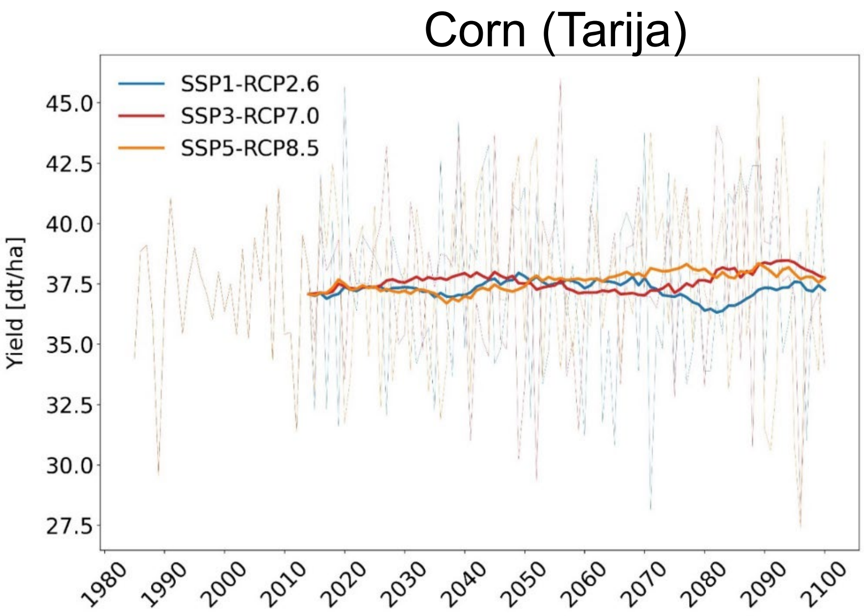


Scenario development Tarija

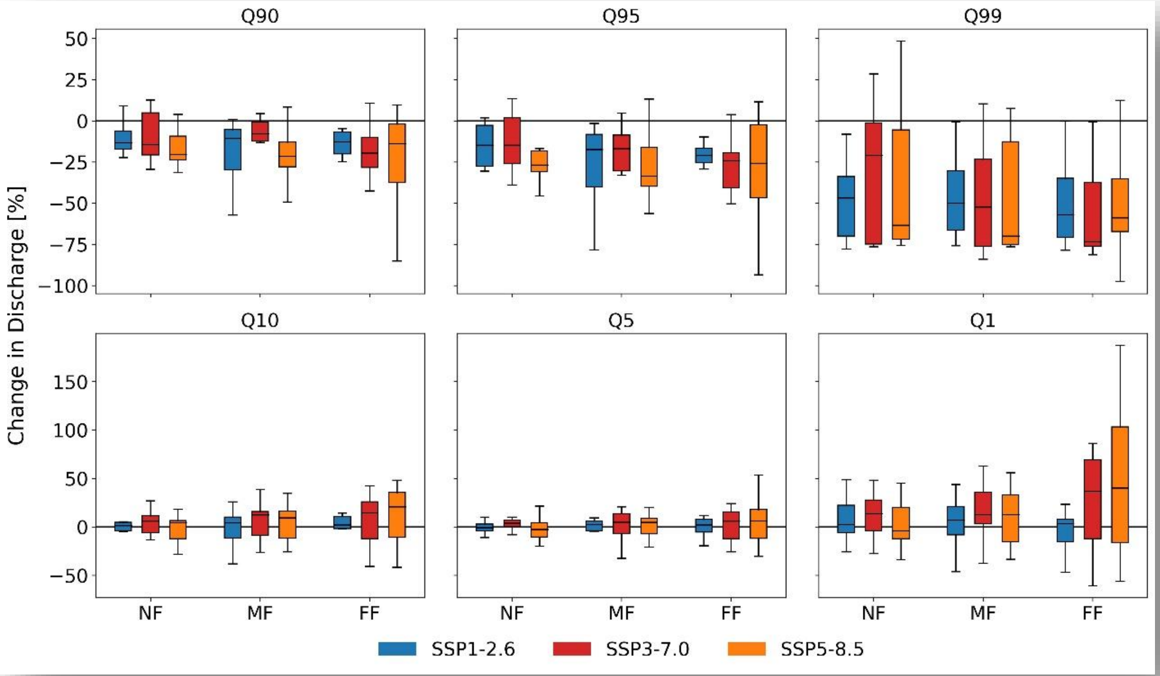
Scenarios	Change of crop rotations	Irrigation of strawberries	Change of reservoir management
Baseline (under current climate conditions)	Corn cultivation	S fl	Priority (first operational objective) on hydropower generation with generation peaks in rainy season, second objective is irrigation (no flood control)
Noadaptation (under CC)			
No regret (under current climate conditions)	Wine	S with drop irrigation	Priority on irrigation, second goal hydropower generation (peak generation in rainy season, no flood control).
Adaptation (under CC)			

Development of crops under CC



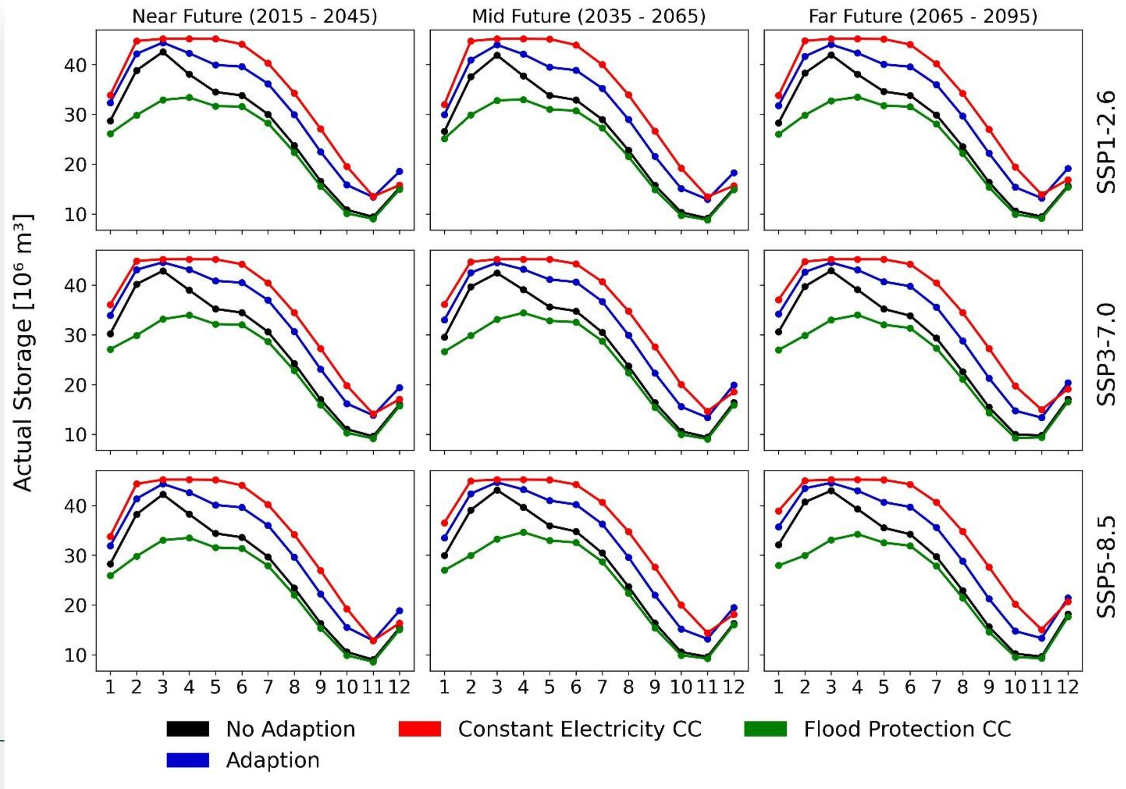


CC impact on discharge into reservoir



Indicators of low (Q90, Q95, Q99) and high runoff (Q10, Q5, Q1) in San Jacinto. SWIM simulations driven by 10 bias-adjusted CMIP6 models and three scenarios.

Water volume in reservoir under scenario conditions



Summary example 2

- Climate change has different manifestations in the different regions of Bolivia;
- The different adaptation strategies are now being systematically simulated and discussed with the experts and those affected;
- Based on this, an economic evaluation will be carried out;

Groupwork

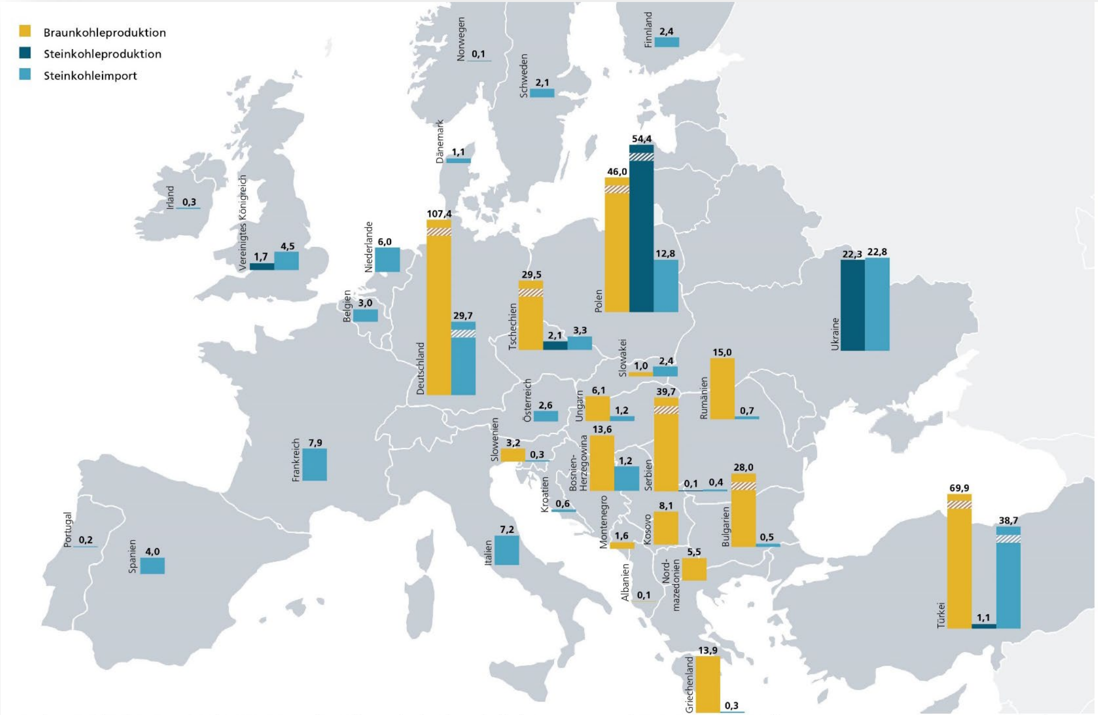
Problem/ Pressure	Solution*	Adaptation measure	Remarks

*A problem may have more than one solution etc.

WEF Nexus Examples

3 Water management in mining areas of east Germany

Coal mining and import Europe in Mio t (2019/2020)



Quellen: BGR (2019): BGR Energiestudie 2019 - Daten und Entwicklungen der deutschen und globalen Energieversorgung (DOI: 10.25928/eg-20189-tab), VDKI (2019), EURACOAL Marketreport 4/2021 (2020)

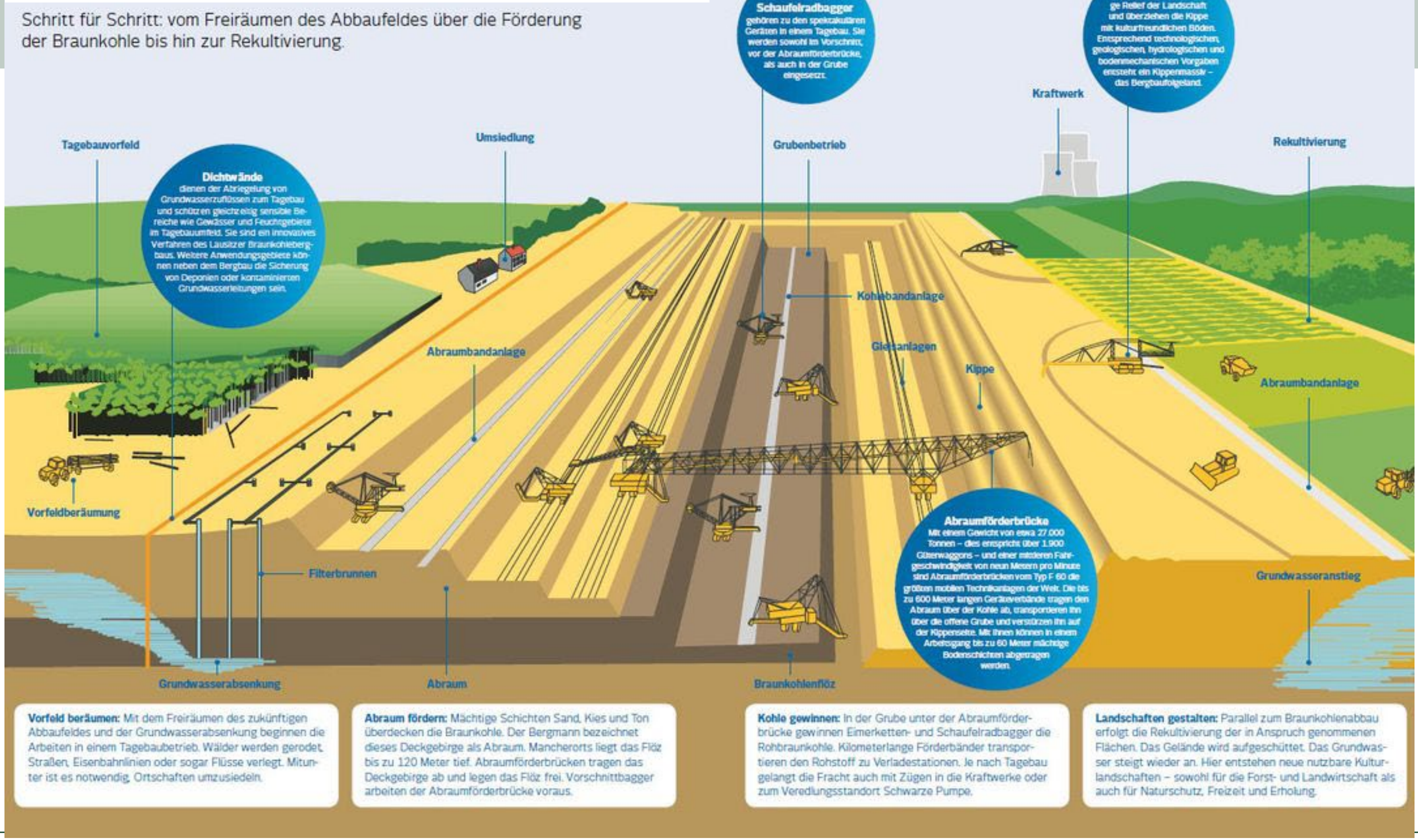
vorläufig, z.T. geschätzt

Stand: 04/2021

Germany is the European leader in lignite (brown coal) production with ~100 million t in 2020

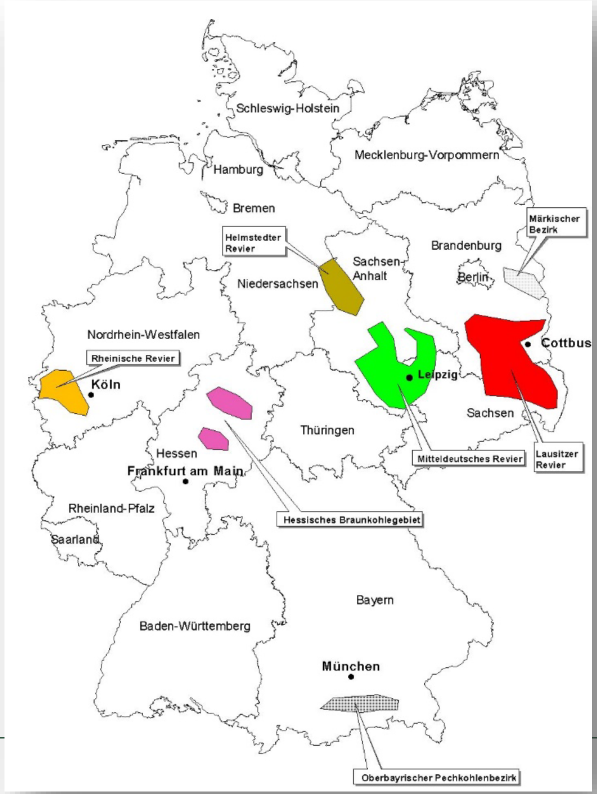
- Lignite/ brown coal mining
- Black coal mining
- Black coal import

What is open pit mining?



Brown coal mining in Germany

- Most of them are in East Germany
- Some in West Germany (e.g. Hambach)



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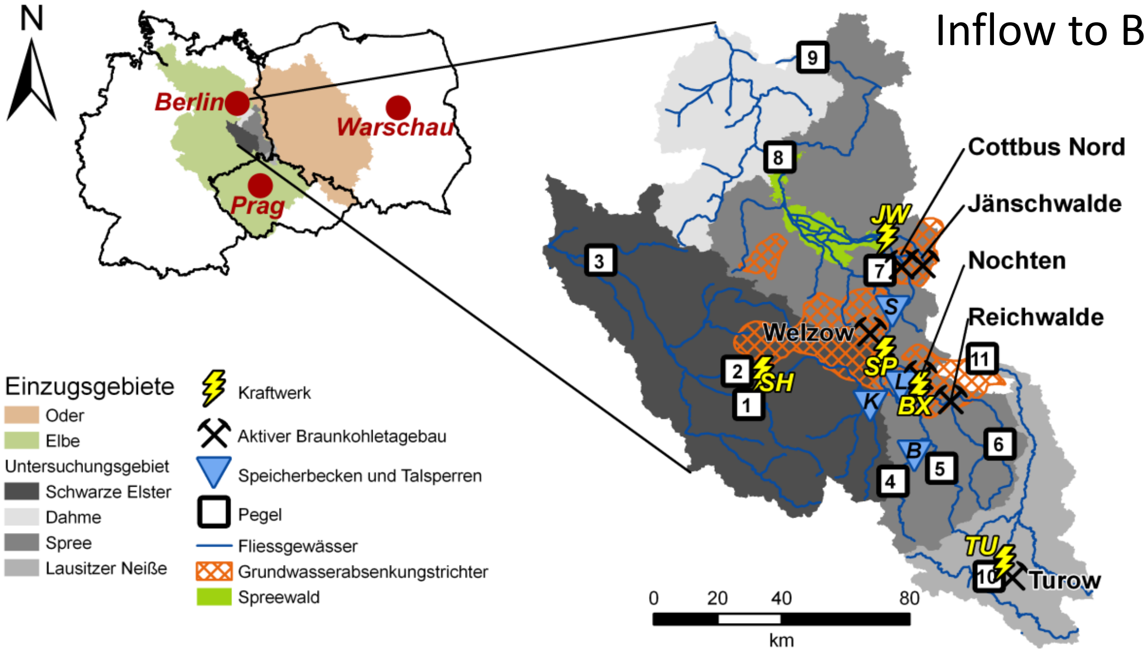
Overview of Lausitz mining district

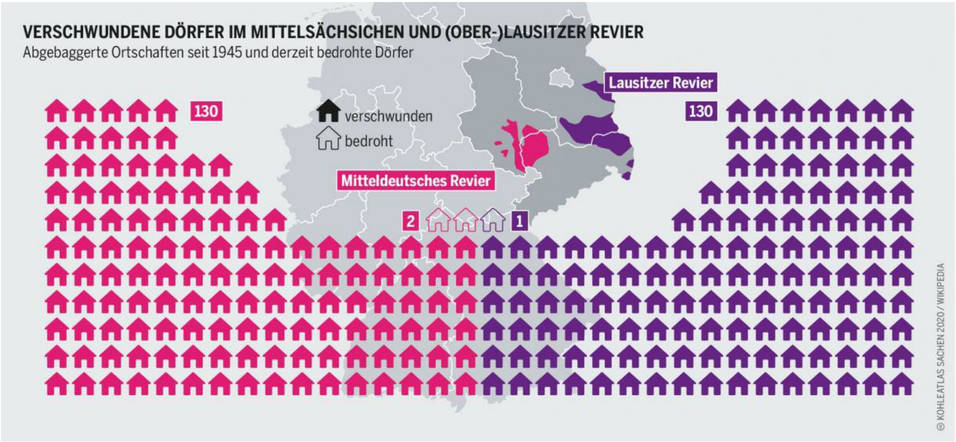


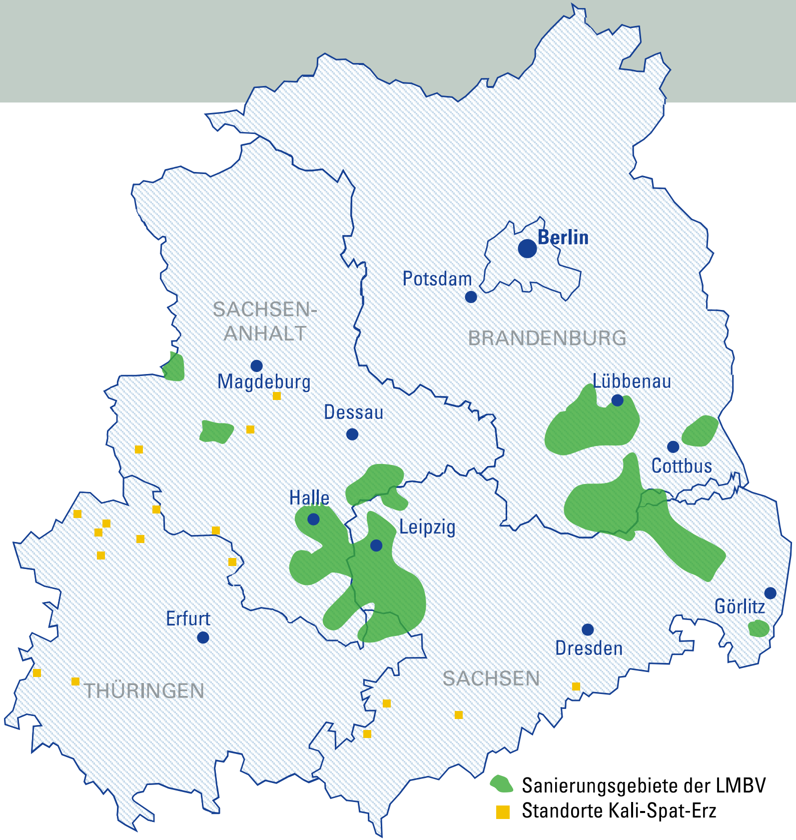
Gauge Große Tränke – Inflow to Berlin

Lusatian mining district - key figures

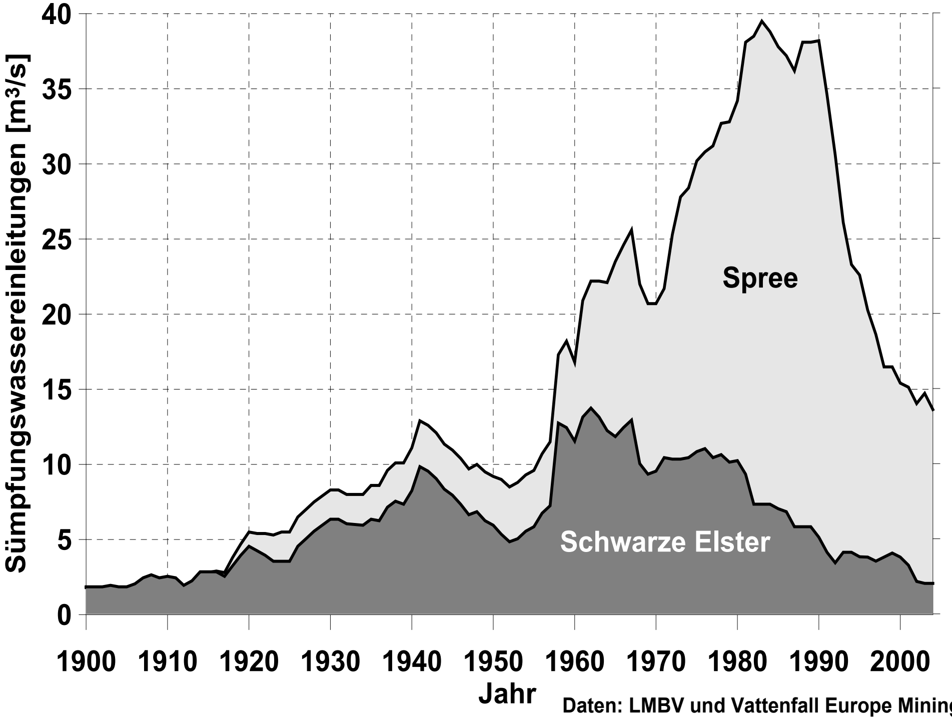
- **Ratio coal to water = 1:6** (For 1 million tonnes of raw coal ~ 6-7 million m^3 of water extraction)
- Landscape consumption per million tonnes of coal = 10 ha
- **Groundwater drawdown: 1-70 m below normal level**
- Groundwater drawdown catchment (1989) 2,100 km^2 (area of the federal state of Saarland)
- **Groundwater deficit (1989) 13 billion m^3**
  - Pore space 9 billion m^3
  - Backfilling of open-cast mining holes 4 billion m^3

Number of village destroyed





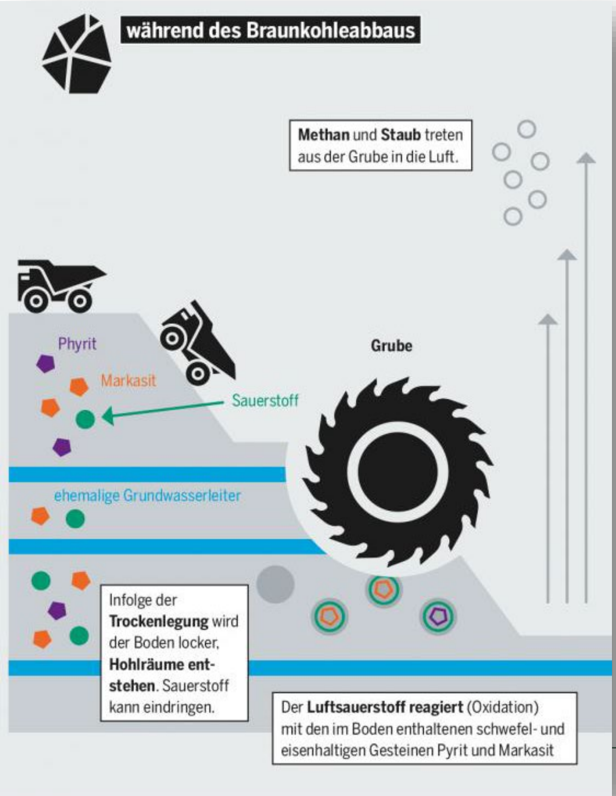
Discharges of water into the Spree and Schwarze Elster rivers



Daten: LMBV und Vattenfall Europe Mining

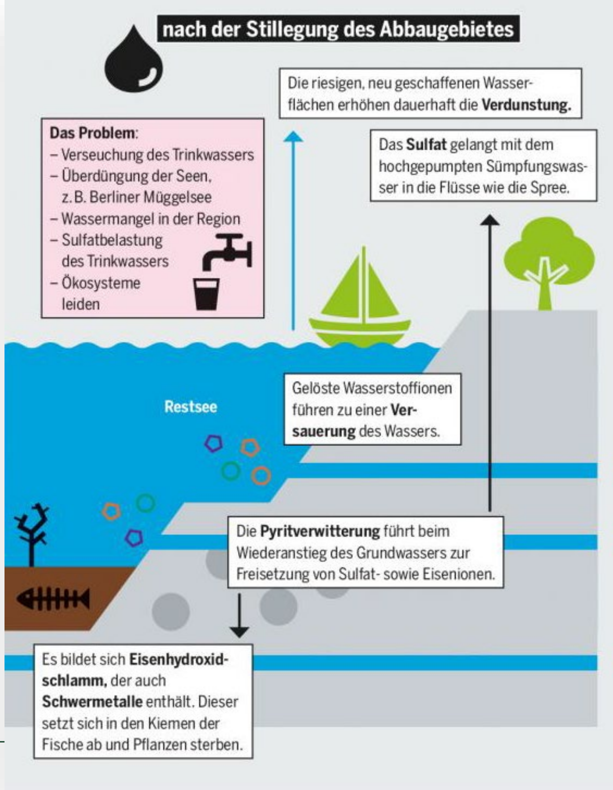
Effects of lignite mining on the soil and water balance

- Huge open pits
- Land and villages destroyed
- Withdrawl of water, lowering of GW table
- Huge impacts on hydrology and ecology



Effects of lignite mining on the soil and water balance

- Large water demand for flooding of pits
- Groundwater passes browncoal layers ->
  - Acidification
  - Iron clogging (Verockerung)



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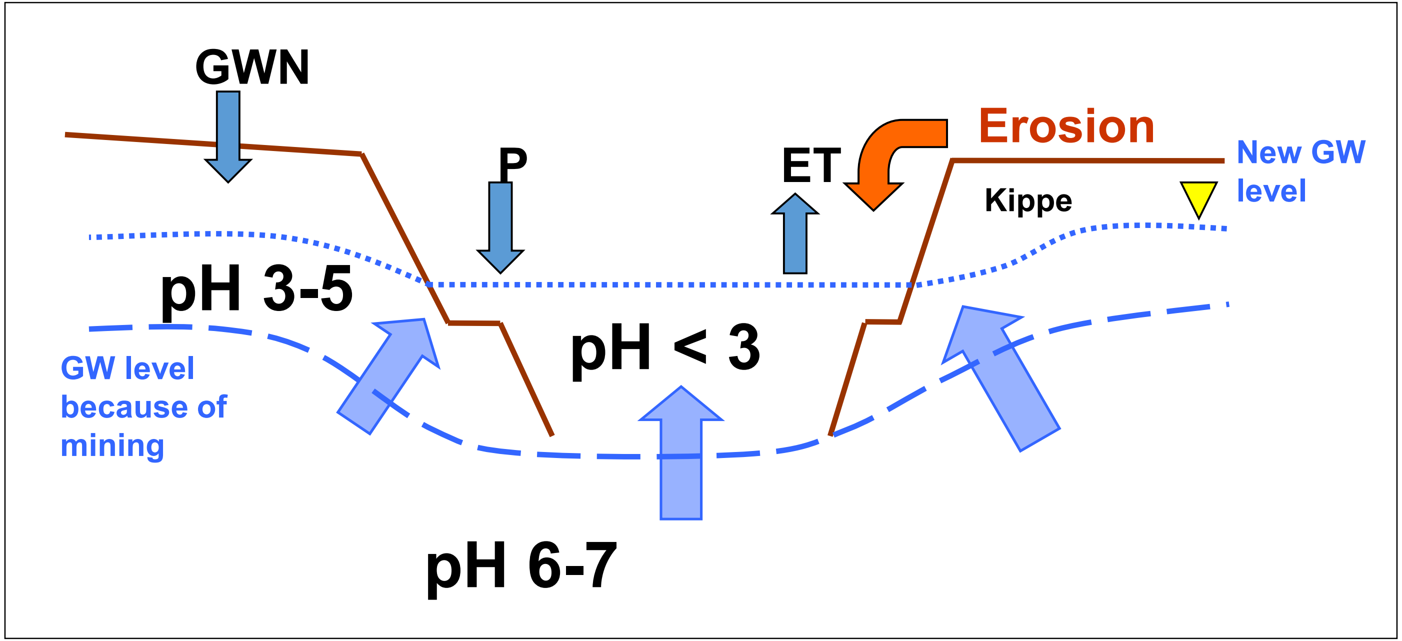
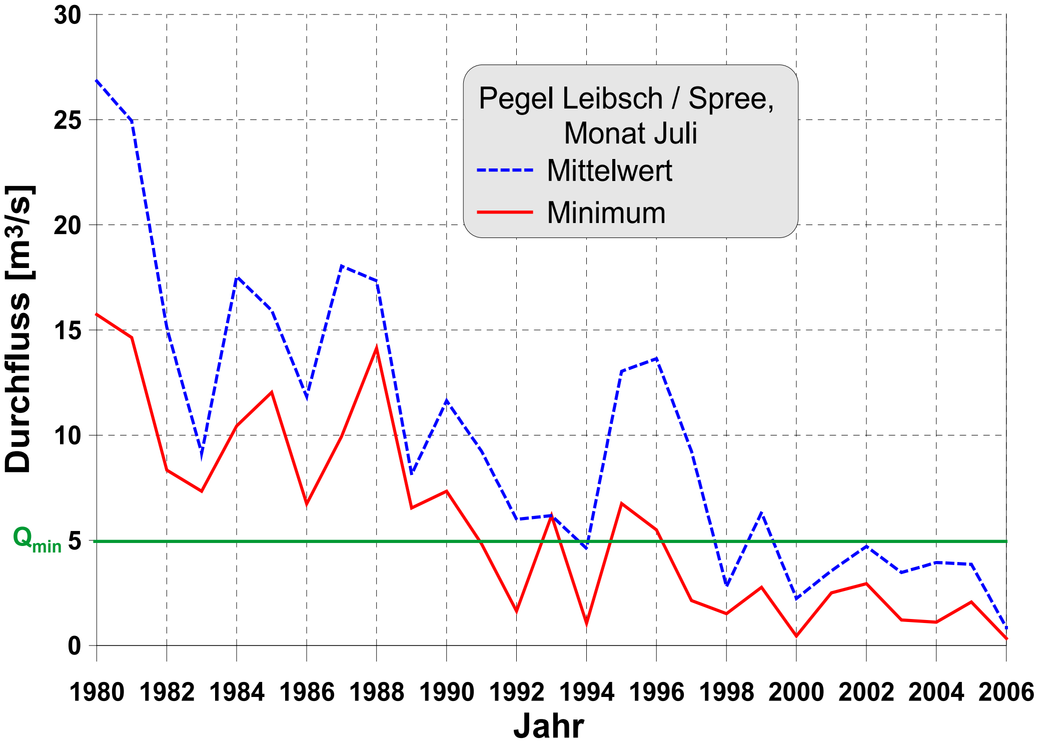
Self-flooding with groundwater (GW)



$$FeS_2 + 3{,}75\,O_2 + 0{,}5\,H_2O \rightarrow Fe^{3+} + 2\,SO_4^{2-} + H^+$$

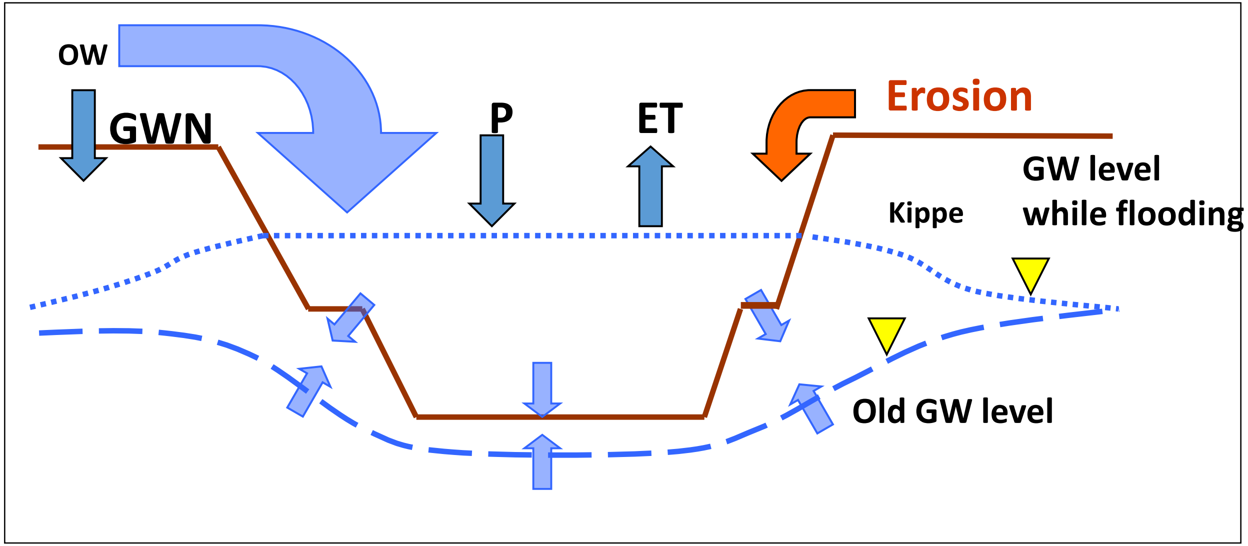
Iron clogging (Verockerung)

Discharge below Spreewald



Daten: LUA Cottbus

Water transfer (flooding) from next rivers



Benefits:

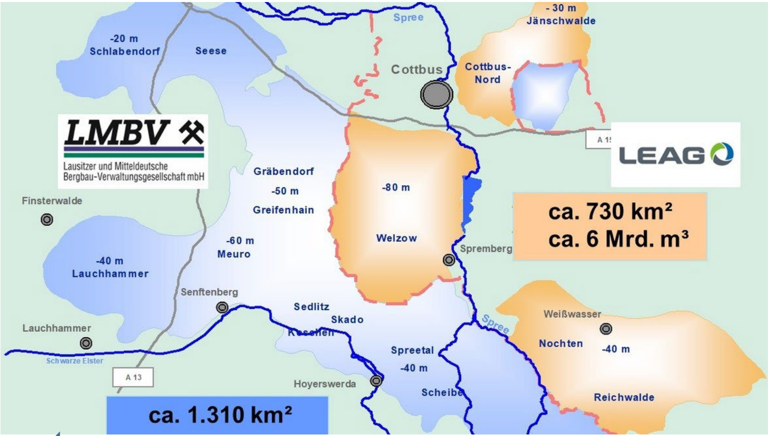
- Displacement of acid groundwater
- Dillution of acid lake water
- Chemical compensation/ neutralisation of the lake water

Challenges to restore the mining landscapes

Low water availability

Low discharge

Schwarze Elster bei Buchwalde



Water quantity

Water quality

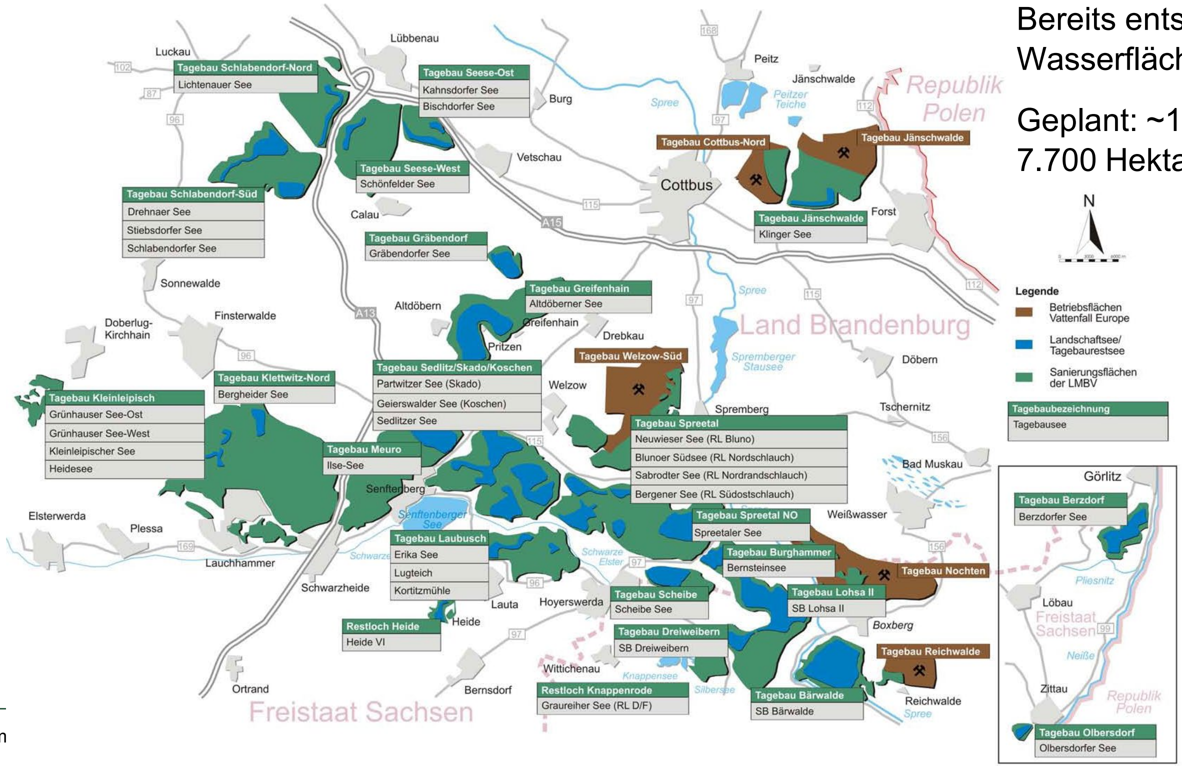
High concentration of sulfate

Iron clogging

acidification

Spree bei Bühlow

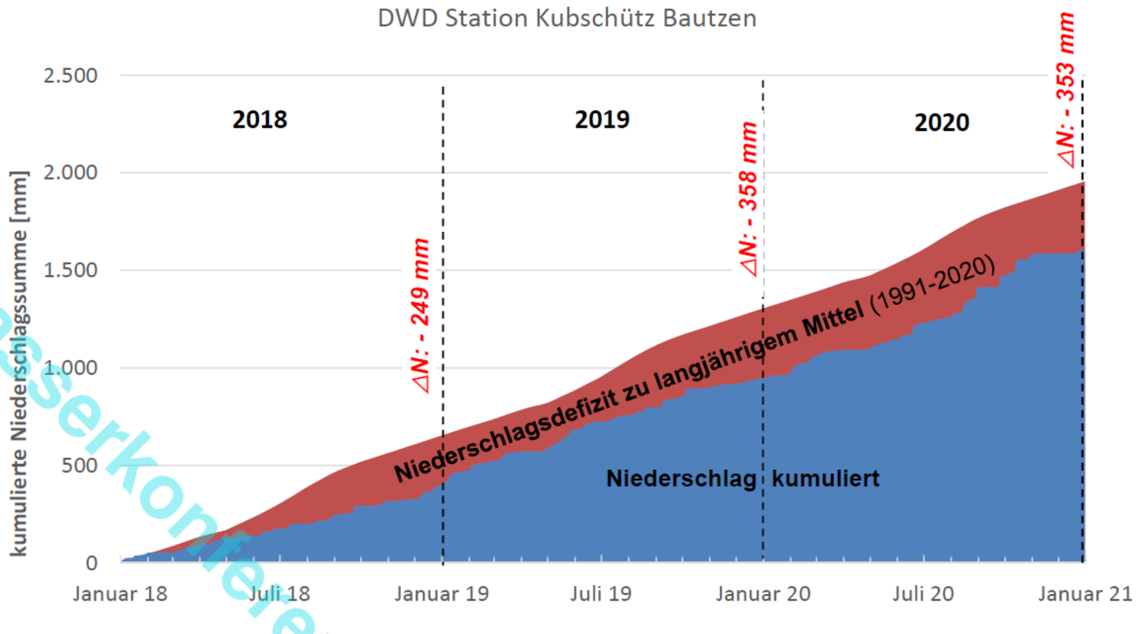
Water management concept – flooding of the pits



Bereits entstandene Wasserfläche = 14.000 ha

Geplant: ~16.000 ha (LMBV + 7.700 Hektar der LEAG)

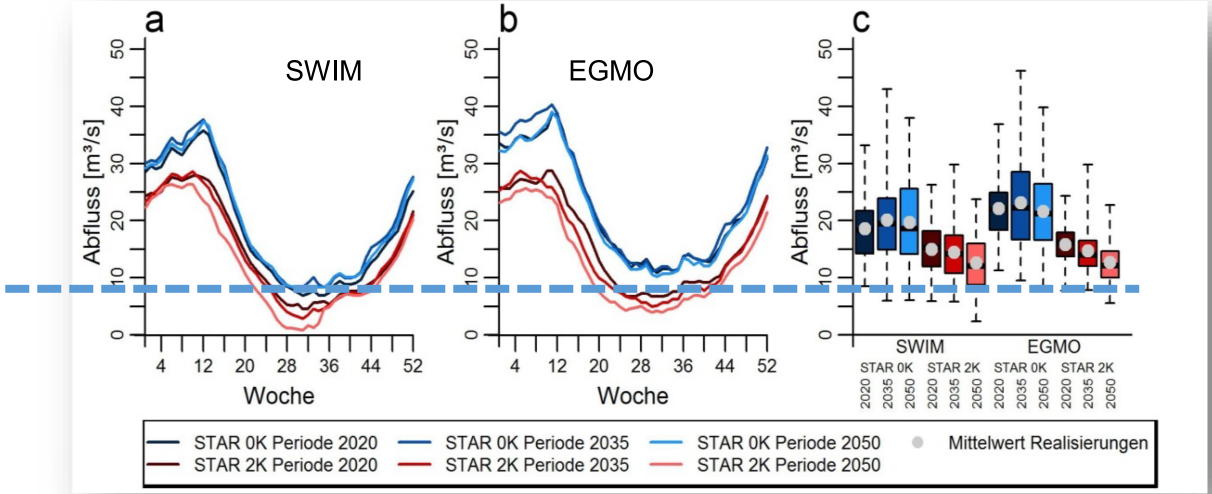
Water quantity – water deficits



Climate change impacts on Berlin inflow (8 m³/s needed)

Un-managed flow Große Tränke

Q_{min}= 8,00 m³/s



Groupwork

Problem/ Pressure	Solution*	Adaptation measure	Remarks

*A problem may have more than one solution etc.

Adaptation options

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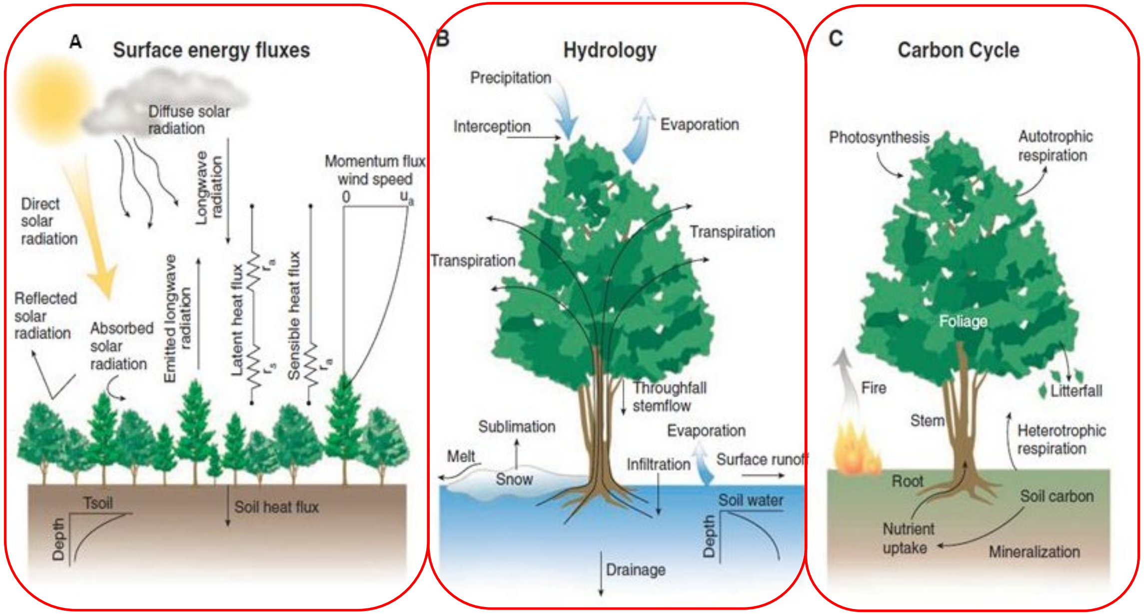
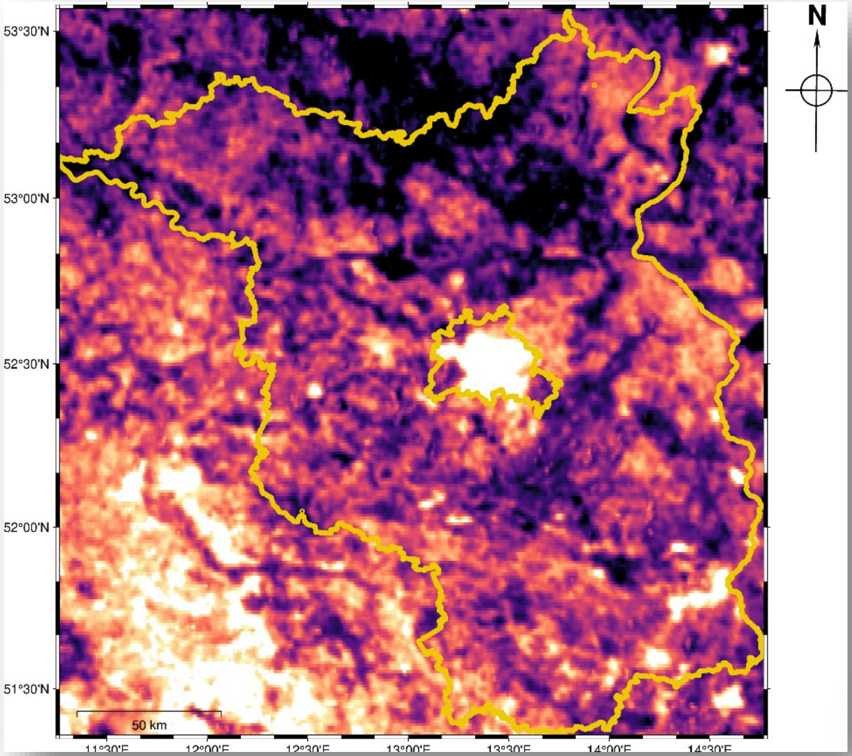
Water deficit in Germany

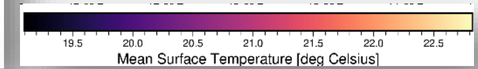
Energy – Water – Carbon

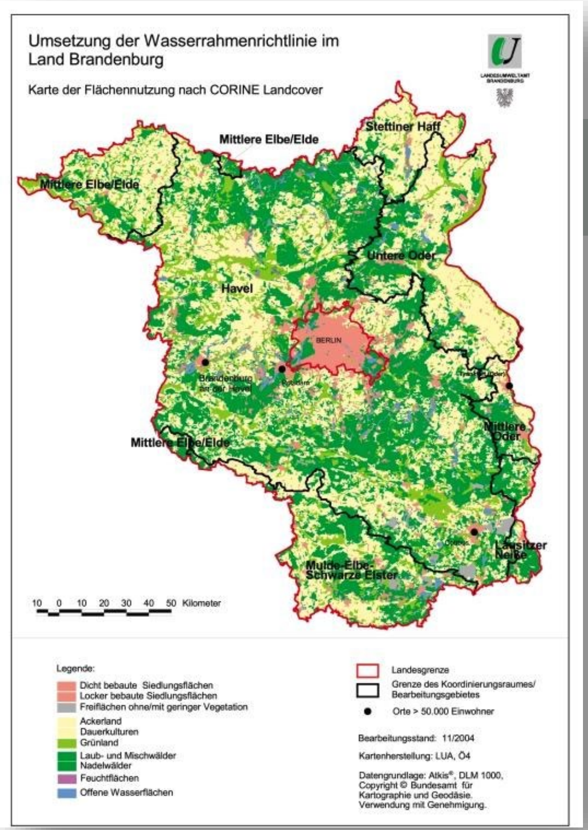


Source. Bonan et al. 2008

Thermal image (Landsat, August)





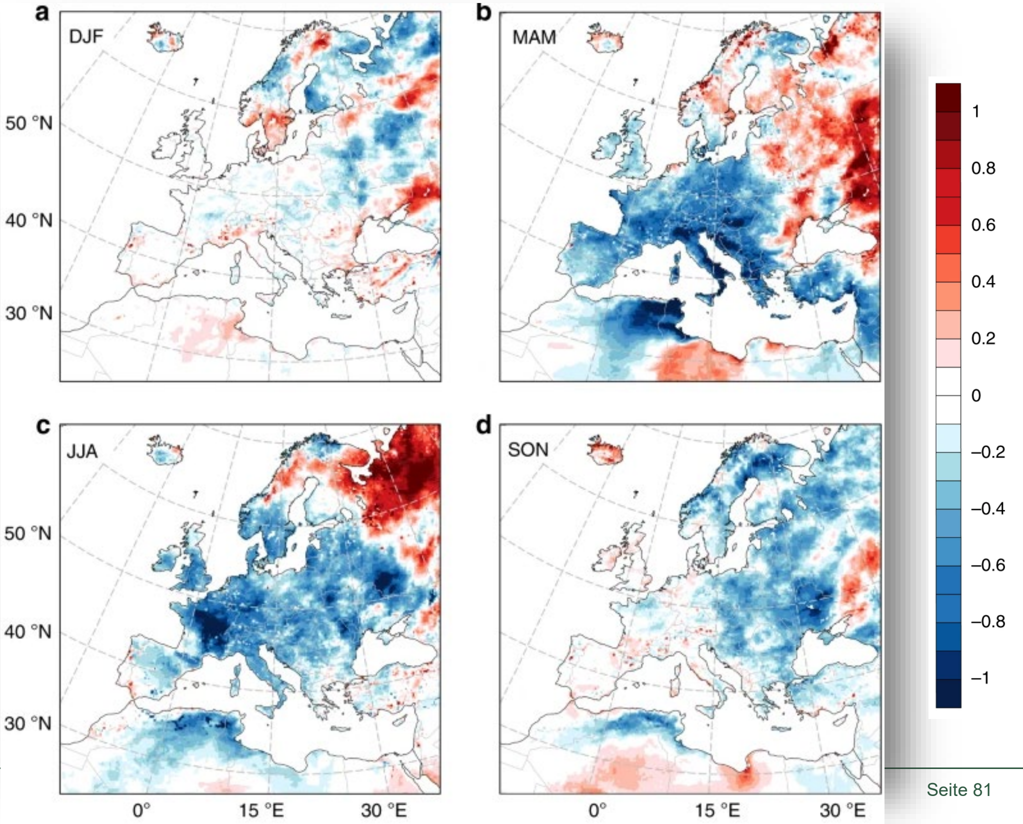


Predominant regional biophysical cooling from recent land cover changes in Europe (Huang et al. 2020, *Nature Communications*)

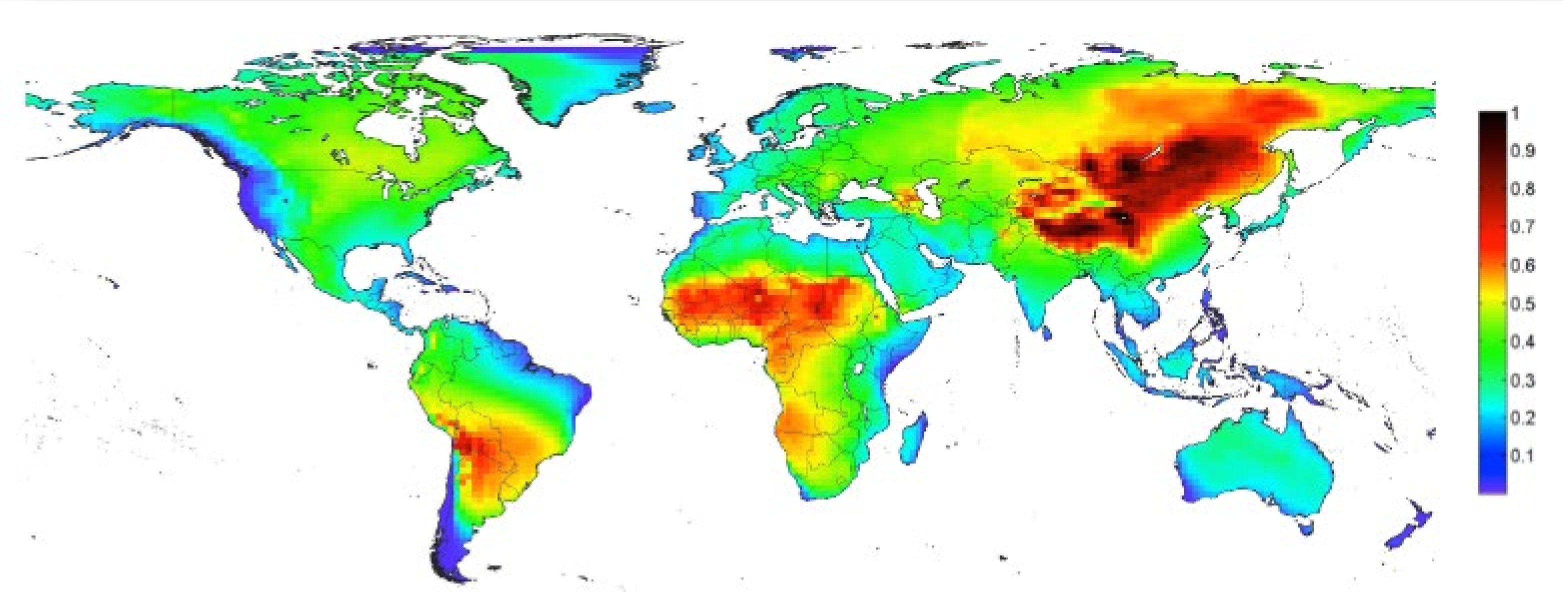
From 1992 to 2015, approximately 25 Mha of agricultural land was left abandoned. **Declines in agricultural land mostly occurred in favor of forests (15 Mha, 7 Mha of net gain) and urban settlements (8 Mha).**

Two simulations with the land cover in 1992 and 2015 are performed and the resulting relative differences in 2-m air temperature and surface air humidity investigated.

Regional climate model WRF (Weather Research and Forecasting model)



Proportion of annual precipitation from land evaporation.



Average ratio of recycled precipitation (1999-2008). The higher the number, the more precipitation comes from land evaporation (Van der Ent 2010 & 2014).

Forest conversion

Groundwater recharge is higher under broadleaf forest than under coniferous forest

About 40 % of Brandenburg is covered with forest, around 1.1 million hectares.
More than 75 % of this is pine forest.

Examples for adaptation in agriculture

Under discussion, but often of little effectiveness in practice:

- Reduced tillage
- Increasing the humus content of the soil
- Agroforest
- Higher water use efficiency through CO_2 fertilisation effect
- Adaptation to shift in the vegetation period
- ...

(Foto: Philipp Weckenbrock; https://www.uni-giessen.de/fbz/fb09/forschung/zentrenundprojekte/agroforst)

Irrigation

- In Brandenburg currently mainly in private areas, on sports fields, in parks, and for special crops (e.g. quality potatoes).
- High evaporation when applied during the day and with the usual technology
- High costs and high effort for the installation of drip irrigation

Maximal groundwater recharge

- Minimal evapotranspiration (low plants, shading of the soil).
- Protection against erosion caused by heavy rainfall
- Energy efficiency approx. 10x that of bioenergy

(https://um.baden-wuerttemberg.de/de/energie/erneuerbare-energien/sonnenenergie/photovoltaik/photovoltaik-freiflaechenanlagen/)

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Alternative Agri-Photovoltaik?

Solar panels over arable or vegetable fields (e.g. Fraunhofer ISE 2020).

Positive effects:

- Multiple use of the area
- Lower evapotranspiration due to shading
- Lower wind speeds
- Protection against heavy rain

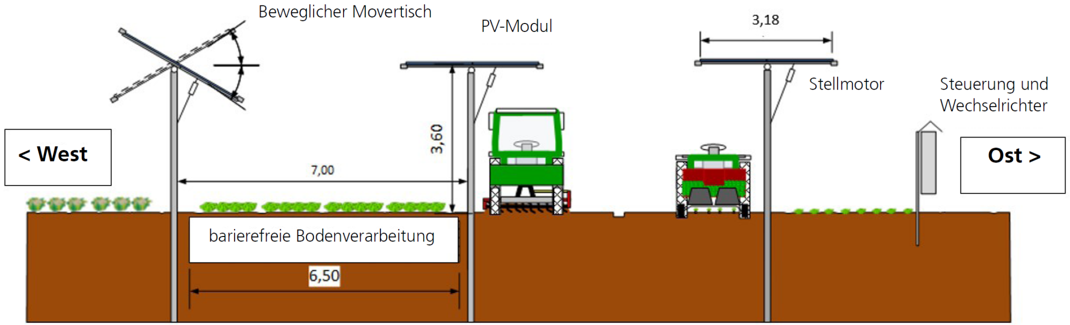
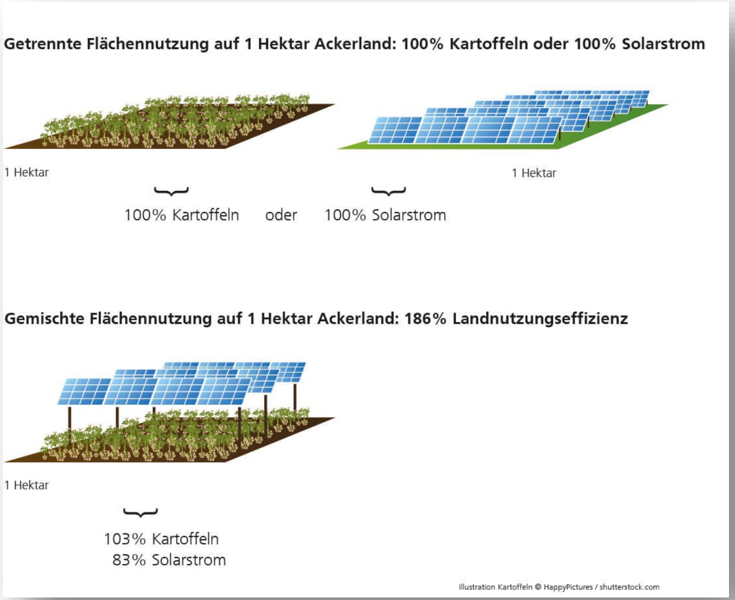
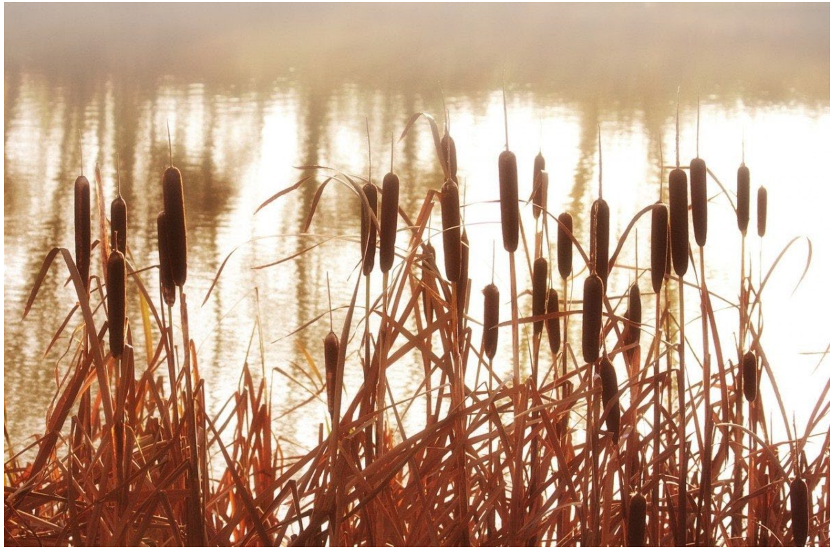


Bild 9: Querschnitt der Agri-PV-Anlage in Weihenstephan. © 2020 B. Ehrmaier, M. Beck, U. Bodmer



Water retention in wetlands/ paludiculture



Plus:

- High ecological value
- Cooling by evapotranspiration
- Carbon storage

Minus:

- The bog and riparian vegetation has never "learned" to use water sparingly.

=> Therefore, especially in small wetlands, disproportionate transpiration!

Sponge cities

Sponge city in Berlin

- Increase of groundwater recharge
- Flash flood protection
- Cooling effect

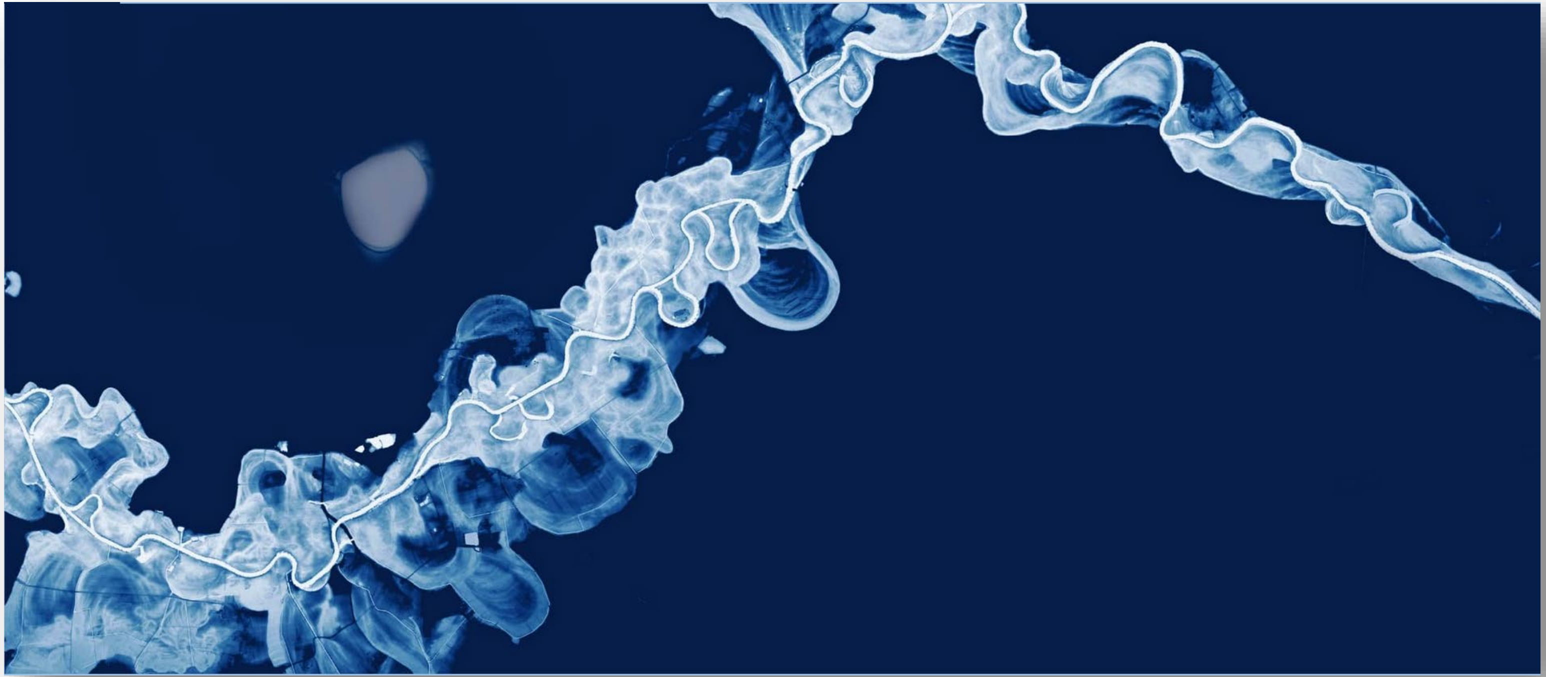
Adaptation in cities

Smart cities world

Adaptation inagriculture

LIFE AgriAdapt project

Restoration of river landscapes



Restoration of river landscapes

Possible task for the groupwork

Adaptation in a water related sector / field:

- Cities (adaptation to flash floods, droughts, heat waves),
- Nature based solutions in river basins or landscapes,
- Re-thinking water storage (at different scales),
- Adaptation to counteract erosion,
- Integrating adaptation and mitigation,
- Water re-use
- …

Groupwork

Problem/ Pressure	Solution*	Adaptation measure	Remarks

*A problem may have more than one solution etc.

Thanks!