Water Resources Engineering and Management

(CIVIL-466, A.Y. 2024-2025)

5 ETCS, Master course

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gruner

Lecture 9.1: Water Management: Allocation, balancing demand and supply

Course learning map

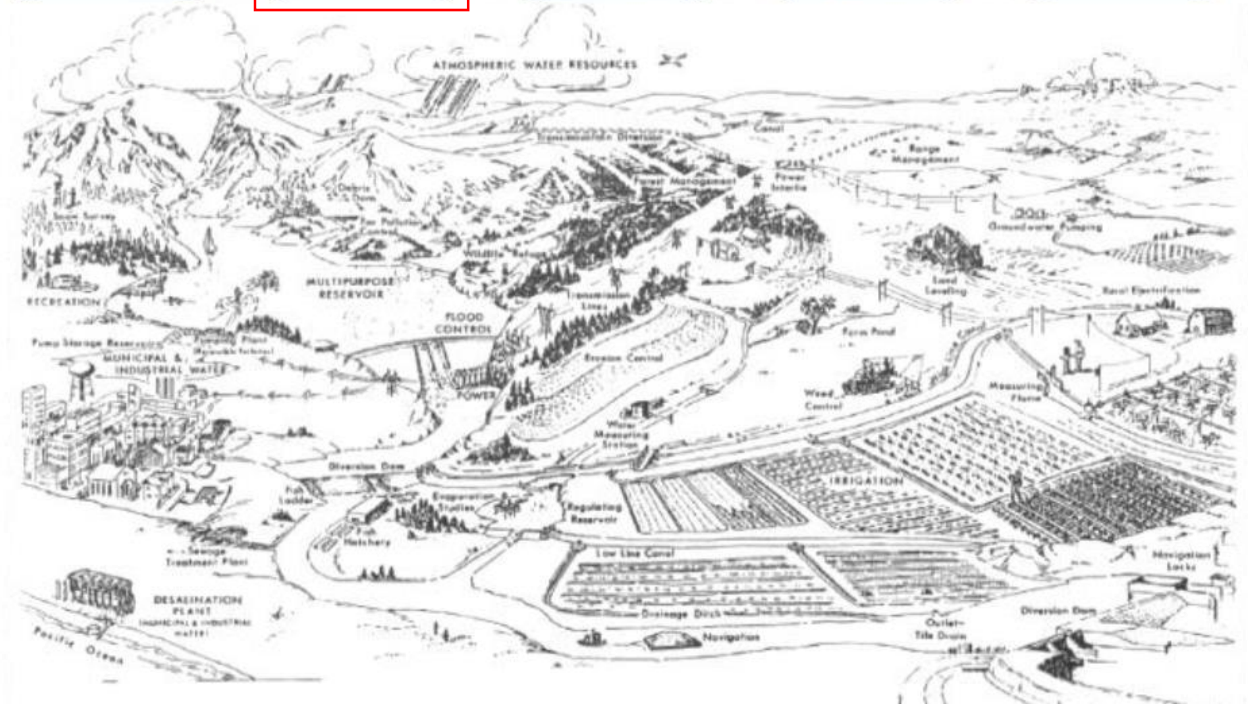
Water Resources Engineering | Water Resources Management

L1. Introduction, history of WRM, defs. → L2. Water availability and freshwater bodies → L3. Hydr. engineering and machines (Review) → L4-5. Water uses → L6-7. (Input) Data analysis and modelling → L8-9. EIA, conflict&coop optimisation → L10--11. Optimisation, eng. Economics, AQUARIUS → L12-13. Financial analysis and optimization in practice → L14. WRAP-UP and exam questions

Lecture 9.1 - Water Management: Allocation, balancing demand and supply

Lecture L9.2 - Water Management: conflict of interest & International river basins

Lecture L9.3 - Water Management: ESG & Sustainable Development



Have you ever wondered how we can ensure that there's enough water for everyone, while also protecting our environment and supporting economic growth?

Balancing demand and supply

Demand

- Institutional
- Commercial
- Domestic
- Industrial
- Public
- Waste and losses

Supply

- Rivers
- Lakes
- Reservoirs
- Springs
- Ground water
- Oceans

Balancing demand and supply

What drives changes?

- Population growth
- Regional development
- Industrial and urban development
- Water pollution
- Technological development
- Climate change

Balancing demand and supply

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

Where can we act?

- Demand-side solutions
  - Awareness campaigns and behavioral change
  - Water pricing and economic instruments
  - Smart meters and leak detection

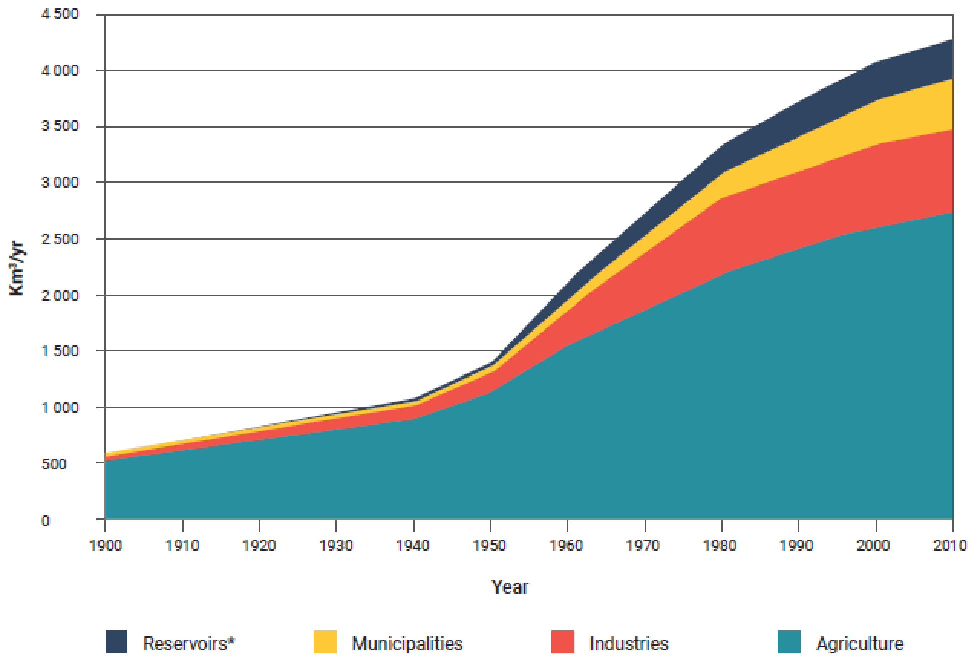
- Supply-side solutions:
  - Diversifying sources (e.g., reuse, desalination).
  - Rainwater harvesting.
  - Managed aquifer recharge.

- Integrated solutions:
  - Integrated Water Resources Management (IWRM).
  - Use of digital tools (forecasting, AI, digital twins, EO).
  - Nature-based solutions (wetlands, green infrastructure).

Balancing demand and supply

- **Challenges & trade-offs**
  - Equity and access to water.
  - Agricultural vs. urban needs.
  - Transboundary water management issues.

Balancing demand and supply

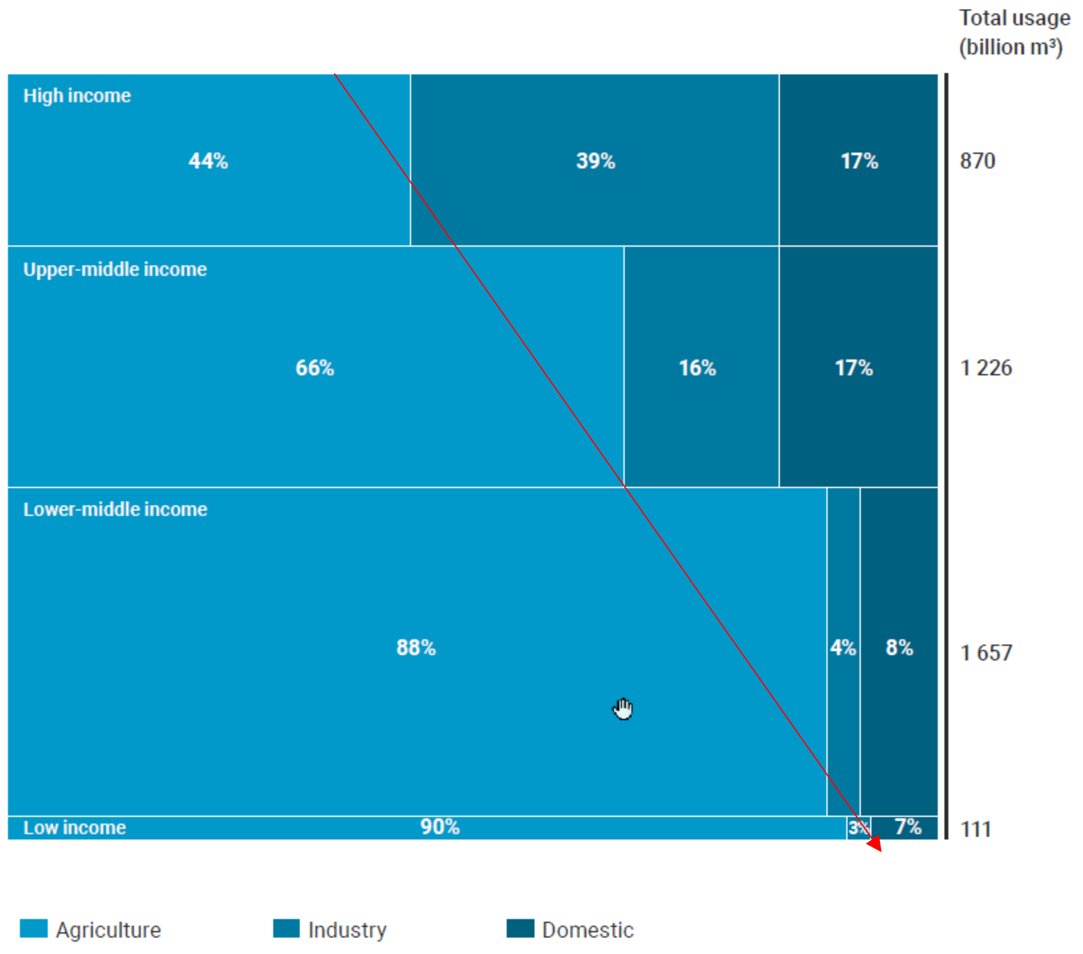


Source: Valuing water – The United Nations Water Development Report 2021

- Global freshwater use increased by a factor of 6 over the past 100 years.
- The main growth comes from emerging economies
- Agriculture accounts for about 70% of global water withdrawal (mainly irrigation) – It can reach 95% in some developing countries
- Industry (including energy and power generation) accounts for about 20%
- Municipalities account for about 10%

Balancing demand and supply

Figure P.1
Water withdrawal by sector (% of total freshwater withdrawal) by income group, 2020



Source: Kashiwase and Fujs (2023, based on data from FAO AQUASTAT).

Source: Water for prosperity and peace– The United Nations Water Development Report 2024

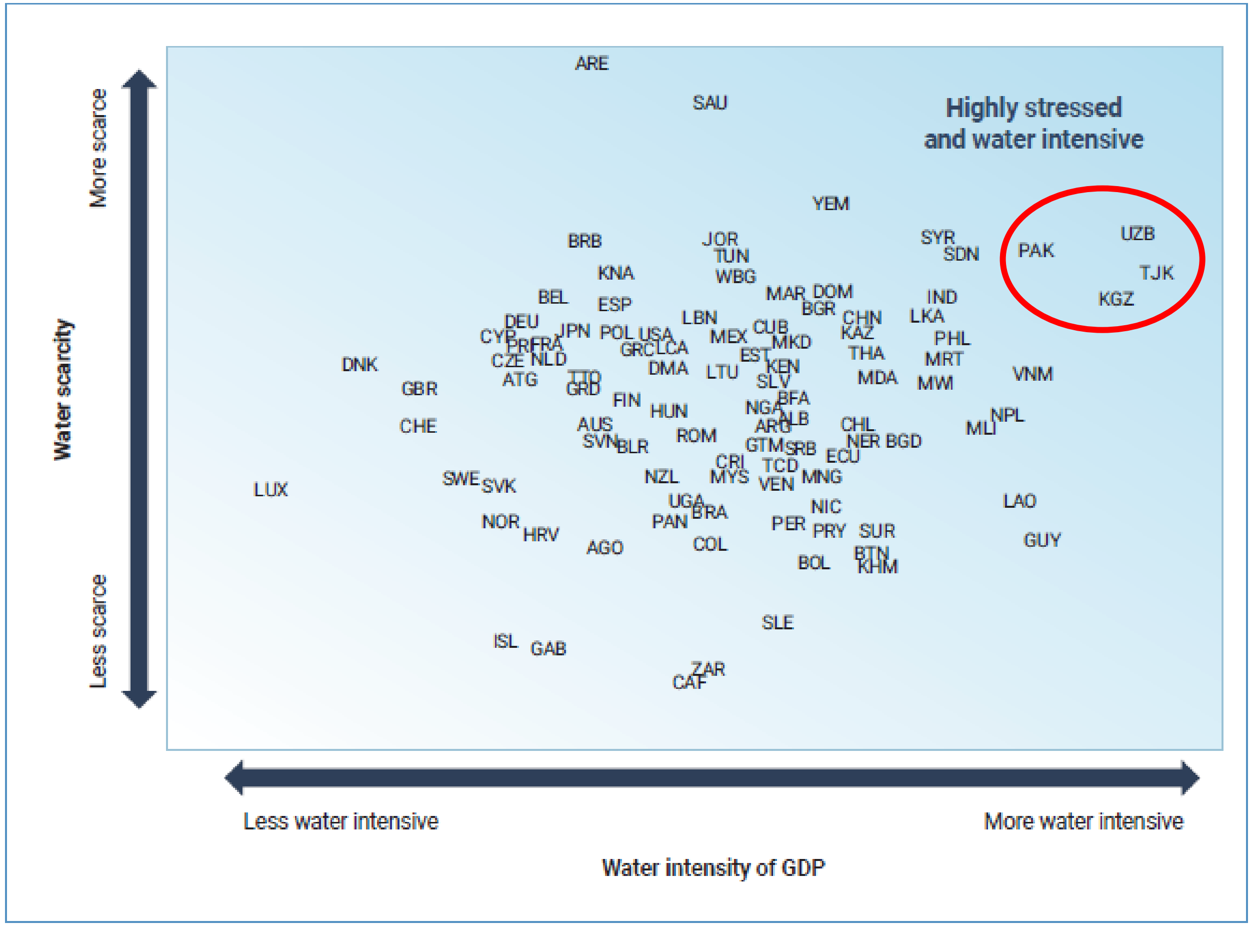
Balancing demand and supply

Figure 1.1

Comparison of water-scarce and water-intensive economies

Note: Figure 1.1 compares water intensity of Gross Domestic Product (GDP) with water scarcity. Water intensity of GDP is measured as the ratio of total economic output to total water withdrawals, and water scarcity is measured as the ratio of total water withdrawals to renewable freshwater resources. Country abbreviations are the International Organization for Standardization's.

Source: Damania et al. (2017, fig. 1.1, p. 10).

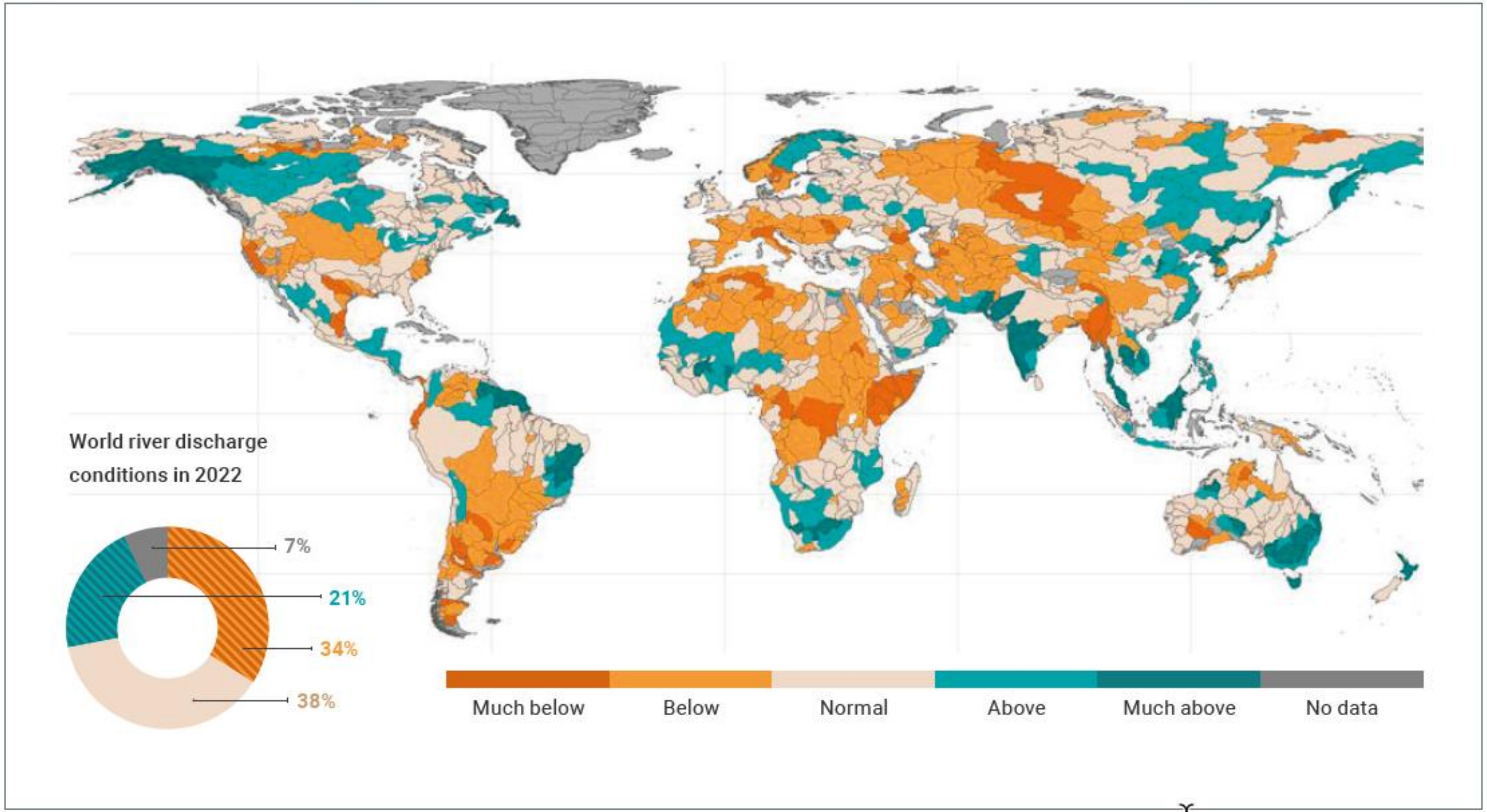


- Countries where water is scarce, it is used more intensively and wastefully than in countries where it is abundant
- Often a consequence of inappropriate policies, regulations and incentives instead of efficient and prudent use of scarce water resources.

Source: The United Nations World Water Development Report 2021

Balancing demand and supply

Figure P.3 Mean river discharge for the year 2022 compared to the period 1991–2020 (for basins larger than 10,000 km²)



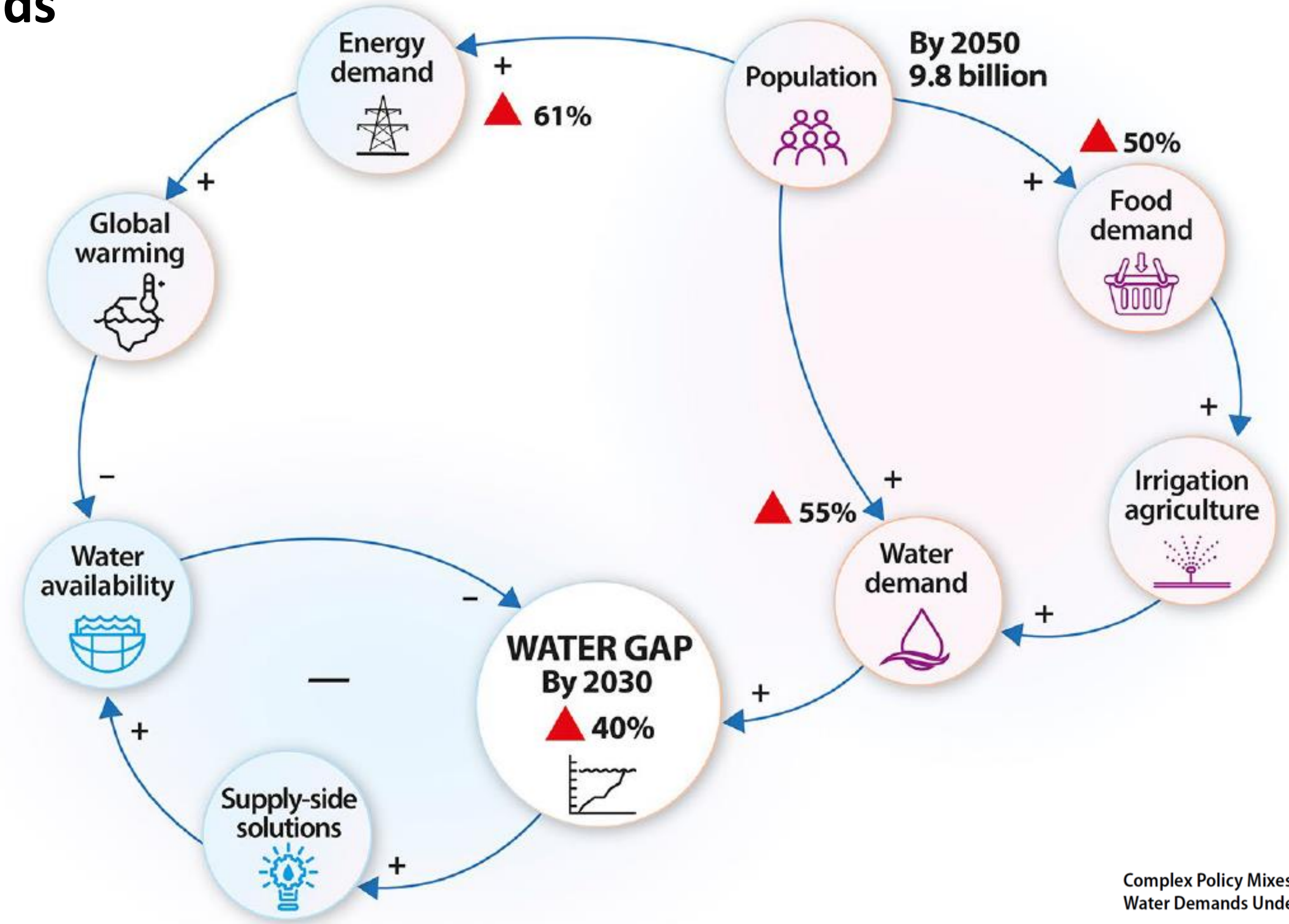
Note: Results are based on simulation, obtained from the ensemble of eight global hydrological modelling systems (GHMSs).

Source: WMO (2023, fig. 3, p. 7).

Source: Water for prosperity and peace– The United Nations Water Development Report 2024

Balancing demand and supply

Agricultural Water Demands



Complex Policy Mixes are Needed to Cope with Agricultural Water Demands Under Climate Change

Jaime Martínez-Valderrama[1,2] · Jorge Olcina[3] · Gonzalo Delacámara[4] · Emilio Guirado[1] · Fernando T. Maestre[1,5]

Received: 17 January 2023 / Accepted: 22 February 2023

Balancing demand and supply

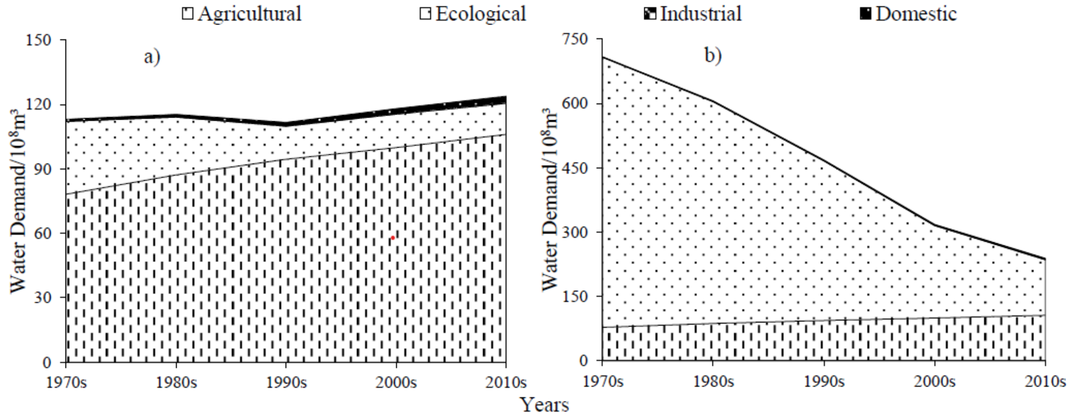


Figure 9. Total of water demand during the 1970s to 2010s. Notes: (a) Without EWD of Aral Sea; (b) With EWD of Aral Sea.

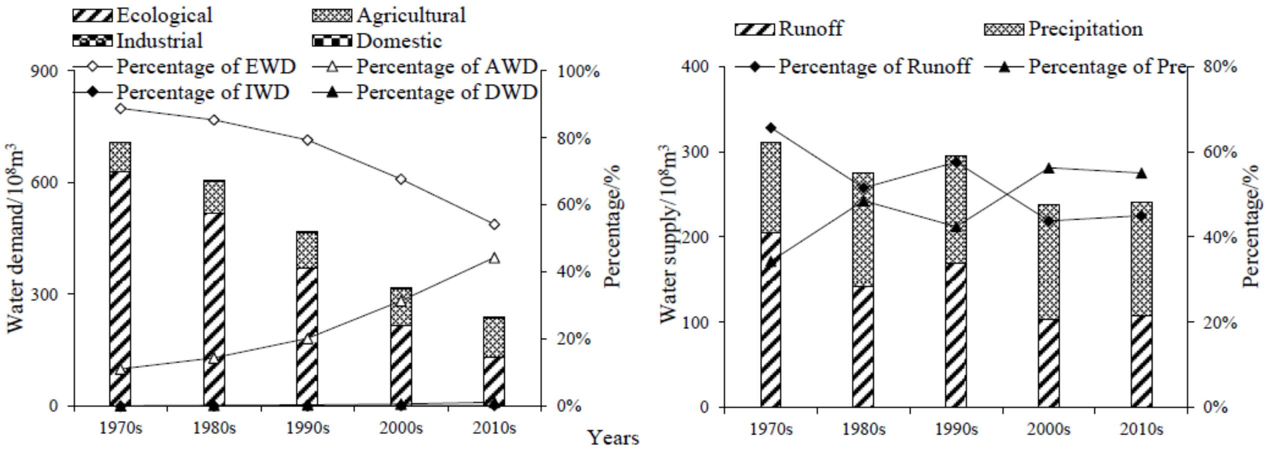


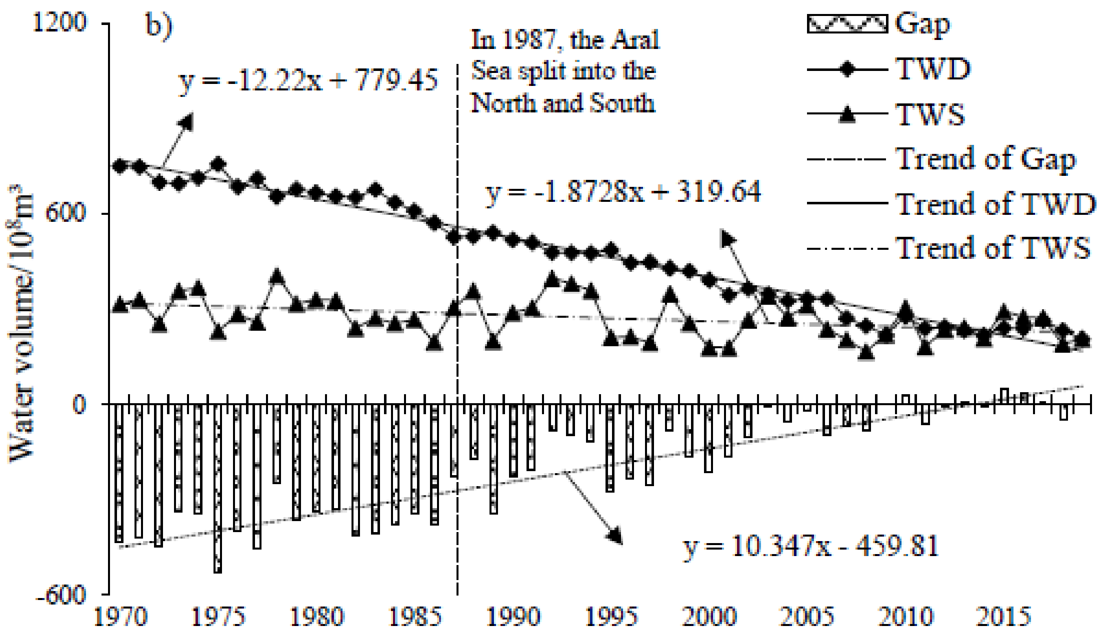
Figure 10. Composition changes of water demand and water supply in the LADB during the 1970s to the 2010s. Notes: EWD, ecological water demand; AWD, agricultural water demand; IWD, industrial water demand; DWD, domestic water demand.

Article

Analysis of the Water Demand-Supply Gap and Scarcity Index in Lower Amu Darya River Basin, Central Asia

Zheng Wang [1,2,3], Yue Huang [1,2,4,5,*], Tie Liu [1,2,4,5], Chanjuan Zan [1,2,3], Yunan Ling [1,2,3] and Chenyu Guo [1,2,3]

Balancing demand and supply



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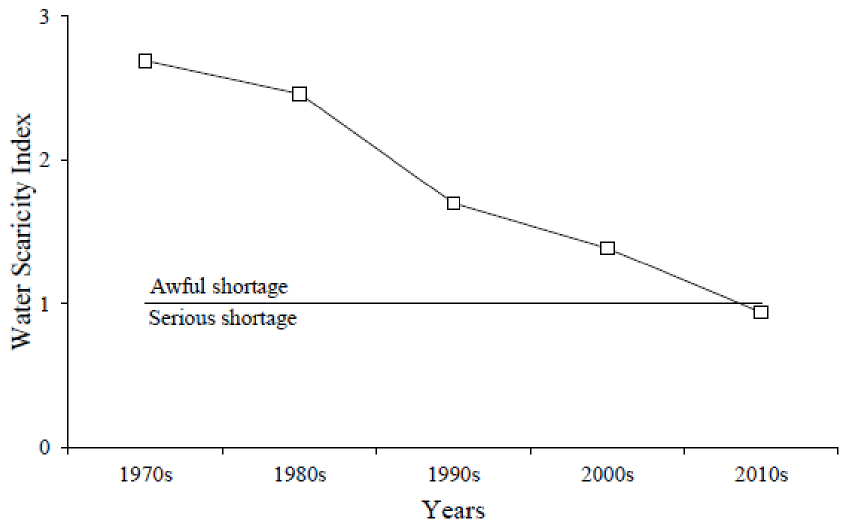
- Water scarcity = situation where insufficient water resources are available to satisfy long-term demand

- WSI = Water demand / Water supply

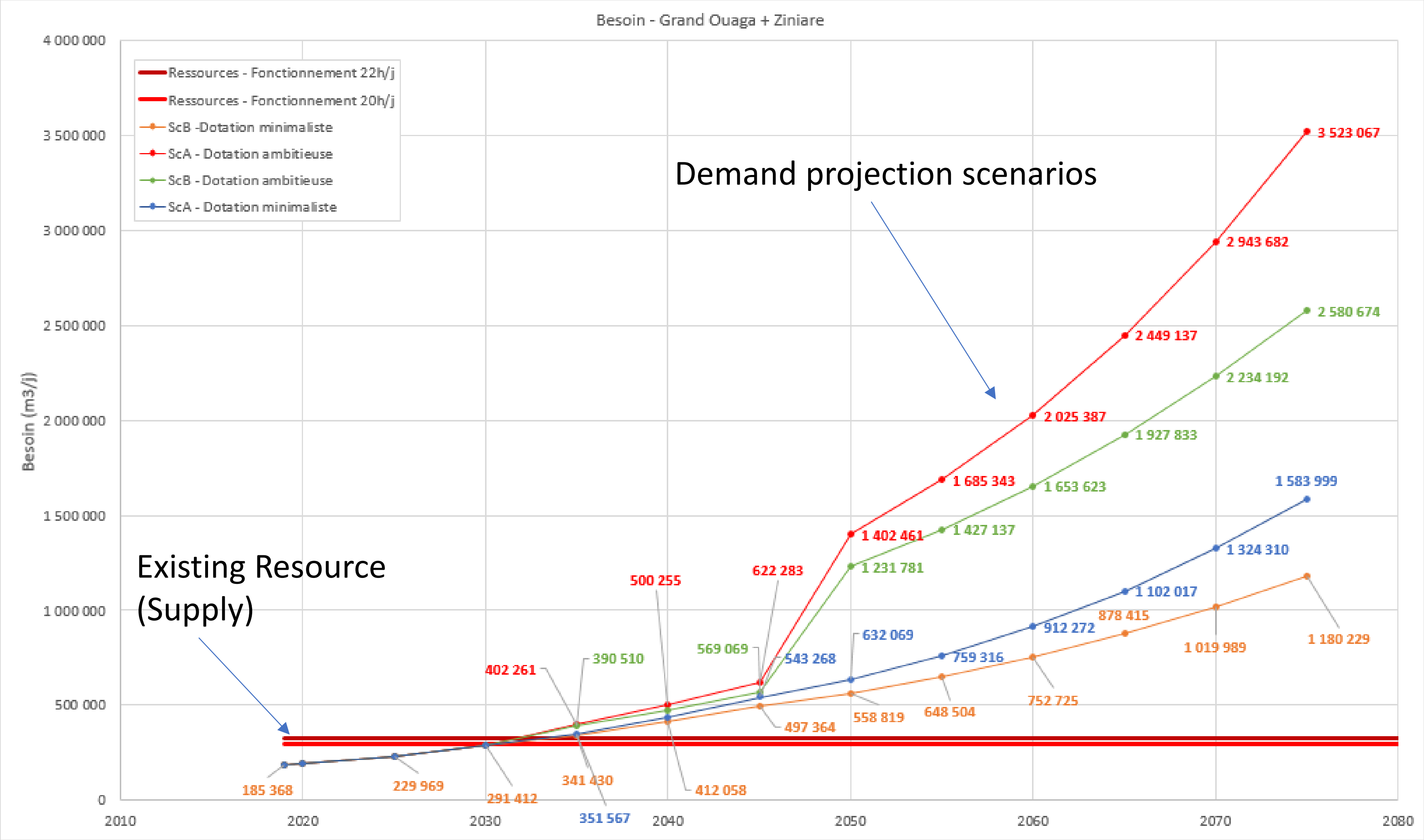


Balancing demand and supply

Ouagadougou 2075

Step 1

- ➢ Demand projections according to different scenarios.
- ➢ Different hypotheses allow for integrating uncertainty.

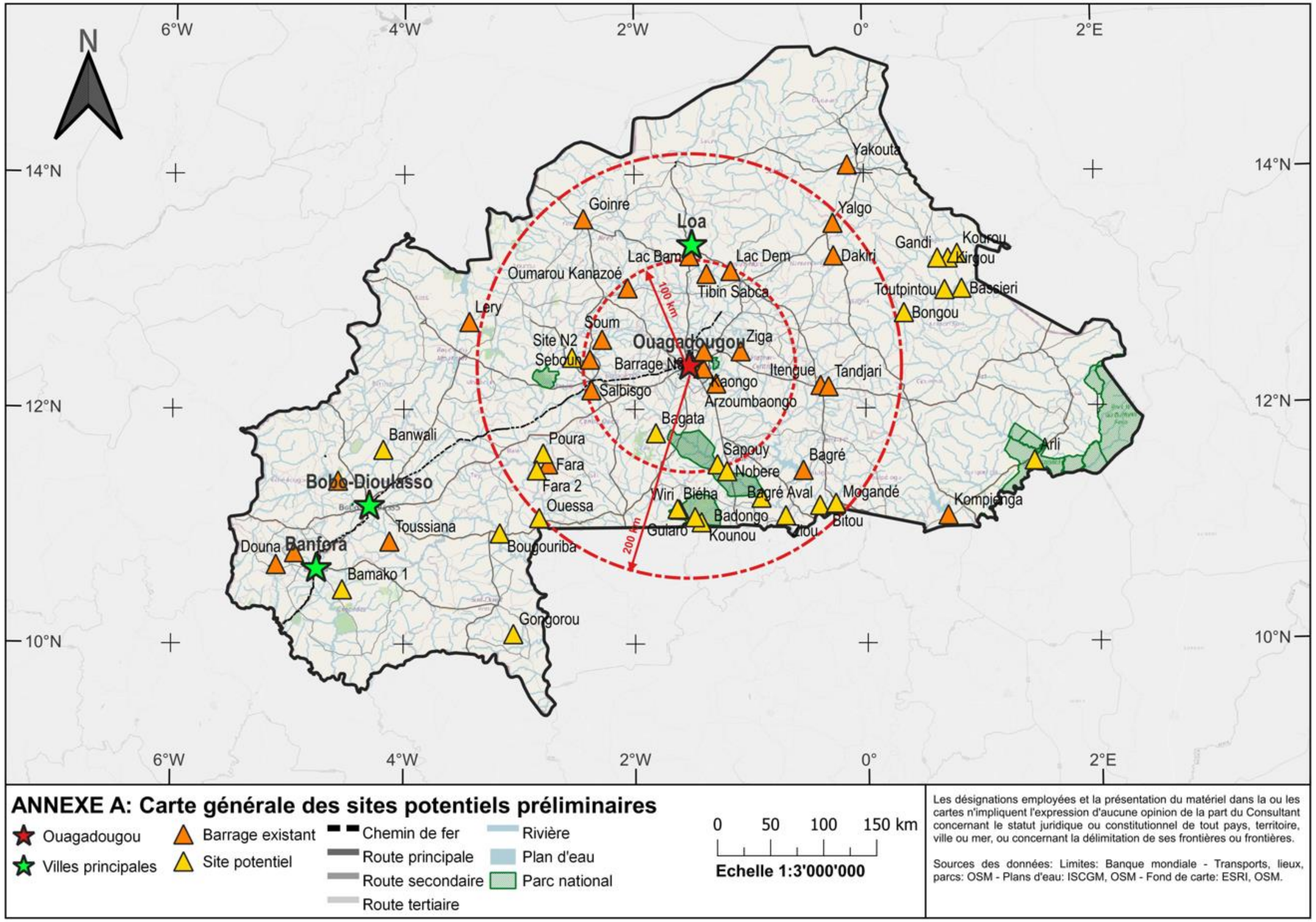


Balancing demand and supply

Ouagadougou 2075

Step 2

- Preliminary dam site identification based on geological, topographical considerations including site visits

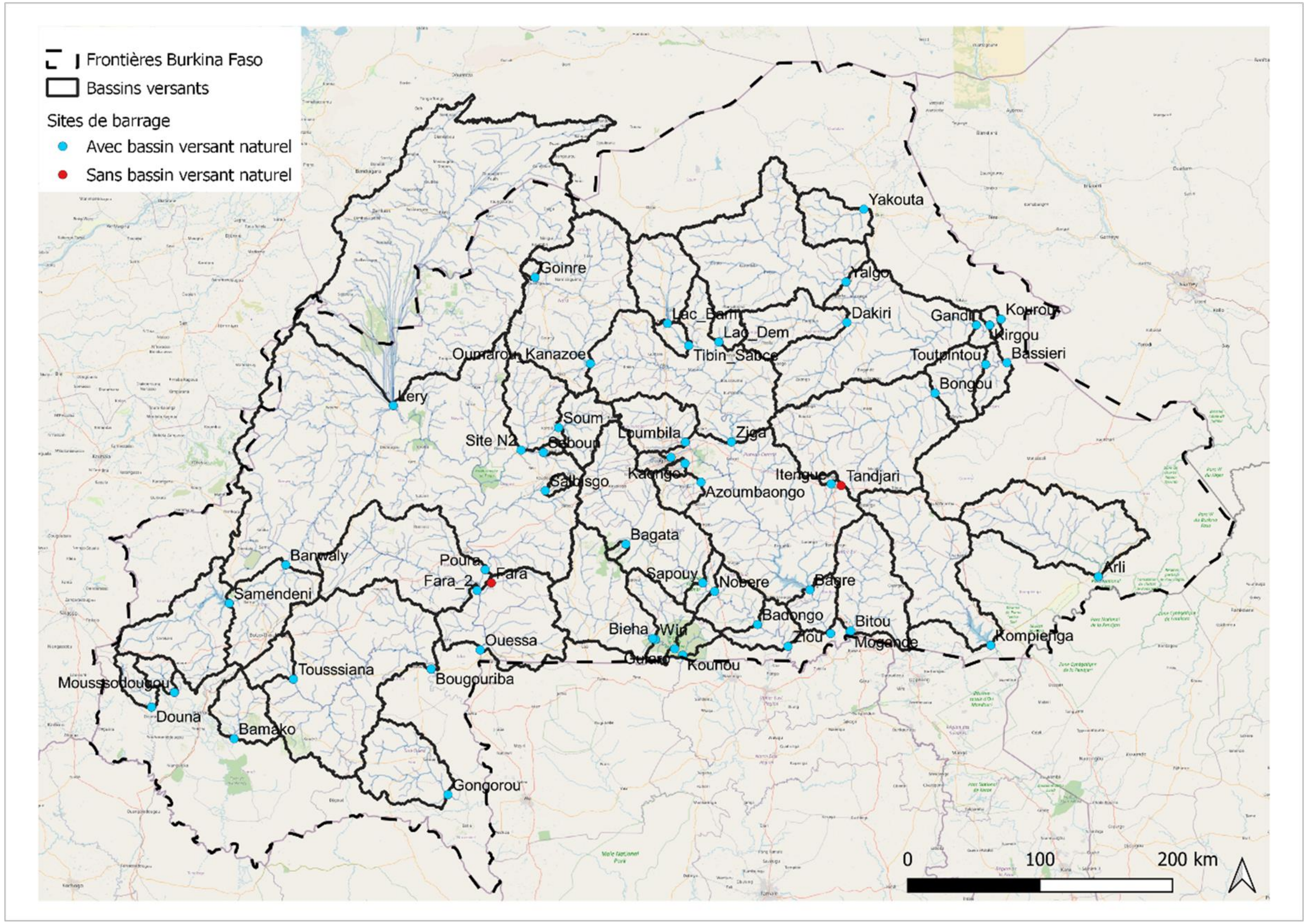


Balancing demand and supply

Ouagadougou 2075

Step 3

- ➢ Hydrological modelling to quantify water availability.

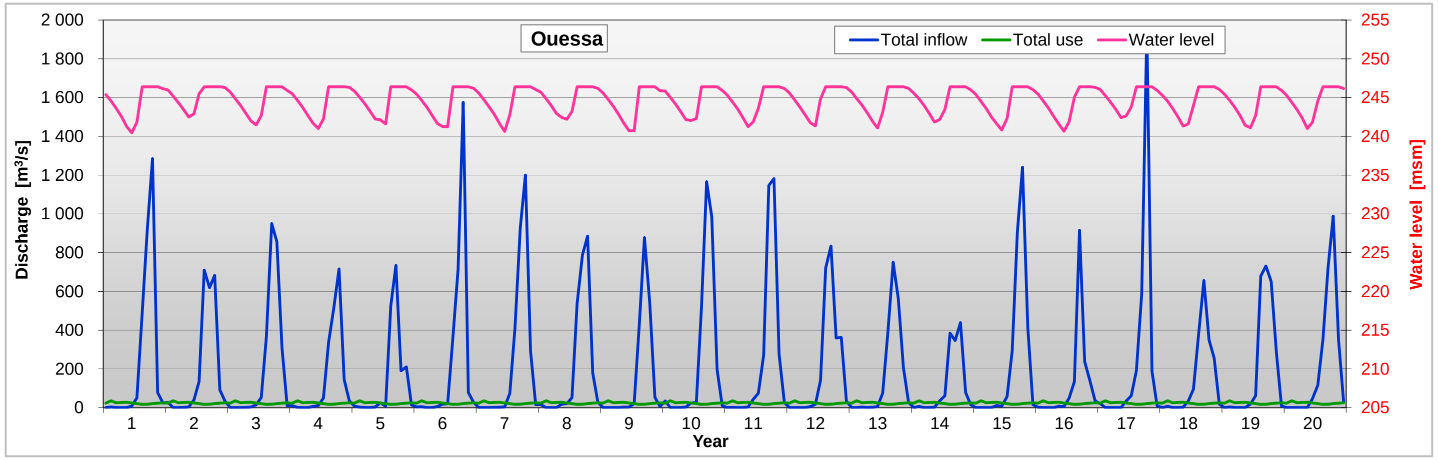


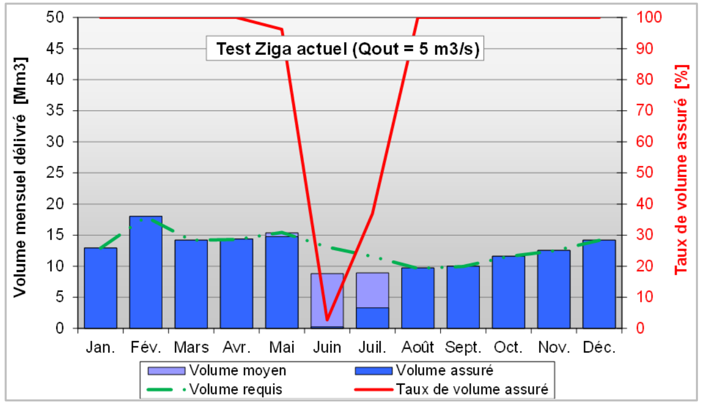
Balancing demand and supply

Ouagadougou 2075

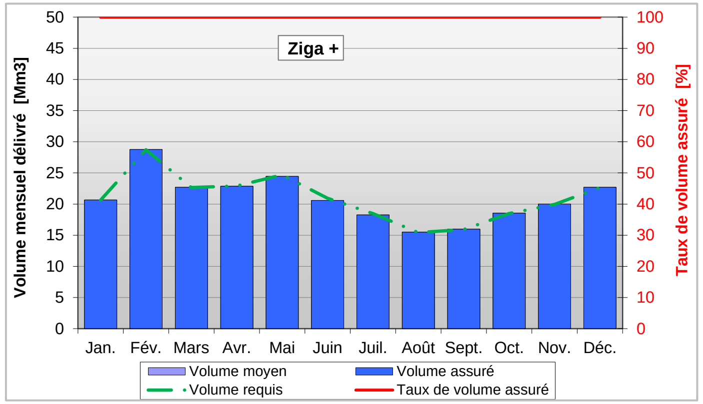
Step 4

- Reservoir operation simulations to assess potential water scarcity issues.
- Calculations have led to the estimation of the maximum average discharge that can be withdrawn for consumption in Ouagadougou with a risk of only 10% for scarcity to occur until 2075.
- The results have shown for example that the existing Zoga dam would need hightening to cope with the average consumption of $5m^3/s$ and balance demand.
- Attention! Dam construction time has not been accounted for!





Existing dam



Hightened dam

Balancing demand and supply

https://radiowest.kuer.org/show/radiowest/2023-01-12/managing-the-colorado-river-100-years-later

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

Sources: U.S. Bureau of Reclamation, Arizona Department of Water Resources, California

- The Colorado River is a major river in the western United States
- It spans over 2,330 km through seven US states: Colorado, Wyoming, Utah, New Mexico, Nevada, Arizona, and California.
- One of the most heavily allocated and managed river systems in the world.
- The river supports numerous uses, including irrigation, municipal water supply, hydropower generation, and recreation.
- The river and its tributaries provide water to over 40 million people, as well as to millions of acres of farmland and numerous industrial facilities.

As the Colorado River Shrinks, Washington Prepares to Spread the Pain

The seven states that rely on the river for water are not expected to reach a deal on cuts. It appears the Biden administration will have to impose reductions.

By Christopher Flavelle **Graphics by Mira Rojanasakul**
Published Jan. 27, 2023 Updated Jan. 31, 2023

Balancing demand and supply

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

- The basin has experienced prolonged drought conditions and reduced snowpack in recent years, which has led to declining water levels in reservoirs along the river.
- There have been conflicts between different states and sectors over water use, particularly between upstream and downstream users.

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Balancing demand and supply

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

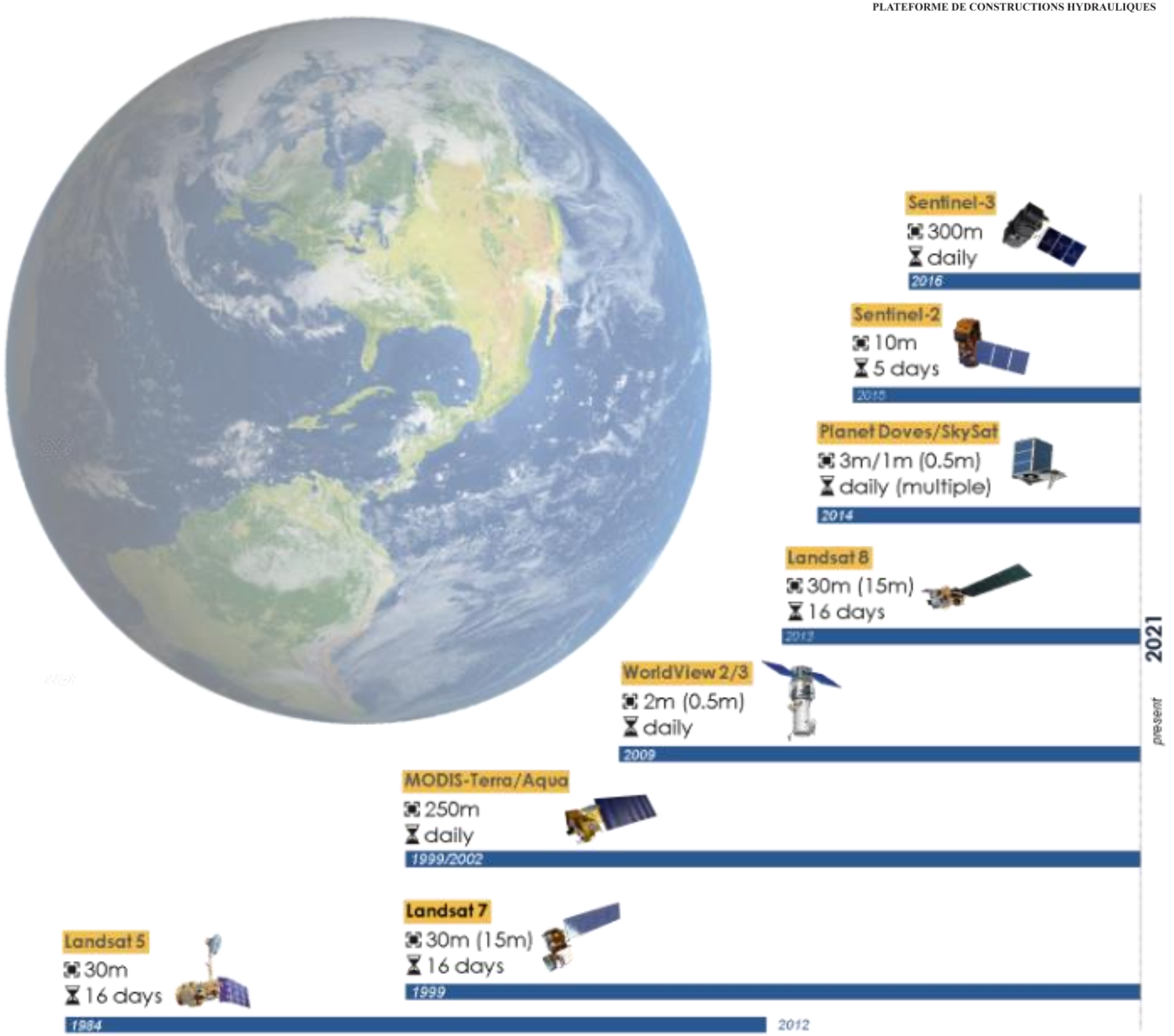
- **Possible solutions ?**
  - Reducing water use for agriculture (e.g growing less water-intensive crops and paying farmers not to grow during periods of extreme water stress)
  - Reducing commercial and industrial consumption
    - variable water pricing;
    - recycling rainwater;
    - using more water-efficient appliances
    - drought-tolerant landscaping
  - Decommissioning of the Glen Canyon Dam
    - Restoration of natural flow
    - Replenishment of ecosystems
    - Restoration of access to lands important to Native American tribes in the region

Glen Canyon Dam - https://www.vox.com/the-highlight/23670139/colorado-river-drought-lake-mead-climate-change-water-cuts

How can EO support water resources management?

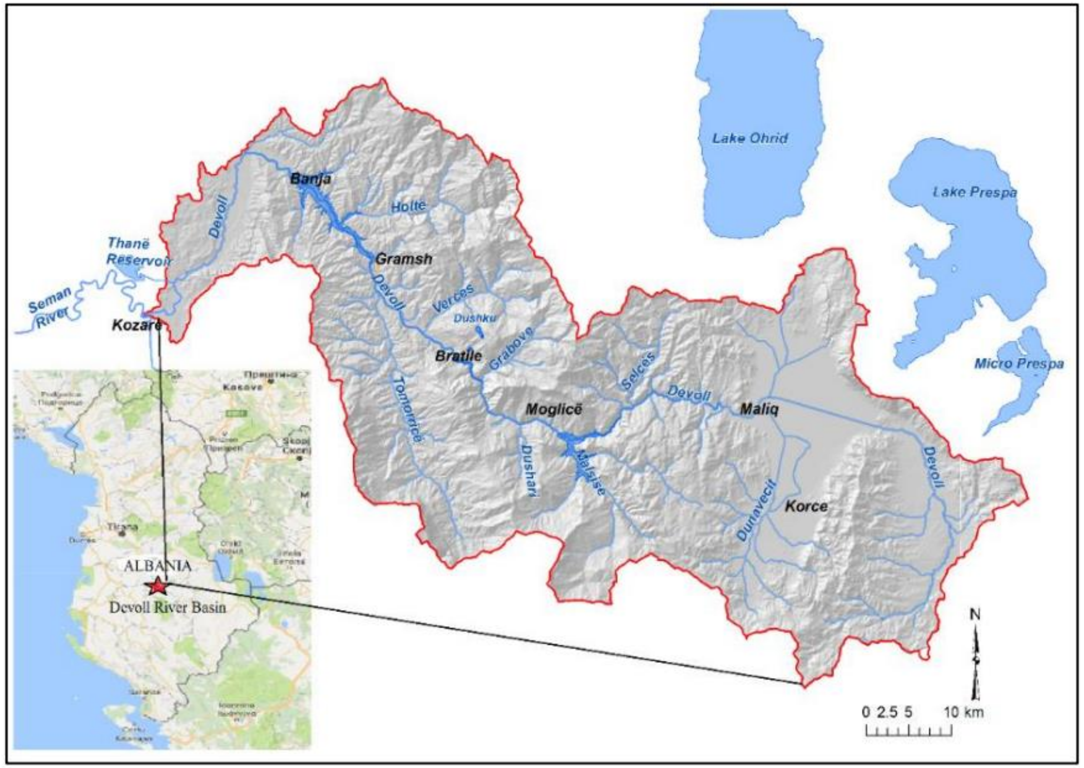
PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

- Monitoring Water Availability
- Detecting Changes in Precipitation
- Mapping Groundwater Resources
- Assessing Soil Moisture
- Monitoring Water Quality
- Predicting Water Demand
- Supporting Policy Decisions
- Etc…



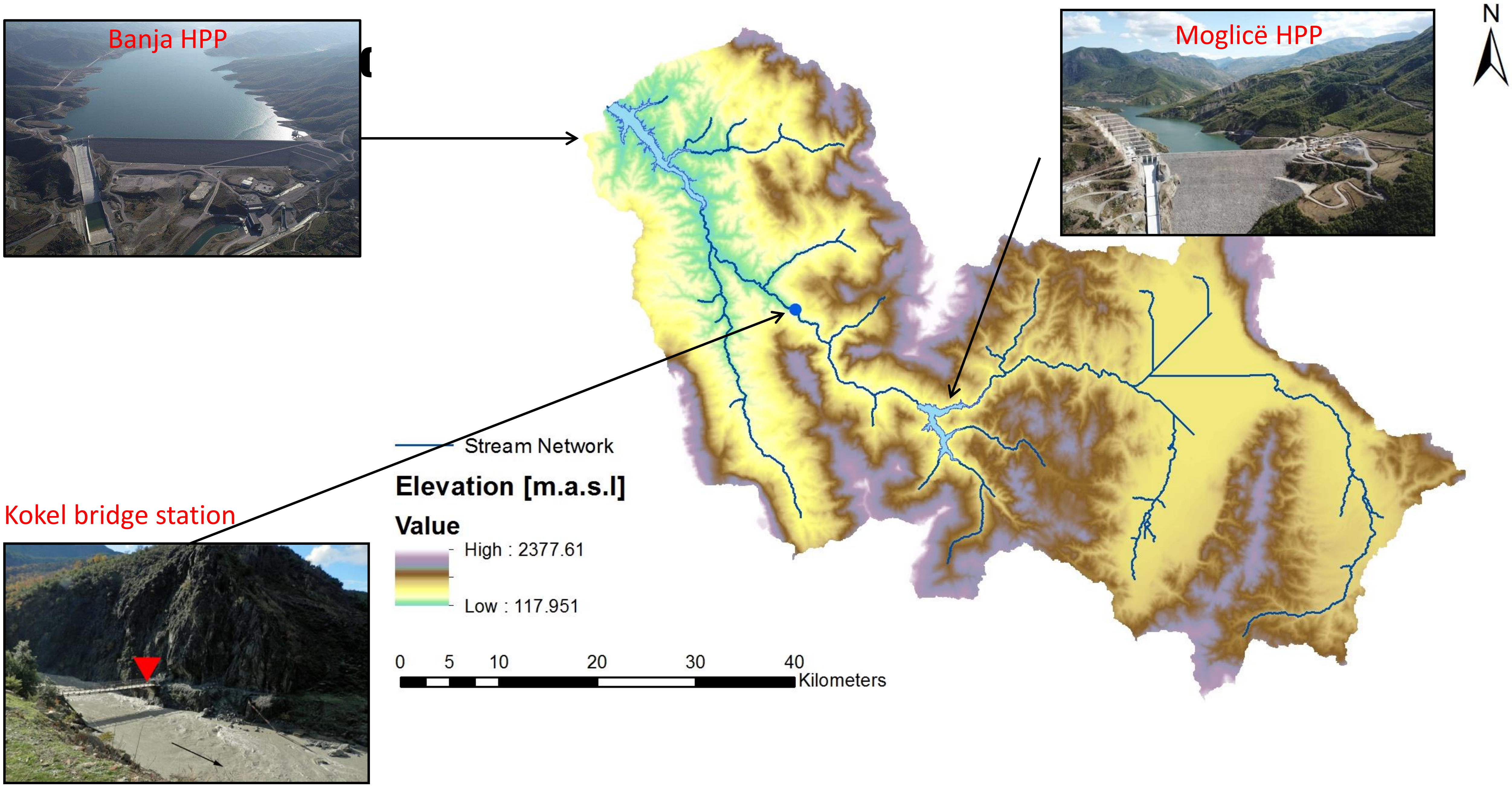
The Devoll Cascade

- The Devoll cascade, owned by Statkraft consists of:
  - Moglicë HPP, commissioned in 2019
  - Banja HPP, commissioned in 2016
- Annual production of around 700 GWh (+17%)



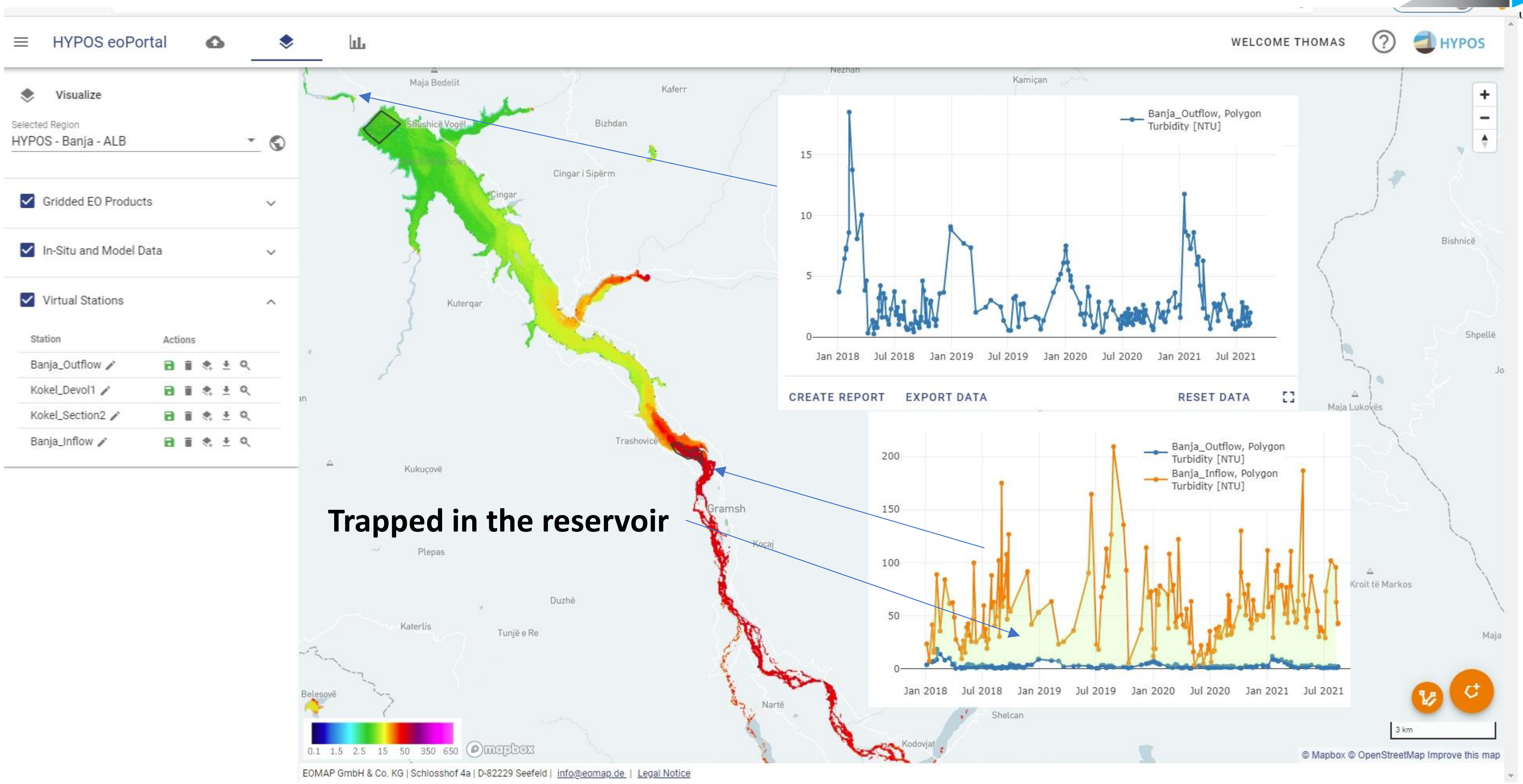
Devoll Hydropower Project
ESIA Final Report - Executive Summary
Norconsult, 2011

* Case study based on Leite Ribeiro, et al (2023)


Banja HPP
Moglicë HPP
N
Kokel bridge station
Stream Network
Elevation [m.a.s.l]
Value
High : 2377.61
Low : 117.951
0 5 10 20 30 40
Kilometers

EPFL

How can EO support water resources management?



https://hypos.eoportal.de/

How can EO support water resources management?

Description
Improved groundwater recharge estimates by assimilating groundwater storage data into models.

Use
Understand and quantify groundwater recharge over time and its trends. Sustainability assessment of current and past groundwater uses.

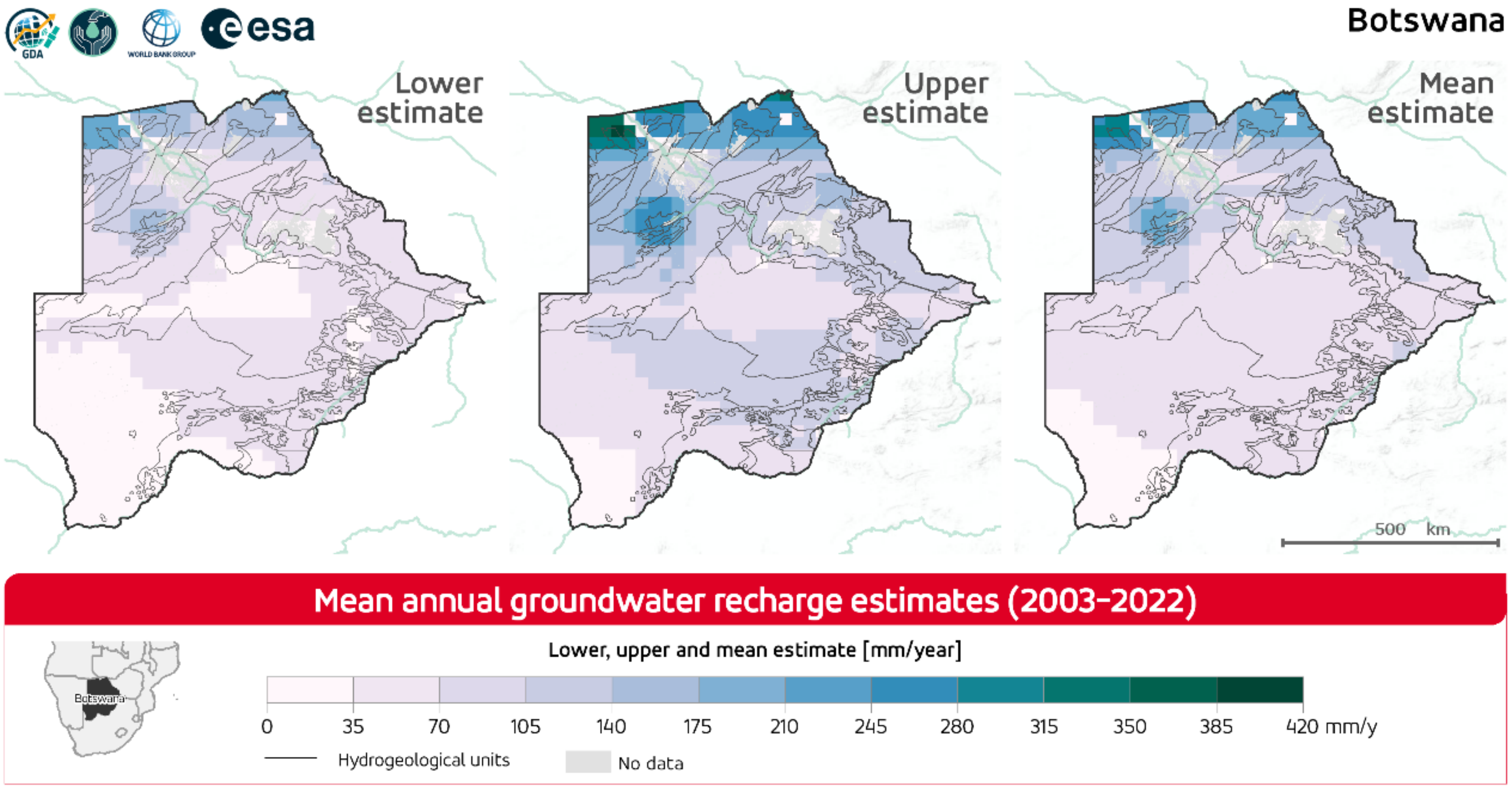
Input
GRACE & GRACE-FO Total Water Storage Anomaly (TWSA) + GLDAS dataset or Copernicus variables.

Spatial resolution and coverage
0.25° x 0.25° (after data assimilation), global

Benefits
- +20 years of regional to national EO-based products on groundwater changes
- Enhanced knowledge on groundwater resources consumption
- Improved groundwater models through EO data assimilation

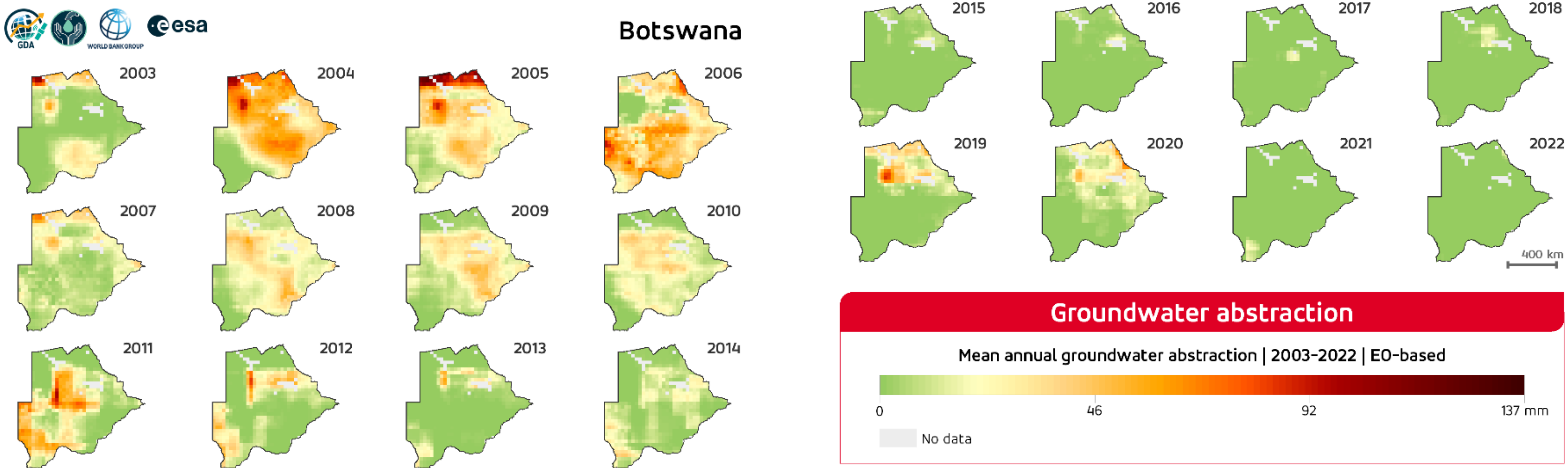
Delivery format
GeoTIFF or Shapefile (Cartographies), Figures and Tables (timeseries and trends), assessment reports

Frequency
Monthly, Large-scale time series & trend analysis



How can EO support water resources management?

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES



Key takeaways

- Balancing water availability while protecting the environment and supporting economic growth is a complex challenge with multiple interconnected factors.
- Sustainable water management practices are essential for addressing this challenge. These practices involve efficient water use, conservation measures, ecosystem protection, and equitable allocation.
- There are often trade-offs between competing water uses and interests.
- Innovation and technology play a crucial role in addressing water challenges.