Ecosystem services supply-demand mismatches under chronic hydrological stress: a case study of the Segura River Basin using the SWAT+ model

SWAT CONFERENCE – Strasbourg, JULY 2024

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Hydrological ecosystem services

- **Benefits on people's well-being produced by aquatic ecosystems**
- Well-being is **multidimensional** (e.g. environmental, social, physical)
- At least one **beneficiary** is a condition to define an **ecosystem service**
- Main classification groups:

Improvement of extractive water and in-stream **water supply**

Natural hazard mitigation

Water-related **cultural** services **provision**

Water-related **supporting services**

Brauman et al. 2007, 2015

Hydrological ecosystem services

- **Eco-hydrological** processes → shape the **quantity, quality, location**, and **timing** of water
- Linking **hydrological attributes** with the **HES**, we can identify the **functions** that require monitoring for effective management
- Consider competitive impacts and trade-offs between different HESs to balance the needs of beneficiaries

Ecohydrologic process (what the ecosystem does)		Hydrologic attribute (direct effect of the ecosystem)	Hydrologic service (what the beneficiary receives)
Local climate interactions Water use by plants	→	Quantity (surface and ground water storage, and flow)	**Diverted water supply:** Water for municipal, agricultural, commercial, industrial, thermoelectric power generation uses ***In situ* water supply:** Water for hydropower, recreation, transportation, supply of fish and other freshwater products **Water damage mitigation:** Reduction of flood damage, dryland salinization, saltwater intrusion, sedimentation **Spiritual and aesthetic:** Provision of religious, educational, tourism values **Supporting:** Water and nutrients to support vital estuaries and other habitats, preservation of options
Environmental filtration Soil stabilization Chemical and biological additions/subtractions	→	Quality (pathogens, nutrients, salinity, sediment)	
Soil development Ground surface modification Surface flow path alteration River bank development	→	Location (ground/surface, up/downstream, in/out of channel)	
Control of flow speed Short- and long-term water storage Seasonality of water use	→	Timing (peak flows, base flows, velocity)	

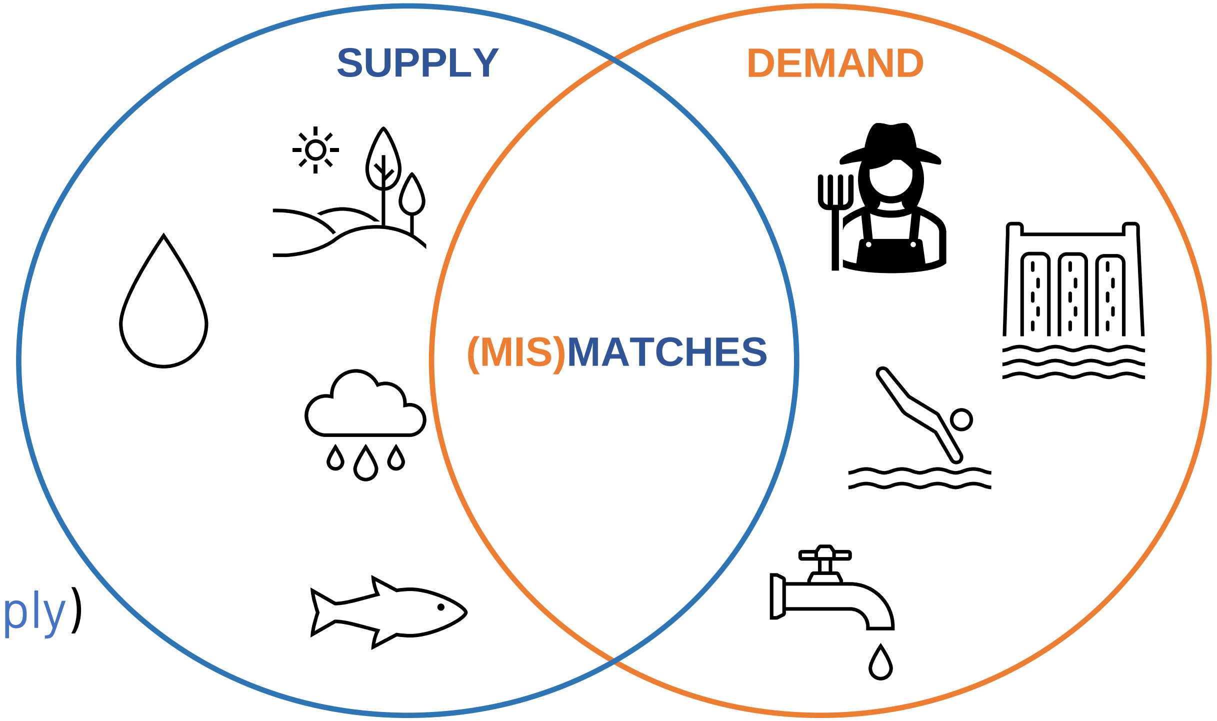
Relationship between ecohydrological processes and HES

Brauman, 2015

Ecosystem Services (Mis)matches

Arise from disparities in either the **quality or quantity** between ES capacity, flow, and demand

Geijzendorffer et al., 2015

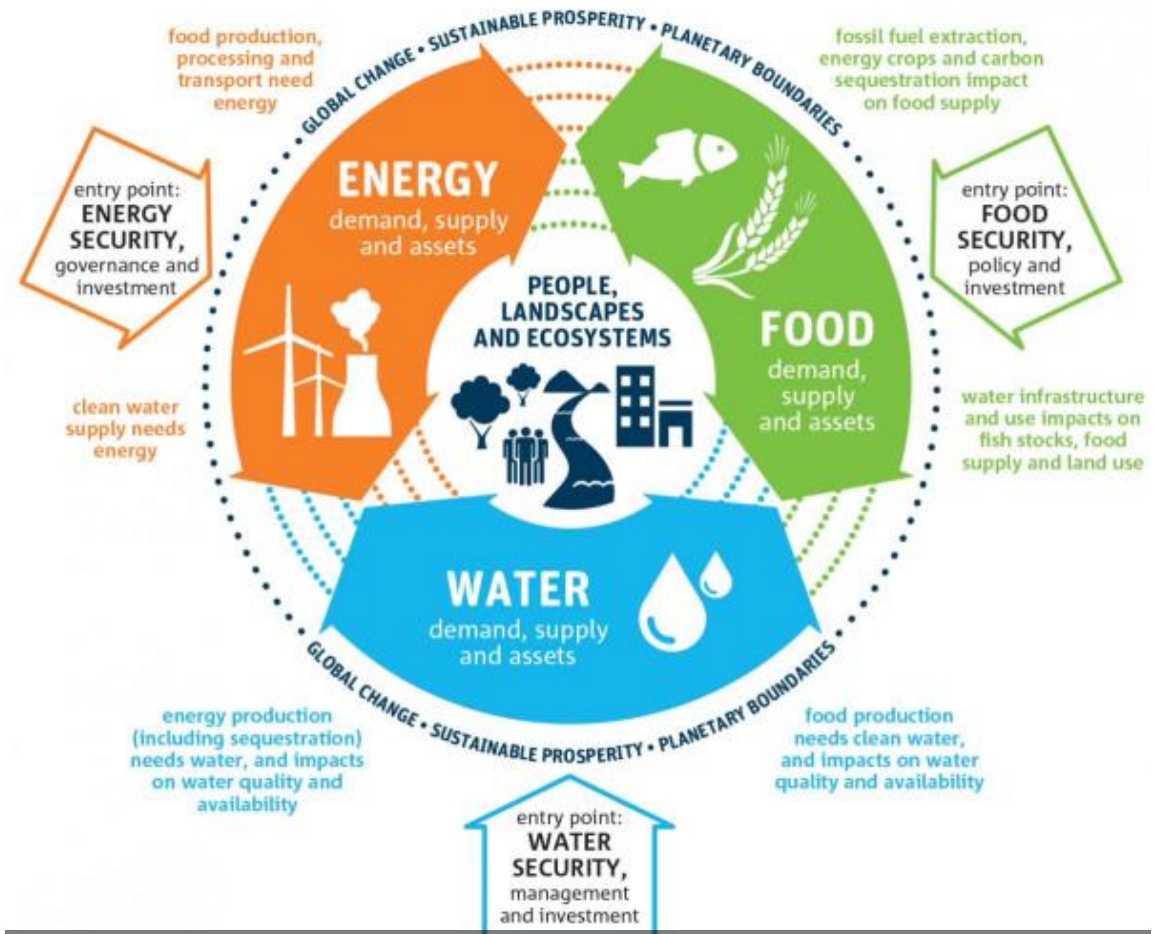


Spatial mismatches:

- Discrepancies between **where** ES are **produced** (supply) and **where** they are **needed** or **utilized** (demand)
- If a wetland provides water purification services but is located far from the urban area that requires clean water → spatial mismatch
- Provides evidence for management and resource allocation + identify good practices when balanced

Water–energy–food nexus

- The Water-Energy-Food (**WEF**) nexus framework recognizes the **interconnectedness** and **interdependencies** among **water**, **energy**, and **food systems** (Hoff, 2011)
- The actions in any one area often can have effects in one or both other areas
- ES have a key supporting role for securing **WEF**
- Human consumption increases by population growth, urbanization, and climate change → **imbalance between the supply and demand of resources**
- Unexpected tradeoffs can arise when water is allocated among competing uses



Source: IWA, 2018. Sustainable Development: The Water-Energy-Food Nexus

Segura River Basin (SRB) – Case study

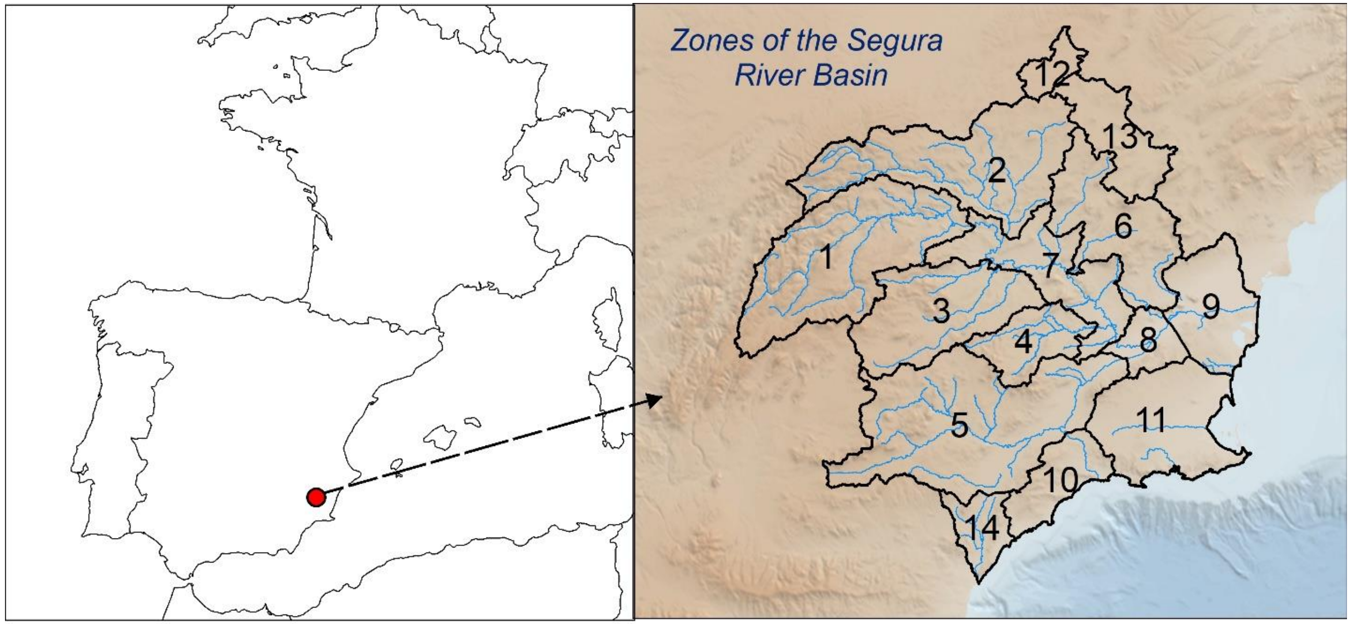
Semi-arid climate: lowest precipitation in Europe (300mm /yr) - variable in space and time

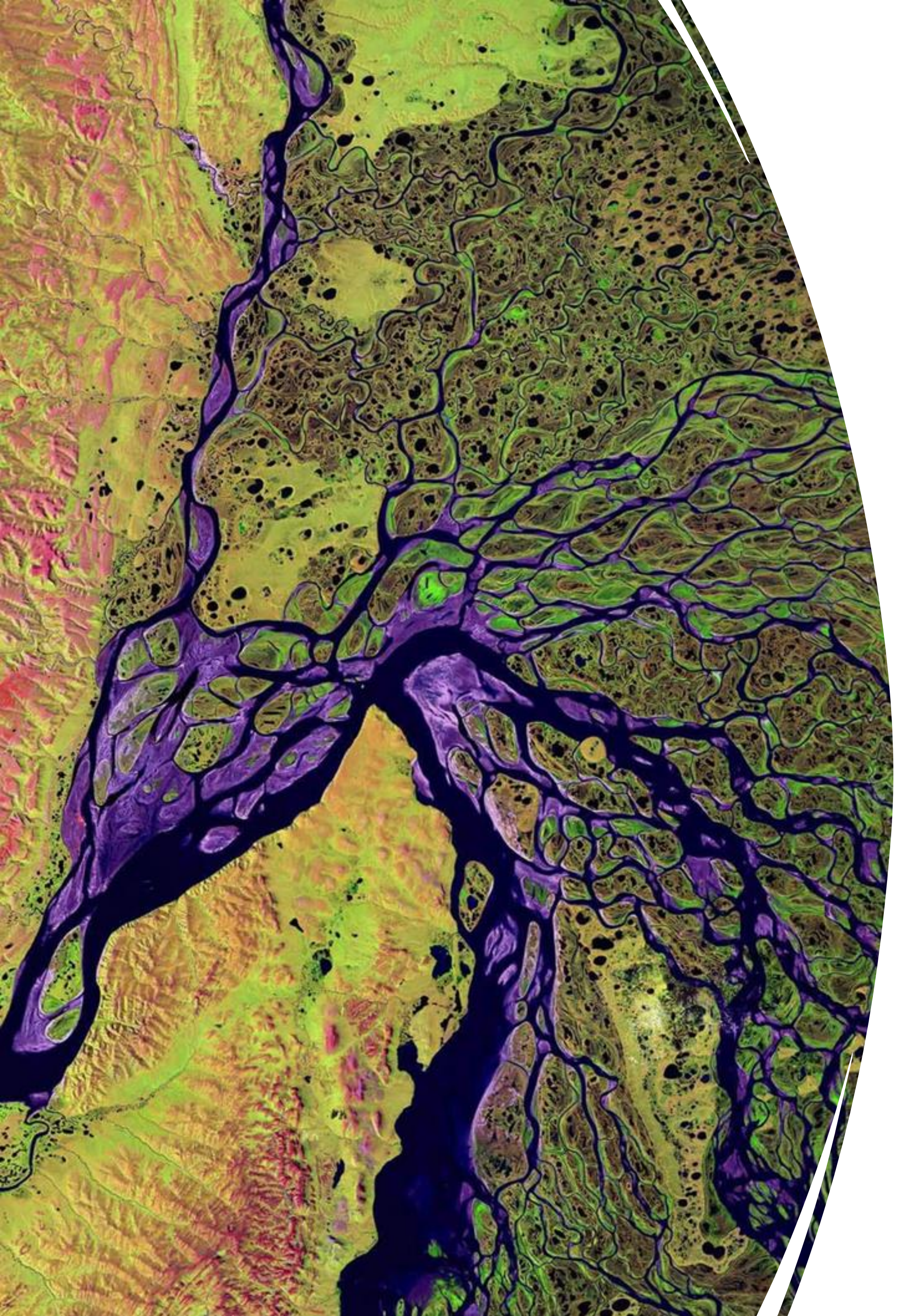
The agricultural sector uses 85% of the water demands→ chronic water deficit

Water demands peak in summer, while resources are most abundant in winter and spring

To address water deficits, SRB relies on transfers from other basins, desalination, and wastewater reuse

SRB is a complex system: Scarce water resources require careful allocation→ WEF tradeoffs





Aim

- **Model ecosystem service supply-demand mismatches in the Segura River Basin under multiple pressures arising from WEF sector**

- Provide evidence-based insights specific to **water management applications in the Segura River Basin**. These should include i) **spatially explicit assessments** of ecosystem services supply-demand mismatches and ii) **identify priority intervention areas** for addressing disparities in water demands

Quantifying ES supply

- Resource categories: 1) **natural**, 2) **external**, and 3) **non-conventional**

- Water Supply (WS):

$$WS = Wnat + Wtst + Wreg + Wdes$$

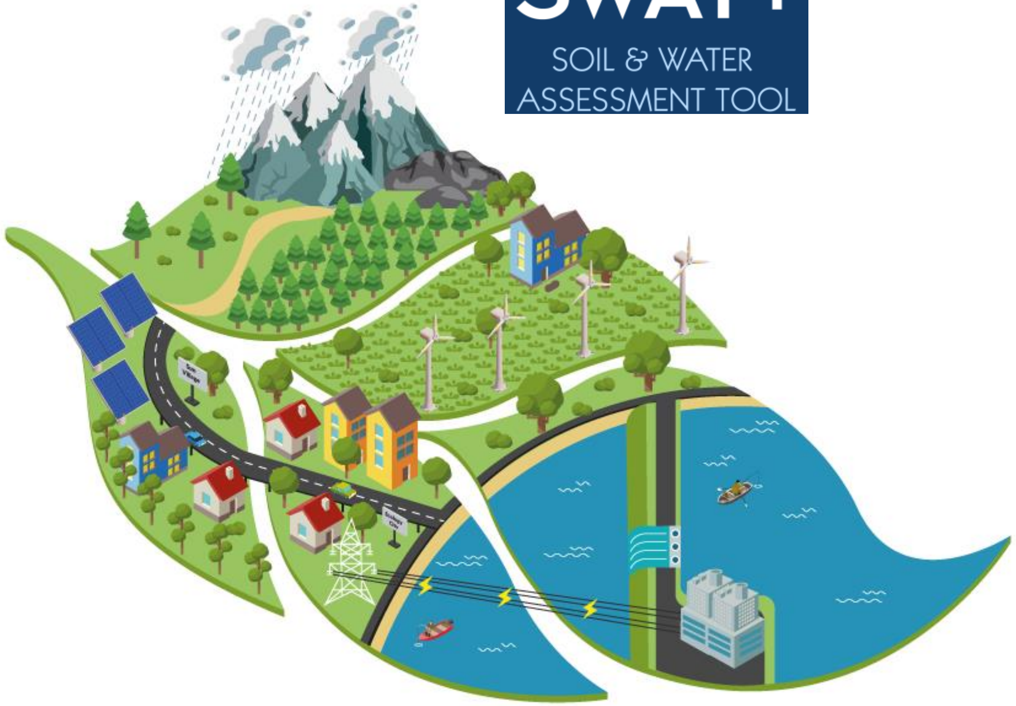
Wnat → **natural water** resources present in the Basin

Wtst → actual water consumption from the **Tajo-Segura Water Transfer (TSWT)** in the Basin

Wreg → **reuse of regenerated** water in the Basin

Wdes → **seawater desalination** supplies in the Basin

SWAT+
SOIL & WATER ASSESSMENT TOOL



Quantifying ES demand

$$WD = Wa + Wi + Wh + Wt$$

Where:

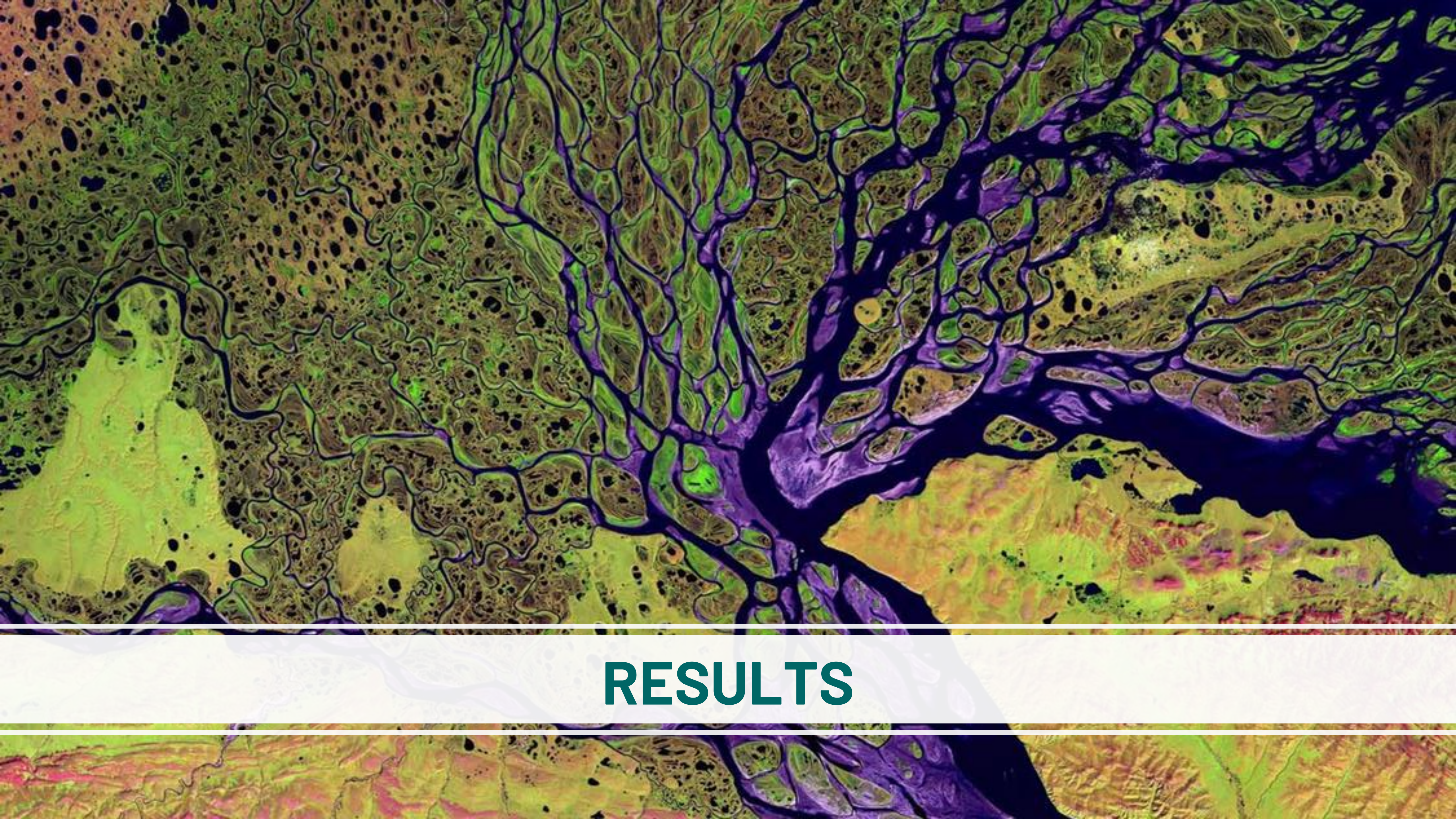
Wa → agricultural water use of the Basin

Wi → industrial use

Wh → household water use

Wt → tourism-related activities water use

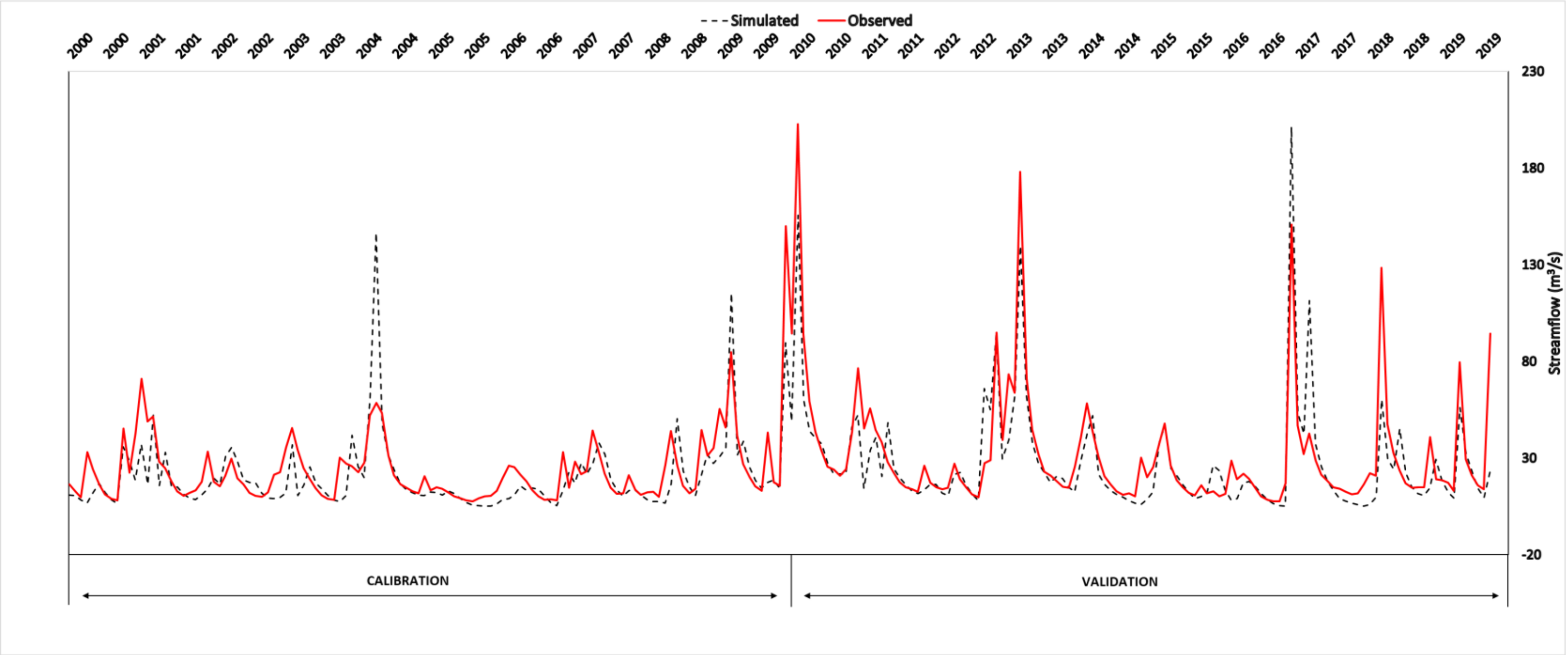
Segura Basin Management Plan



RESULTS

SWAT+ model – Calibration and validation

Monthly Statistical Indices				
Period	**KGE**	**NSE**	**PBIAS**	**R^2**
Calibration (2000 – 2009)	0.67	0.53	17.59	0.60
Validation (2010 – 2019)	0.77	0.70	13.52	0.72
Simulation (2000 – 2019)	0.76	0.63	13.78	0.66



SWAT+
SOIL & WATER ASSESSMENT TOOL

ES Supply – Water Yield

Total Supply (WS) in SRB → 1400 hm^3

- Main sources of WS → **headwaters and southeastern** zones (1, 9, 11, & 5)

Natural contributions (Wnat): → 55% of WS

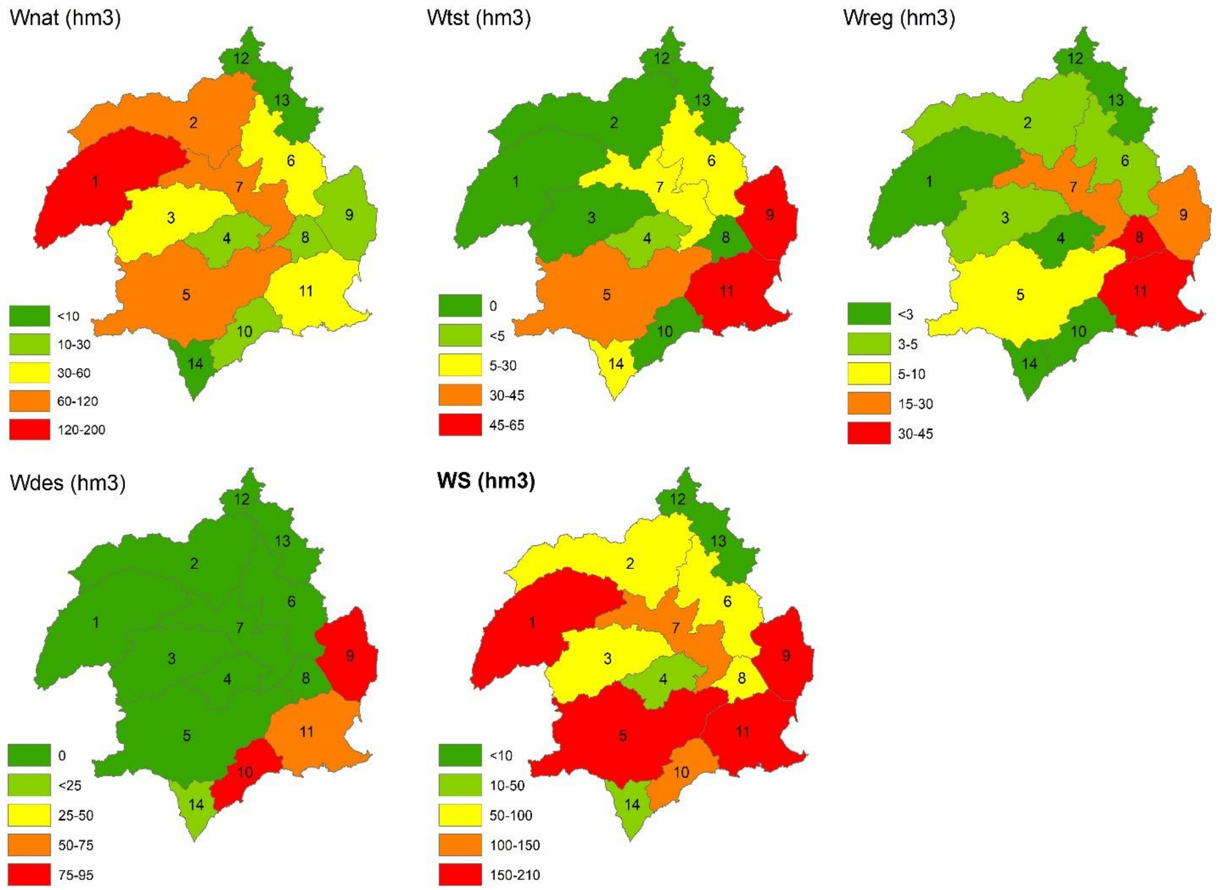
- Headwaters (zone 1) → Largest contributor at 200 hm^3

External contributions (Wtst) (Tagus-Segura Water Transfer) → 15%

- Concentrated in areas of **high agricultural activity** (9 & 11)

Non-conventional resources → 30% of WS

- Regenerated water (Wreg) → **southeastern** part of SRB
- Desalinated water (Wdes) → **coastal area** of SRB, proximity to the Mediterranean Sea in zone 9



ES Demand – Water Yield

- **Total Demand (WD)** in SRB → 1800 hm^3
- **Agriculture**: 85% → (mainly supported by groundwater pumping and the TSWT)
- **Household water** →14%

<u>Zones of water consumption</u>

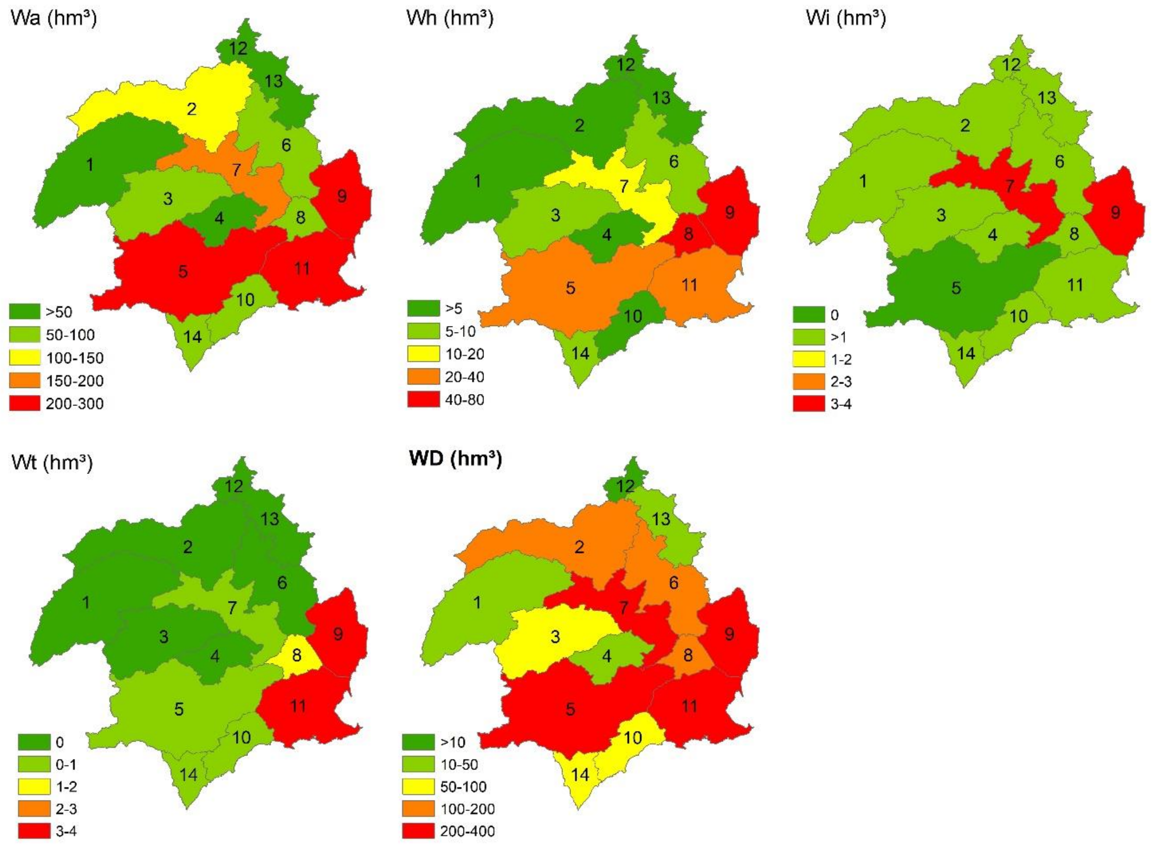
- High **agricultural demand** (9 & 11):

Over 30% of the total consumption across the 14 zones

- High **urban water demand** (9 & 8):

largest populations

- Lowest **agricultural demand** (1 and 12):
  Headwaters, less than 0.1% of the total demand

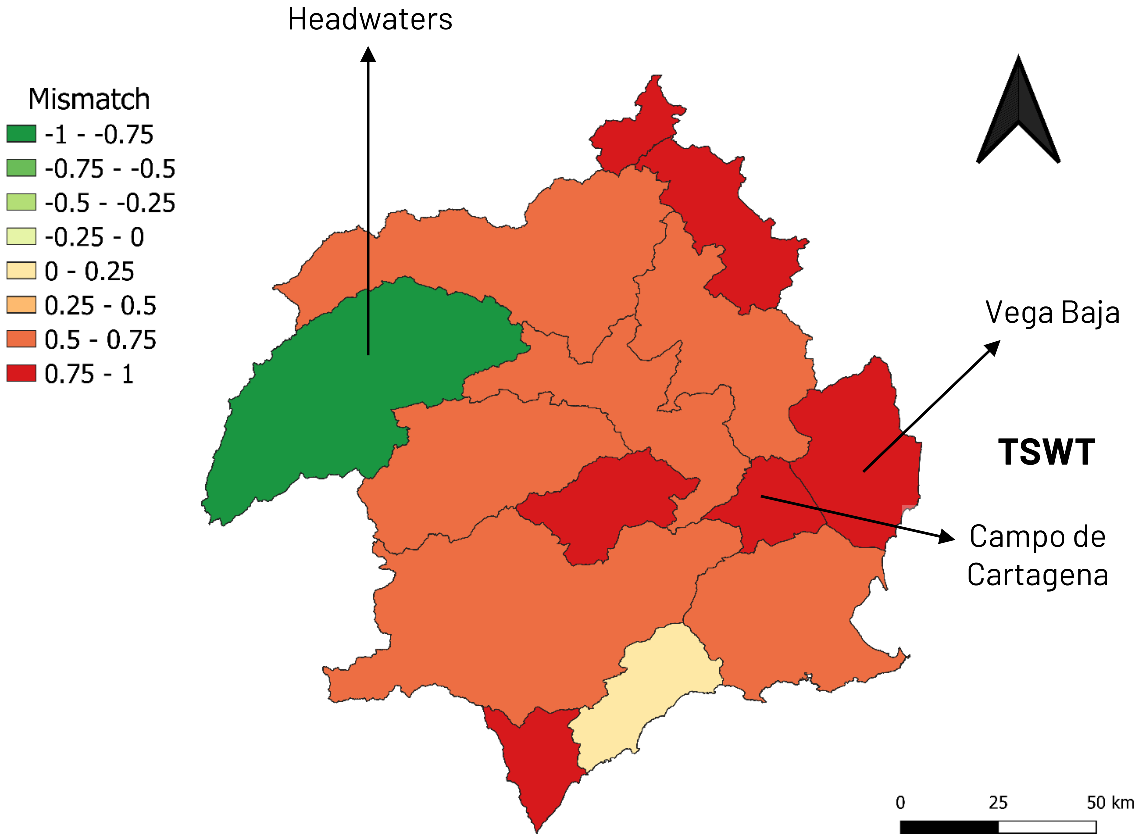


ES Mismatches

- Supply – Demand = Mismatch (values from 1 to -1)
- **Higher values** → supply **deficit**
- **Lower values** → supply **surplus**
- **Close to 0 values** → WS supply = demand

  - **WS surplus** → Headwaters
  - **Balance** → Desalinization (non-conventional source)
  - **WS deficit** → High agricultural activity areas + Population dense

SRB mouth
Campo de Cartagena
Tajo-Segura Water Transfer (TSWT)
Vega Baja



Accumulated supply-demand mismatch values at the sub-watershed level: ***-1 (supply > demand) to 1 (supply < demand)****, with values closer to 0 indicating balance (supply = demand).*

Management implications

Challenges: Available Water vs Demand → Segura River Basin

Key to integrate an ES perspective to keep management related to human well-being

ES supply deficits → Address by recycling and recovering resources within the water use and treatment cycle

Action: **Unconventional** uses in SRB → **Desalination** achieves balance in some zones

Unforeseen tradeoffs and environmental impacts within the **WEF** nexus should be considered → Energy implications: desalinization plants are energy intensive but can support agriculture and water supply

Management implications

Despite non-conventional uses → ES supply deficit

Which sub-watersheds are in highest need of management interventions? → Addressing ES mismatches requires collaboration across sectors (water, energy, agriculture, tourism)

WEF management problems: Innovations related to desalinization and irrigation efficiency can add dependencies to energy resources (e.g. energy to drive water pumps) to the water-food nexus

How can we align circular water economy principles with the management of the **WEF** nexus?

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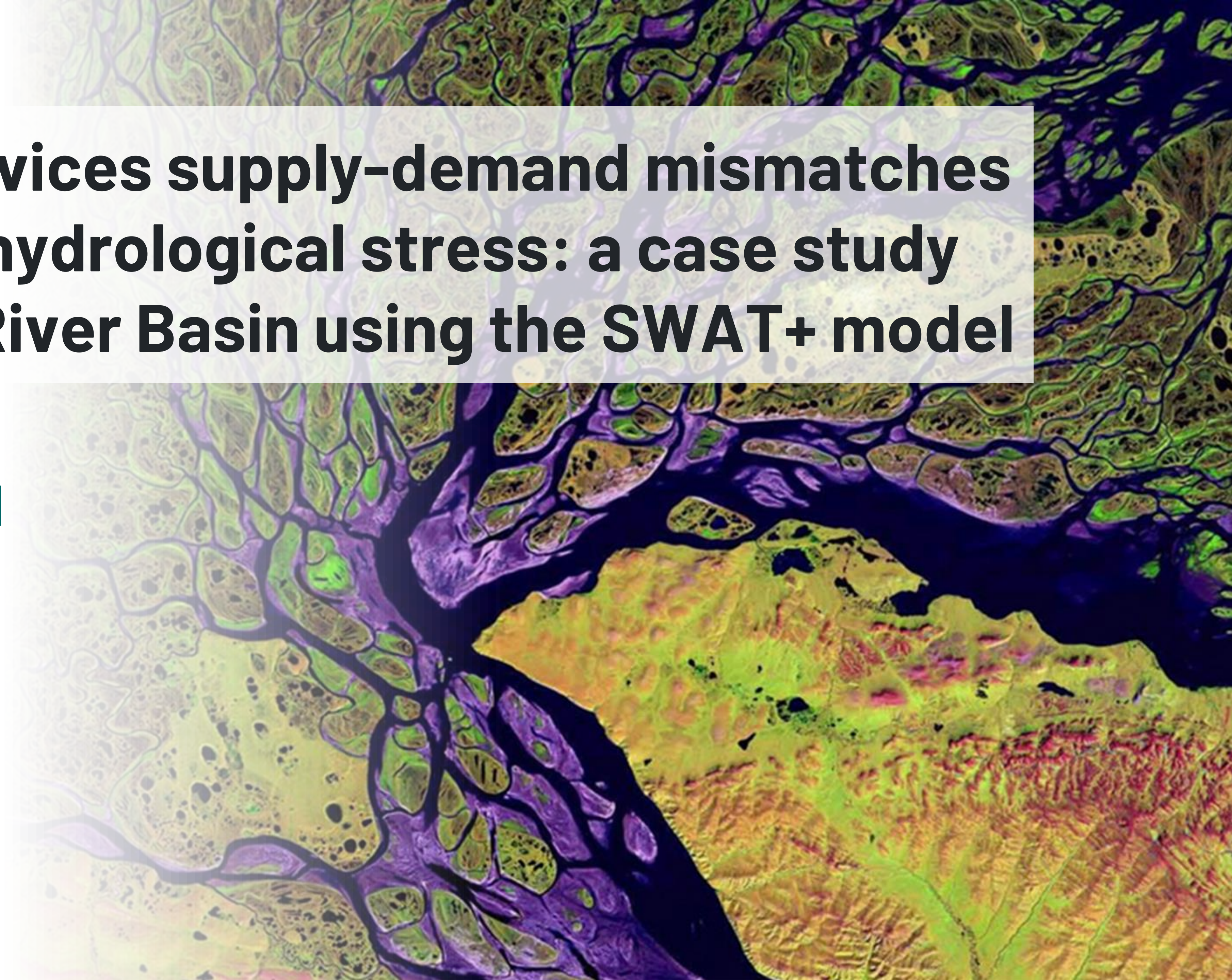

Thank you

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