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Crop Water Use and Future Irrigation Scenarios within a Safe Operating Space Framework in the Danube Basin

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International Institute of Applied System Analysis

SOS Water

EGU2026/Vienna

The Danube river basin

- 19 countries
- 801,000 km²

Crop production:

- Both rainfed and irrigated
- High heterogeneity
- Irrigation more pronounced in downstream areas

Image source: ICPDR

Increasing water scarcity

Many countries have plans or incentives to expand irrigated agriculture due to increasing drought risk under climate change.

Journal of Hydrology: Regional Studies
Volume 59, June 2025, 102404

Climate change threatens water resources for major field crops in the Serbian Danube River Basin by the mid-21st century

Jamshid Jalali [a], Nishan Bhattarai [b], Jillian Greene [a], Tao Liu [c], Oskar Marko [d], Mirjana Radulović [d], Molly Sears [e], Sean A. Woznicki [a]

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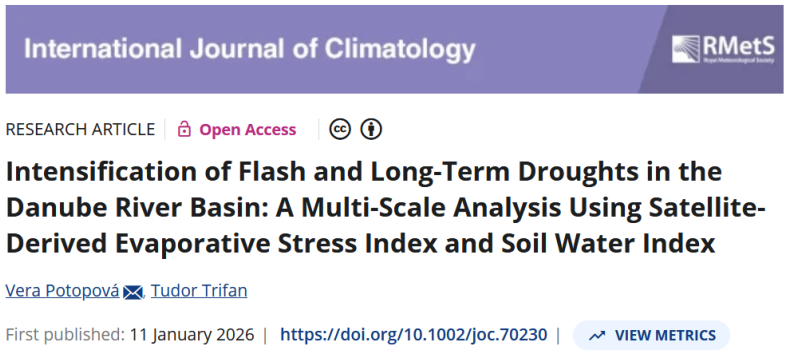

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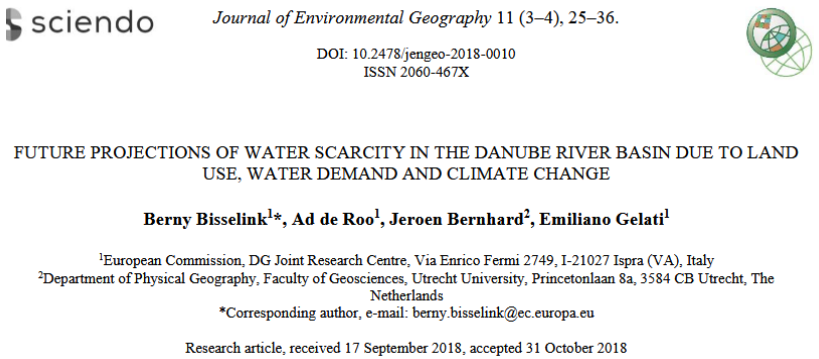

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FUTURE PROJECTIONS OF WATER SCARCITY IN THE DANUBE RIVER BASIN DUE TO LAND USE, WATER DEMAND AND CLIMATE CHANGE

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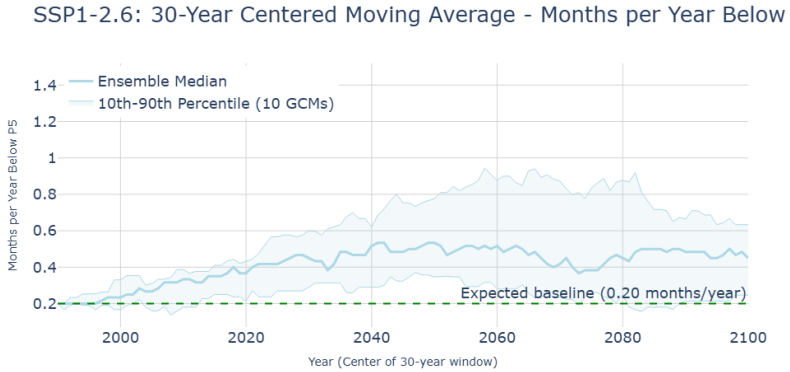
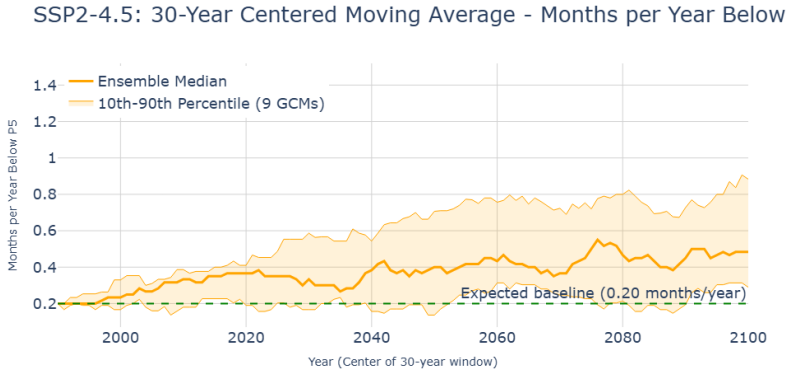
This may exacerbate water scarcity, alter river flow regimes, and intensify pressures on aquatic ecosystems.

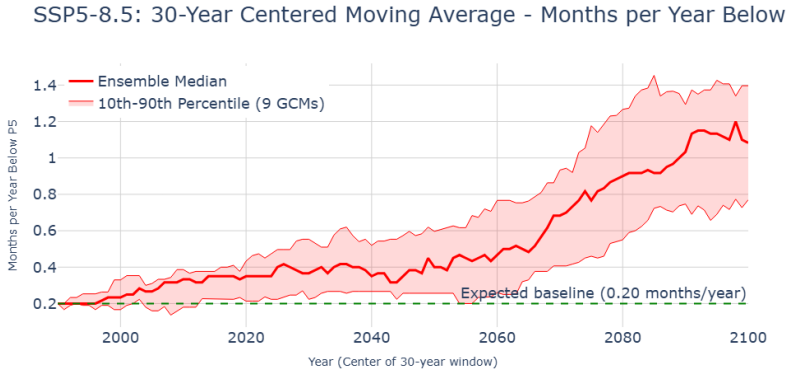
Need for a coordinated, basin-wide and adaptive future agricultural water management.

Increasing water scarcity

30-year moving average – months/year below P5 for **soil moisture** data in the Tisa subbasin







What is the Safe Operating Space (SOS)?

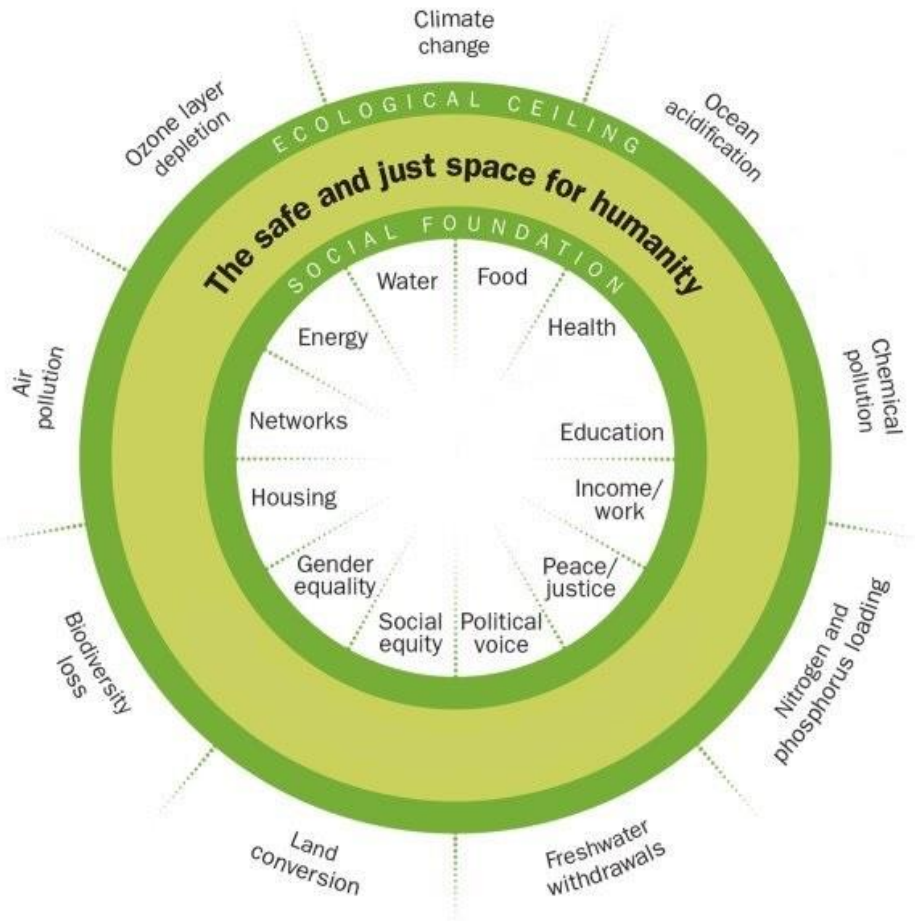


Image Source: Time, https://time.com/5930093/amsterdam-doughnut-economics/

A sustainability concept for the complex Earth System (including for water resources).

- Social foundation
- Environmental/Ecological ceiling
- Environmentally safe and socially just space for humanity to thrive

Develop a SOS framework for the Danube river basin

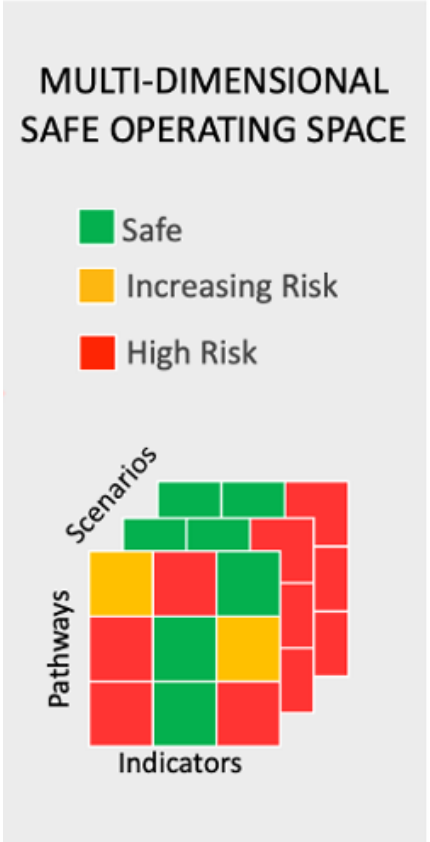
Support water planning and management at local to regional levels

- Ensure a sufficient and reliable supply of water
- Both for human activity and natural ecosystems

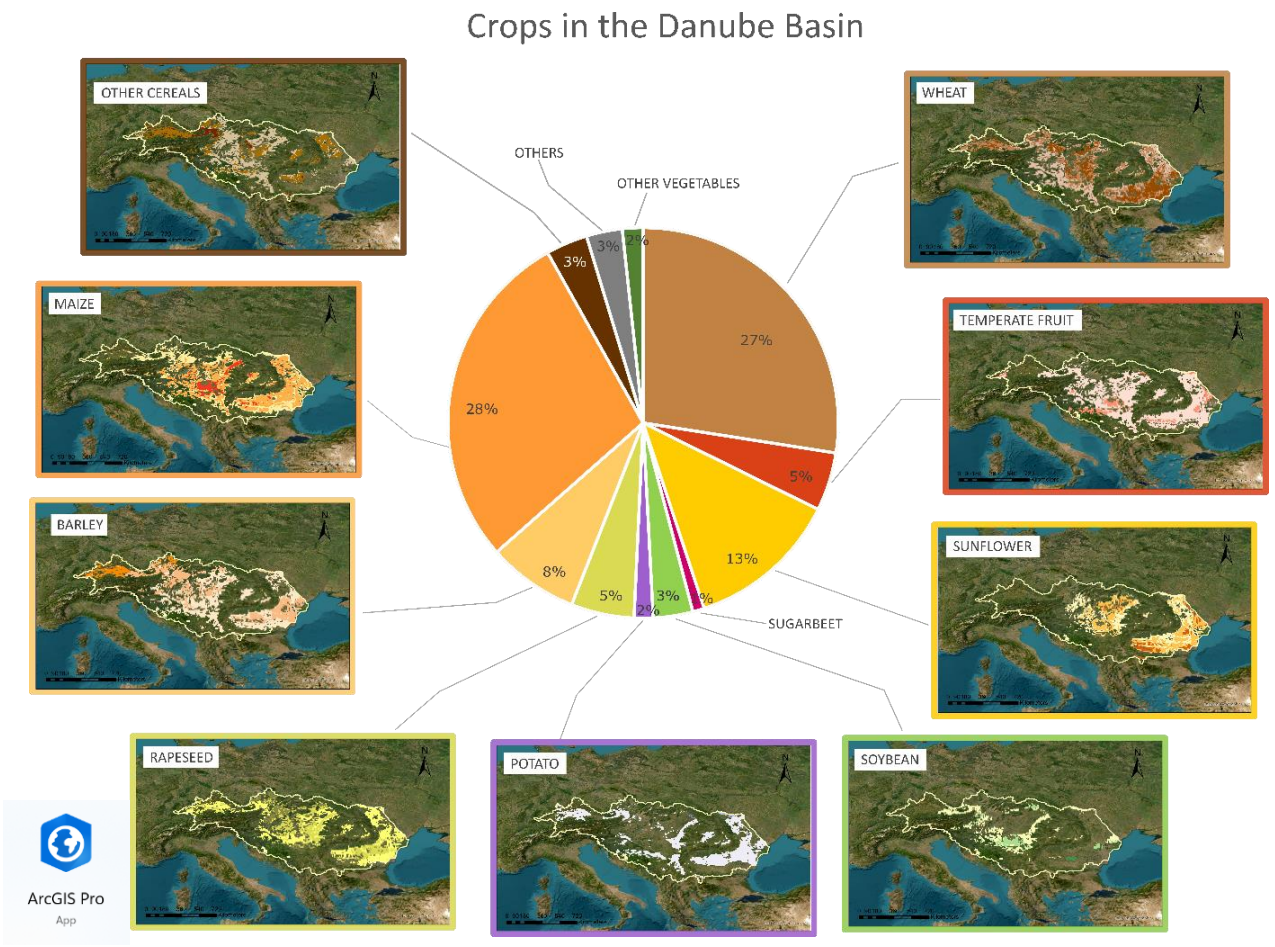
SOS-Water Evaluation Framework Overview

The SOS is evaluated using a set of **indicators**, i.e. measurable variable which can be used to assess the state of different water functions or processes in the Danube basin, also with respect to human use.

Within the SOS, agricultural water use is a key component of the coupled human–water system and is analysed using **integrated modeling** and **stakeholders-informed future scenarios.**



Crops and irrigation in the Danube basin

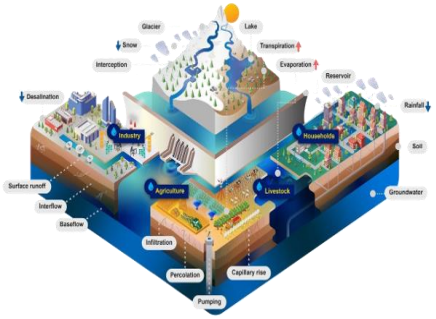


In the Danube basin, we included a total of 14 crops, of which 11 also irrigated:

- Barley
- Bean
- Chickpea
- Lentil
- Maize
- Small Millet
- Potato
- Rice
- Sorghum
- Soybean
- Sugarbeet
- Sunflower
- Tobacco
- Wheat

SPAM2020 (IFPRI, 2024)

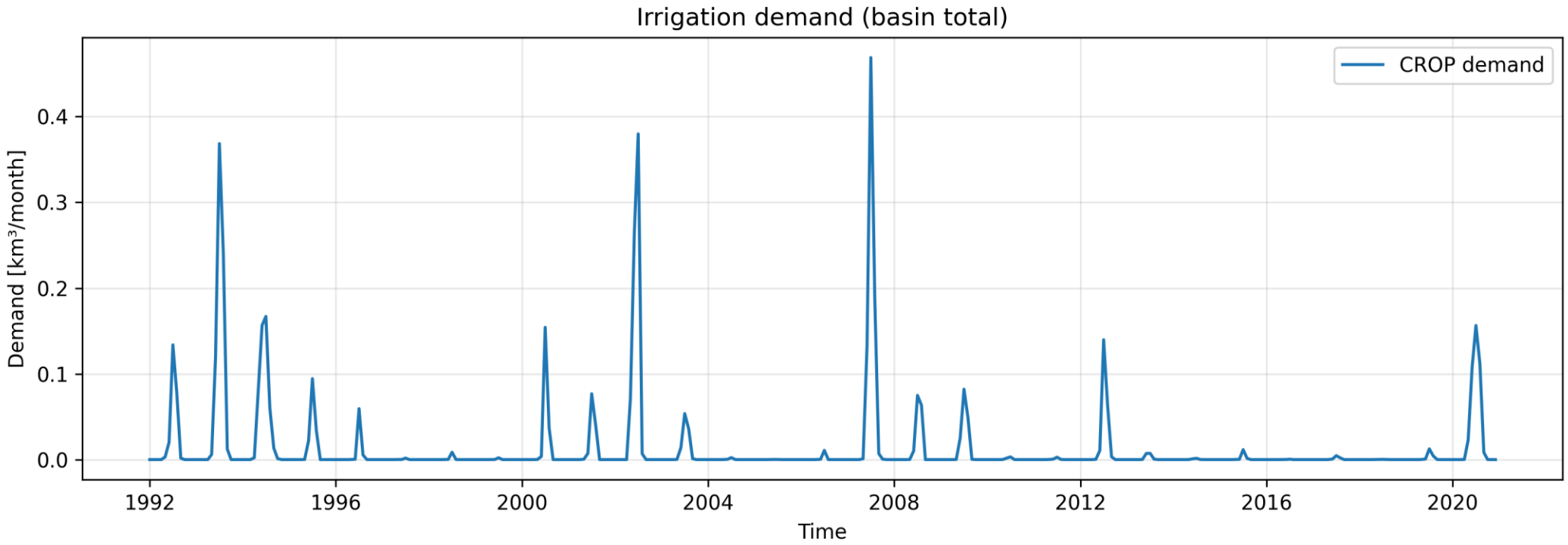
Community Water Model (CWatM)



https://cwatm.iiasa.ac.at/

Water demand for irrigation in the Danube basin

Including specific crop maps and parameters



Future scenarios

1. SSP1-2.6: An der schönen blauen Donau (Sustainability)

Theme: Strong international cooperation and a shared vision for sustainability.

2. SSP3-7.0: Dies Irae (Fragmentation & Conflict)

Theme: Increasing socio-economic disparities and lack of cooperation.

3. SSP5-8.5: Der Radetzky-Marsch (Fossil-fueled Development)

Theme: Strong cooperation driven by economic growth and technology.

Irrigation expansion scenarios

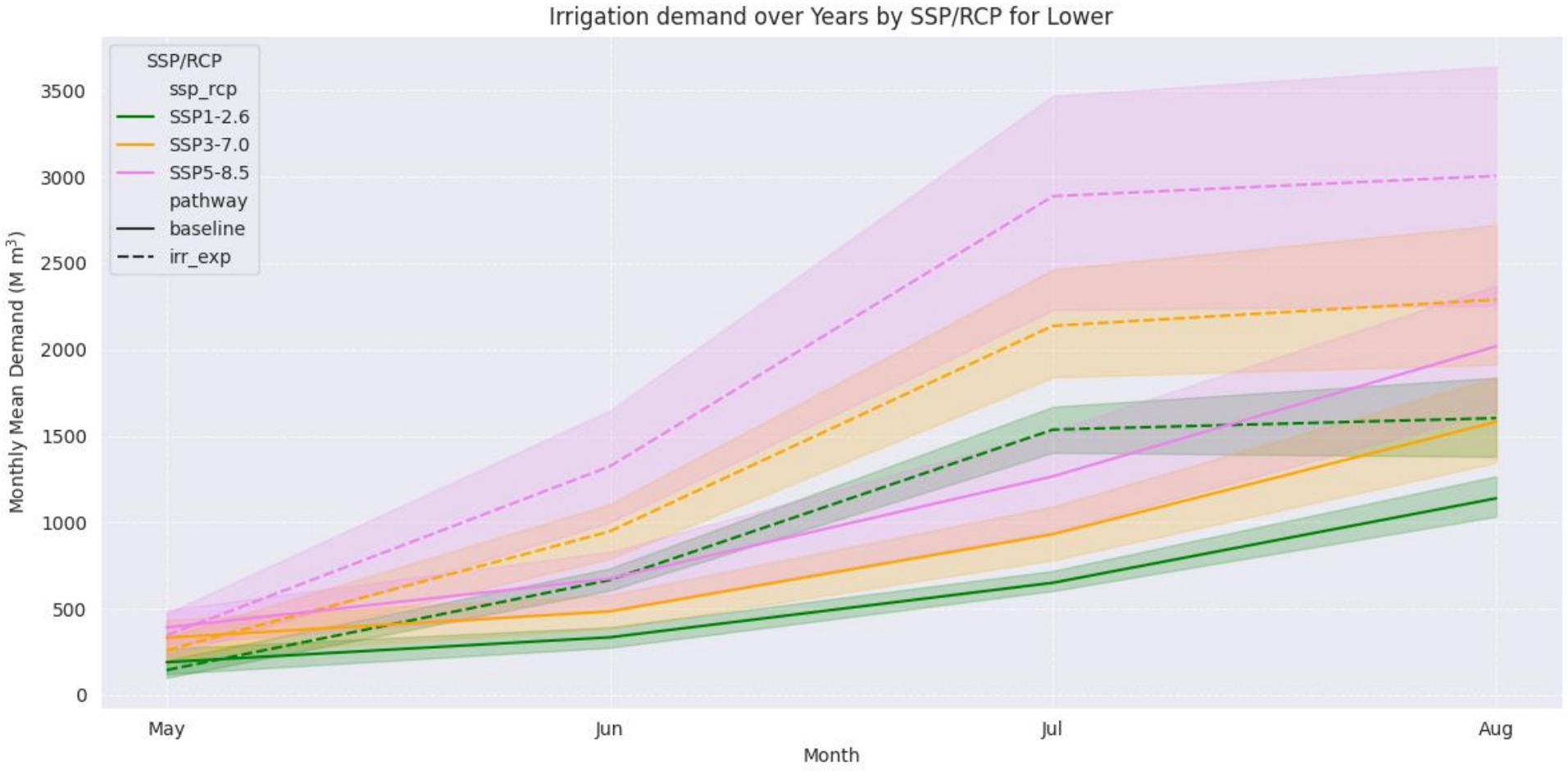
Estimated irrigated area increases (2015-2100) in the Danube basin

	Total irrigation % increase			Annual irrigation % increase*			Efficiency annual increase%**		
	SSP1	*SSP3*	*SSP5*	*SSP1*	*SSP3*	*SSP5*	*SSP1*	*SSP3*	*SSP5*
Upper	2	15	40	1	2	10	1.1	0.6	1.3
Middle	10	15	40	0.6	0.5	10	1.1	0.6	1.3
Lower	12	15	40	0.6	0.5	10	1.1	0.6	1.3
Basin mean	10	15	40	0.6	1.5	10	1.1	0.6	1.3

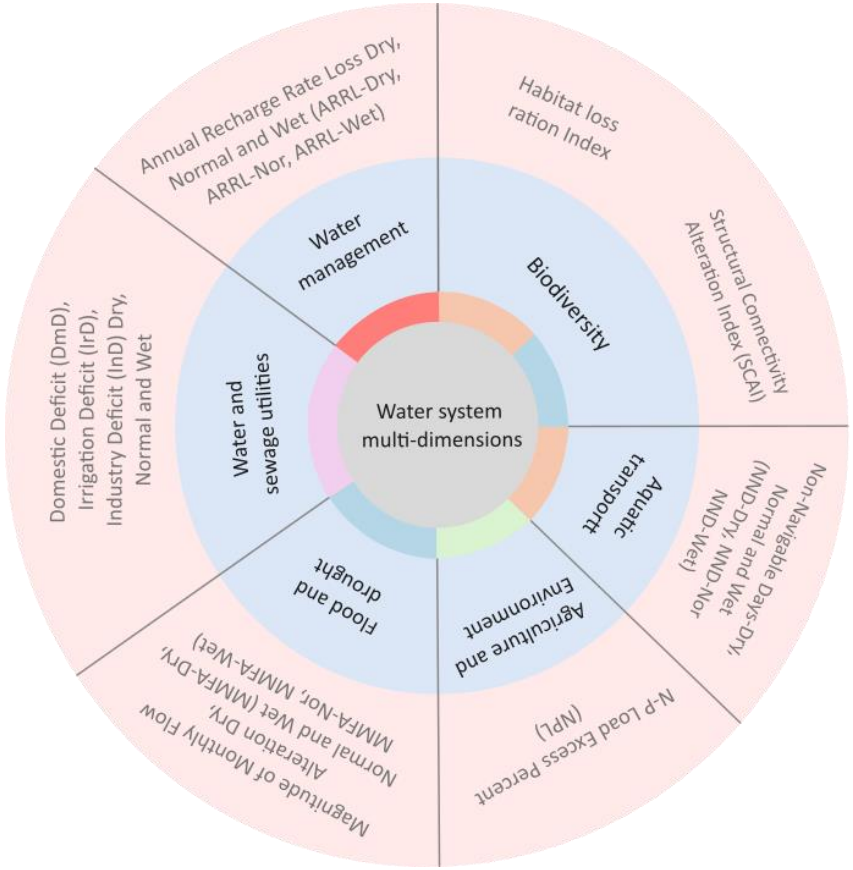
*Annual increase until the total % increase is reached. ** Annual increase in efficiency

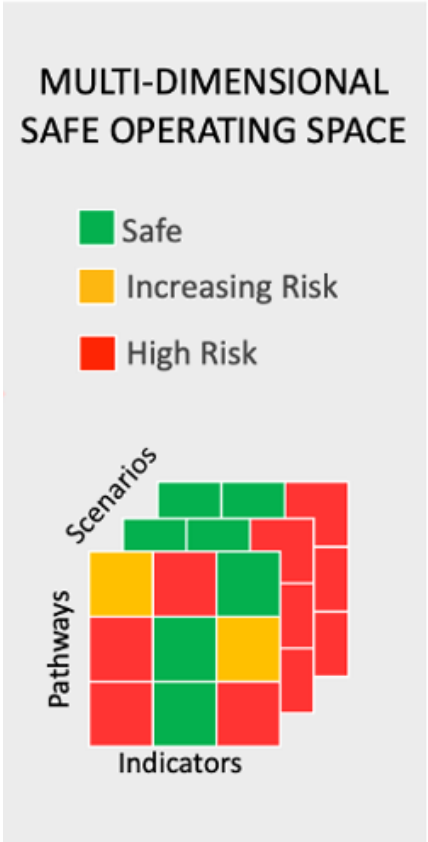
Effect of irrigation expansions on water demand

Mean future monthly irrigation water demand for the Lower Danube



How can the SOS be used for water management?





Castelletti, Invernizzi et al., *unpublished;* modified by Silvia Artuso

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Thank you very much for your time!

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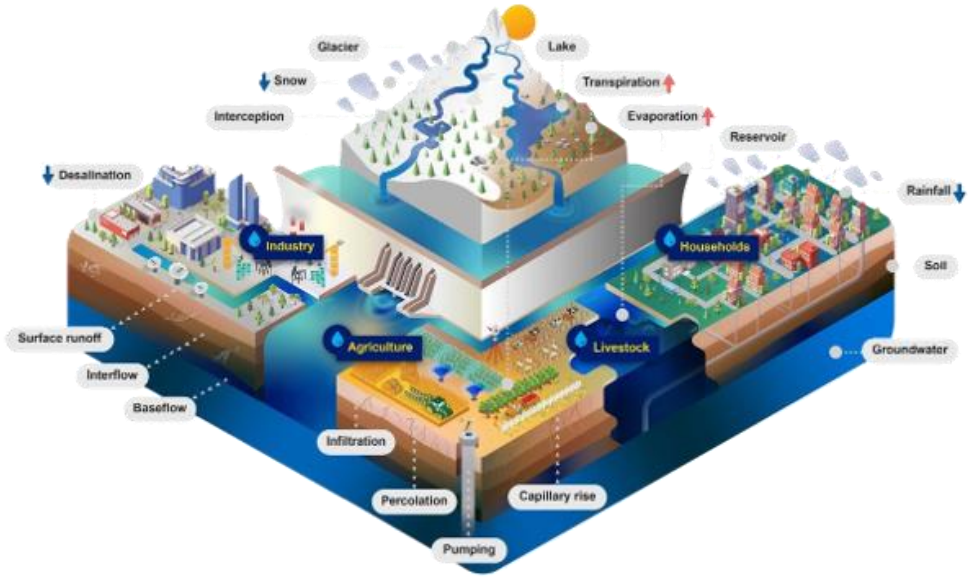
Integrated water modelling system (IWMS) for the Danube basin

Community Water Model (CWatM)



https://cwatm.iiasa.ac.at/

Community Water Model (CWatM) is a hydrological model simulating the water cycle daily at global and local levels, historically and into the future, maintained by IIASA BNR Water Security group.

CWatM assesses water supply, demand, and environmental needs, including water management and human influence within the water cycle. CWatM includes an accounting of how future water demands will evolve in response to socioeconomic change and how water availability will change in response to climate and management.

CWatM is open-source and community-driven, and its modular structure facilitates integration with other models.