Fourth Edition

"NATURAL HAZARDS AND CULTURAL HERITAGE"
PRESERVATION STRATEGIES
19 - 26 July 2026

Drought risk assessment: a "systemic" perspective

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***Todi, Istituto Ciufelli* - 24 July 2026**

UNITED NATIONS AGENDA 2030

Consiglio Nazionale delle Ricerche
CNR IRSA

GOAL 6 – CLEAN WATER AND SANITATION

This Agenda is a plan of action for people, planet and prosperity … All countries and all stakeholders, active in collaborative partnership, will implement this plan (from the preamble)

Ensure availability and sustainable management of water and sanitation for all

- by 2030, achieve universal and equitable access to safe and affordable drinking water
- …
- by 2030, substantially increase water use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity
- by 2030, implement integrated water resources management at all level
- …
- Support and strengthen the participation of local communities in improving water and sanitation management

WATER RESOURCES – SURFACE WATERS


RIVERS


LAKES (NATURAL RESERVOIRS)


ARTIFICIAL RESERVOIRS (DAMS)

GROUNDWATER RESOURCES - SPRINGS

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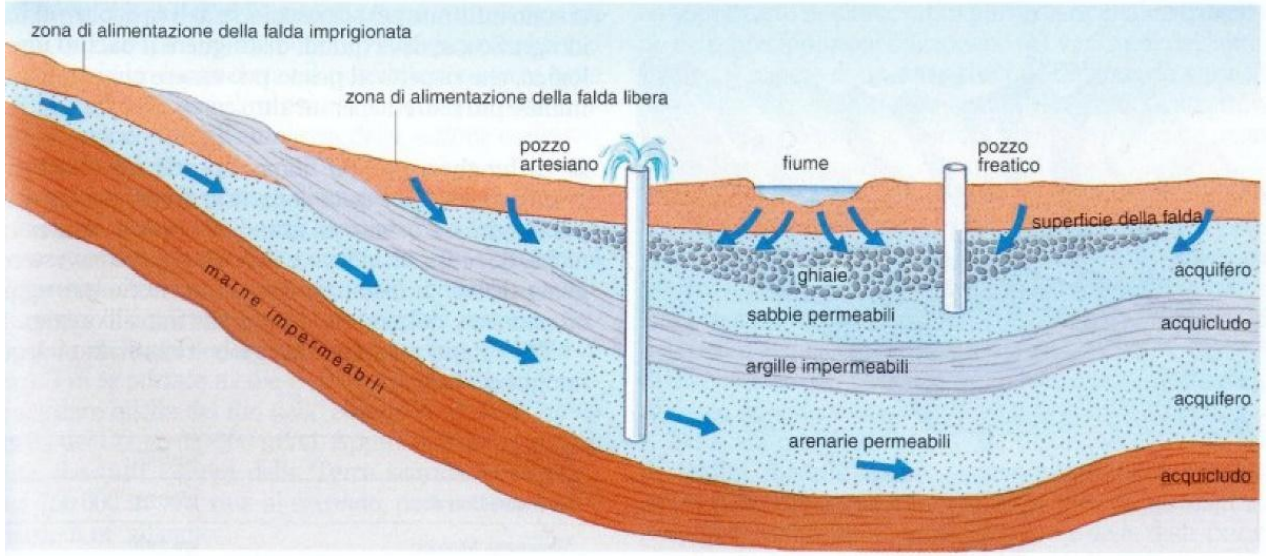
SPRINGS


LUPA SPRING


PESCHIERA SPRING

AQUIFERS



WHO ARE THE WATER USERS?

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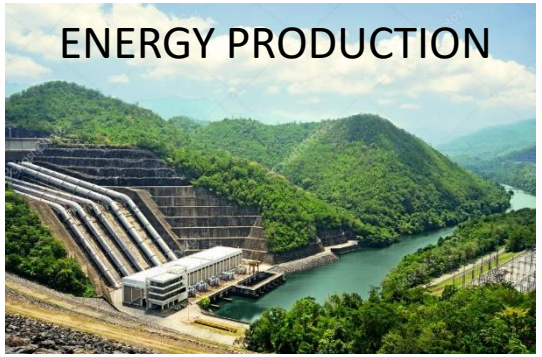

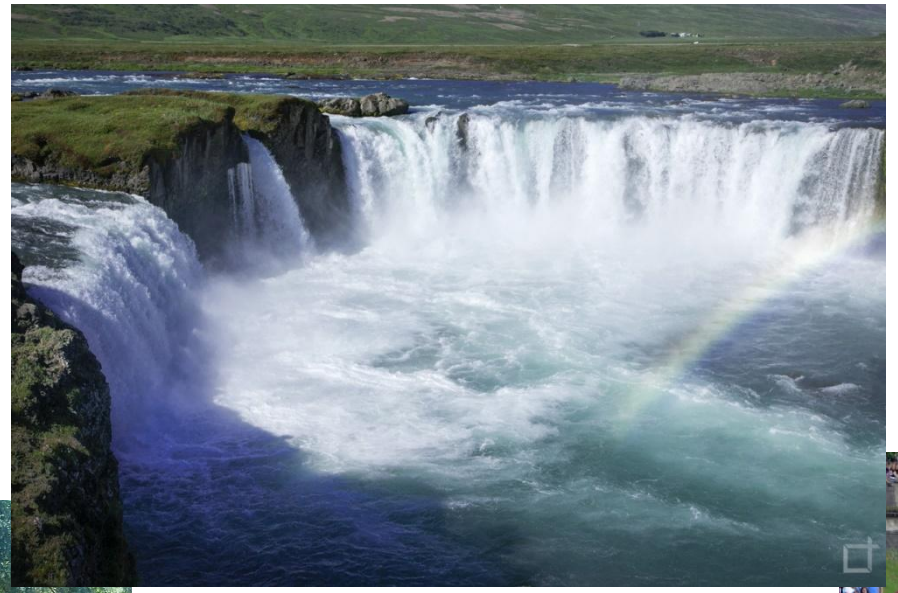

WATER SUPPLY SYSTEMS

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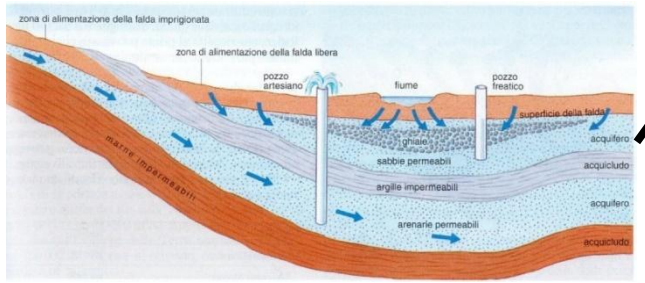
Water abstraction, conveyance and distribution services for various uses (domestic, irrigation, industrial, hydropower generation, etc.), as well as wastewater collection and treatment services

WATER RESOURCES

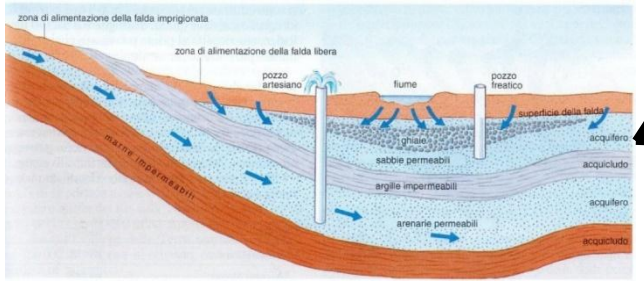


USERS

WATER SUPPLY SYSTEMS

Water abstraction, conveyance and distribution services for various uses (domestic, irrigation, industrial, hydropower generation, etc.), as well as wastewater collection and treatment services

WATER RESOURCES



USERS

WHERE DOES THE WATER COME FROM?

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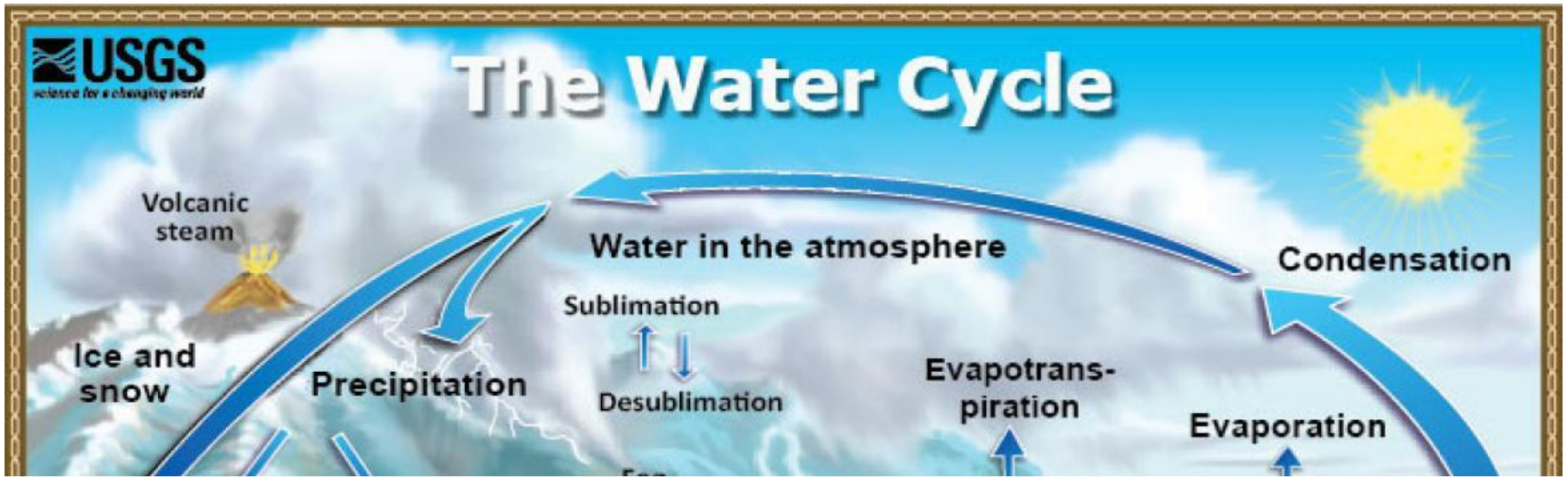
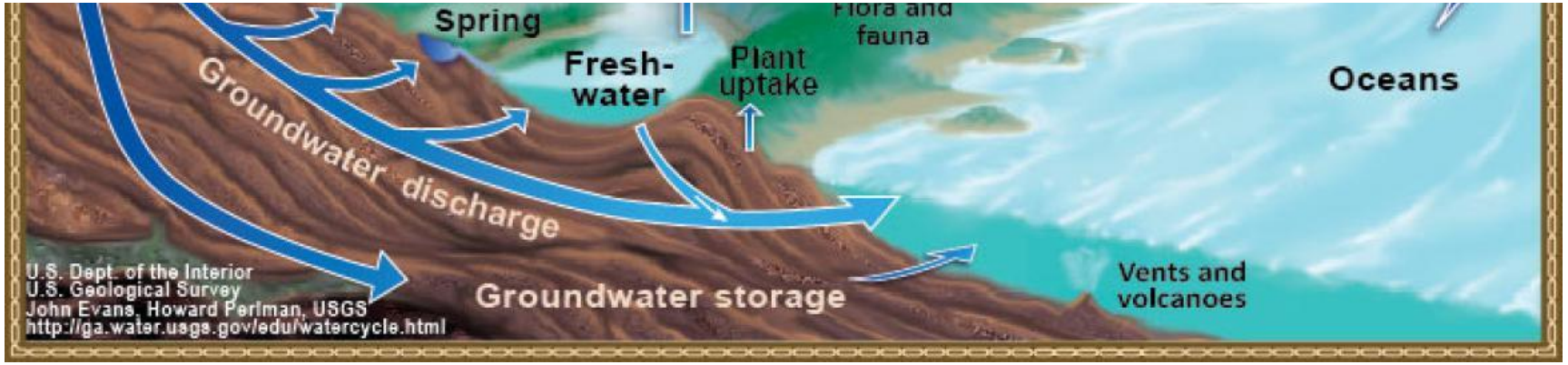


We do not produce water… we collect it, use it, and return it back to nature



DROUGHT – SCARCITY – SEVERITY

Meteorological drought

Climate – meteorological conditions

Agricultural drought

Hydrological and hydrogeological drought

Water resources status

Socio-economic and environmental drought

Meeting the water demand

DROUGHT

A spatially and temporally limited condition characterized by a significant reduction in precipitation (natural factors)

SCARCITY

A condition characterized by a significant decrease in water resource availability, resulting from both natural and anthropogenic factors

SEVERITY

A spatially and temporally limited condition characterized by insufficient water resource availability relative to the associated water demands (environmental requirement included)

Methodological approach

THE LAKE MAGGIORE AND THE PO RIVER BASIN

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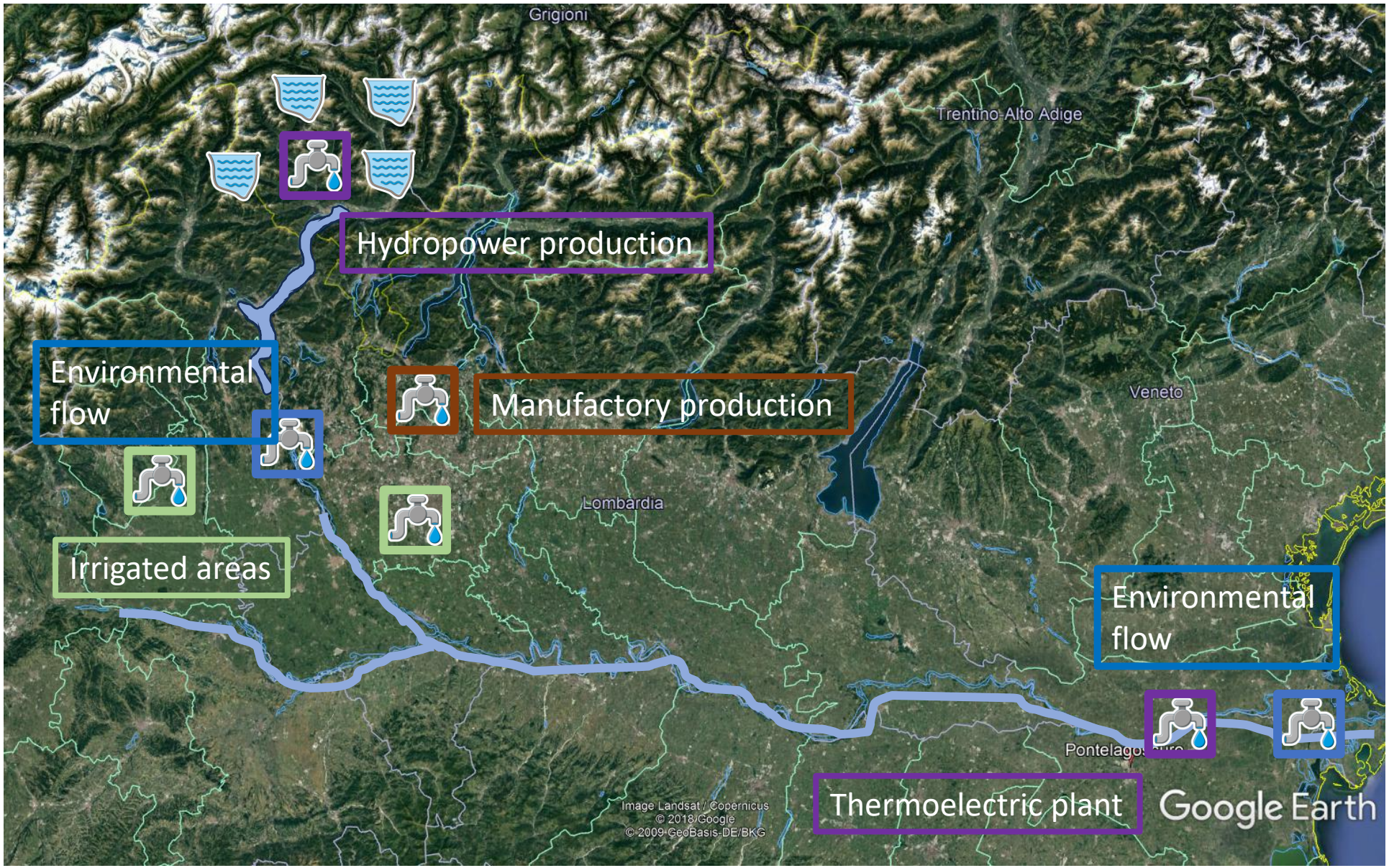

THE 2003 WATER CRISES IN THE PO RIVER BASIN

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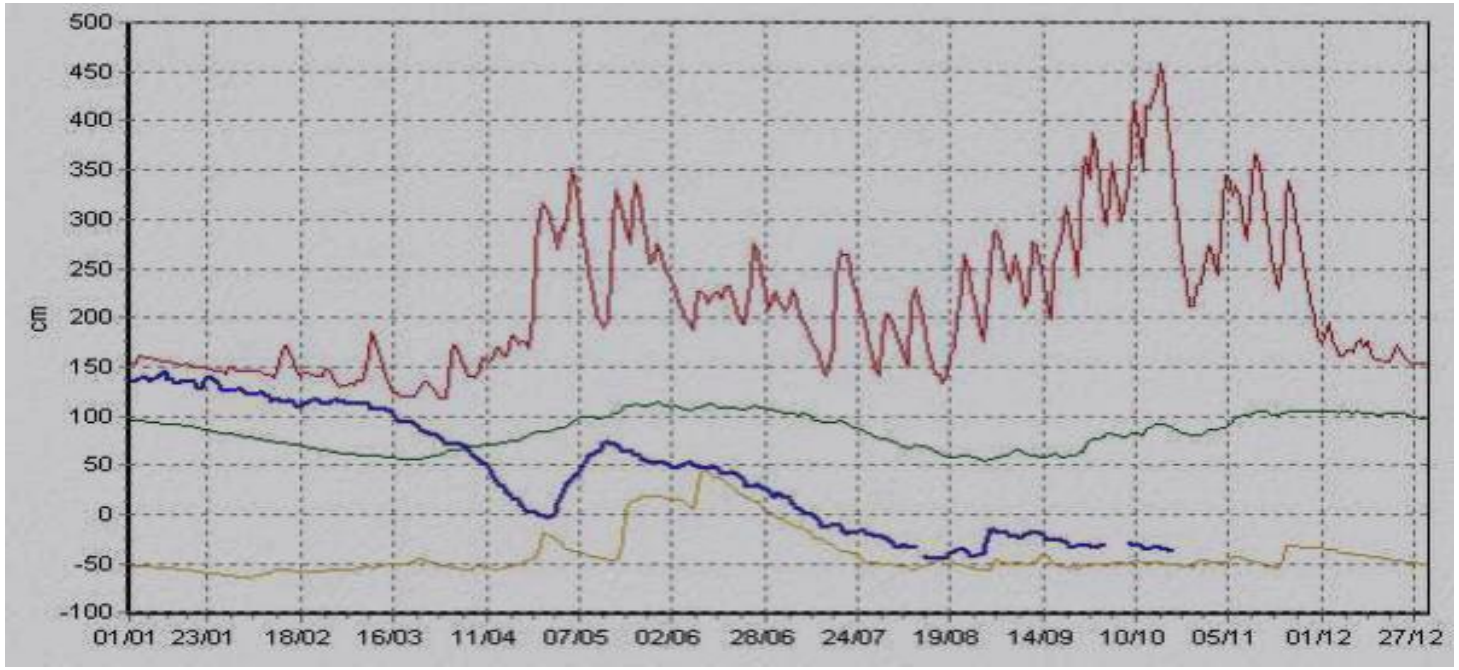
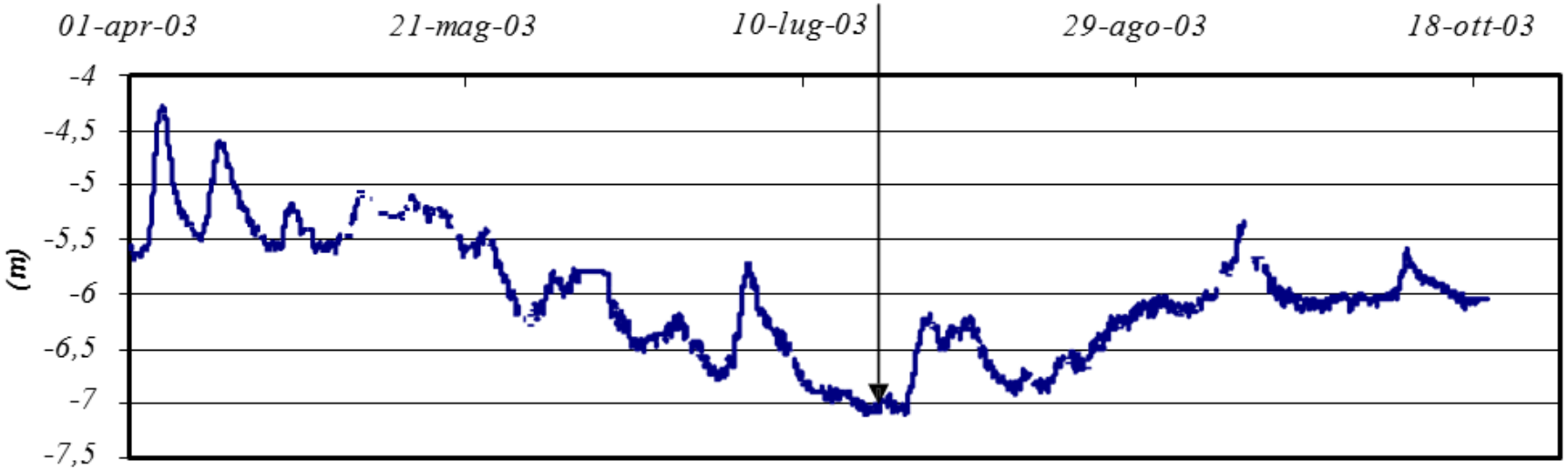


Lake Maggiore level



Po at Pontelagoscuro – Level

THE ENERGY CRISIS IN 2003

- High temperatures
- Scarcity of winter and spring precipitation throughout Northern Italy
- Summer crisis of the national electricity system due to increasing energy demand
- Crisis in the national electricity system, also caused by limited water availability
- Insufficient water levels for thermoelectric power generation

DECLARATIONS OF DRINKING WATER SUPPLY EMERGENCIES

PIEDMONT → Crisis affecting Alpine and foothill springs
EMILIA-ROMAGNA → Crisis affecting foothill springs and the water supply system of the city of Ferrara

THE MEMORANDUM OF UNDERSTANDING OF SUMMER 2003

Consiglio Nazionale delle Ricerche

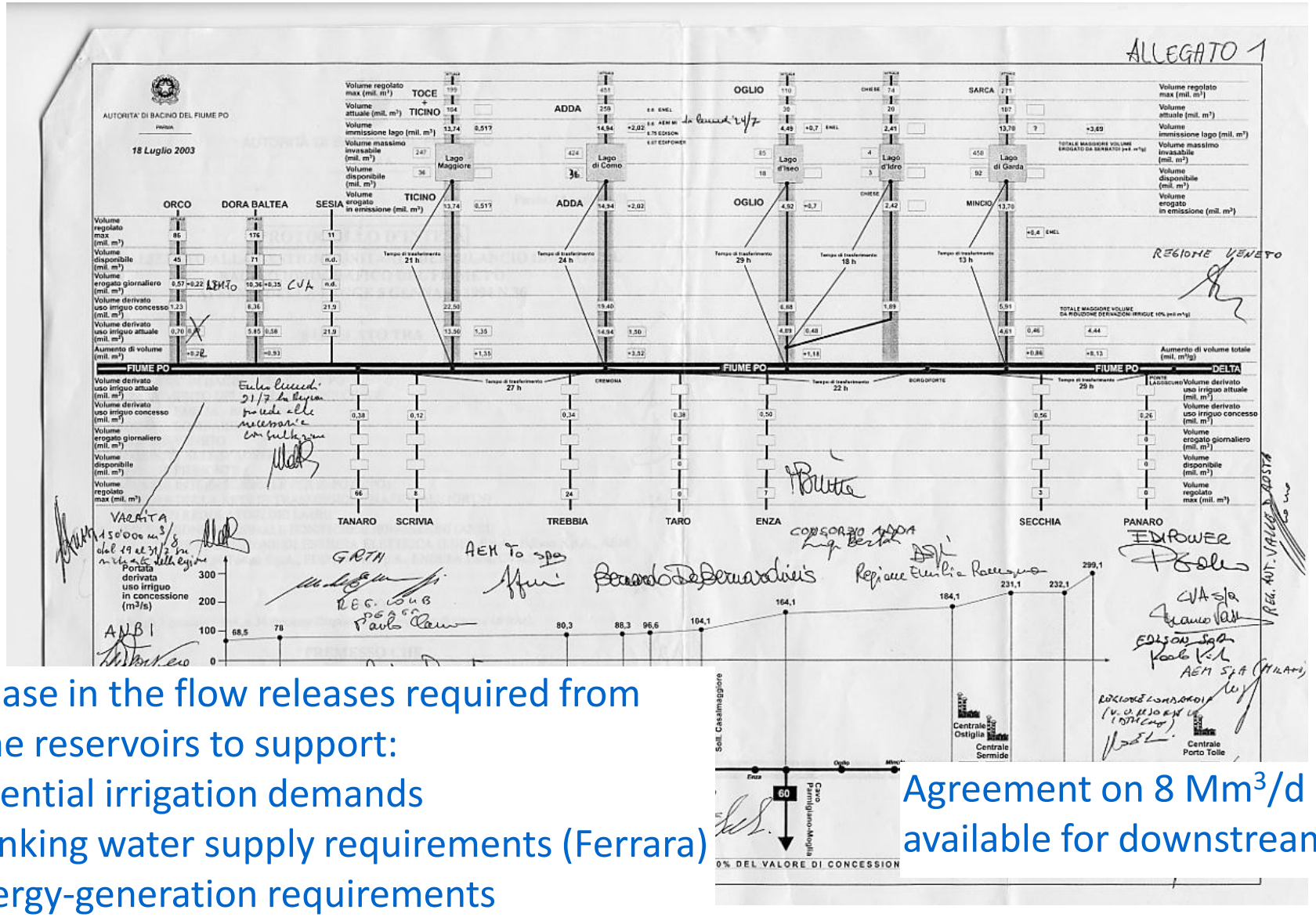
CNR IRSA

AIMED AT THE INTEGRATED MANAGEMENT OF THE WATER BALANCE OF THE PO RIVER BASIN PURSUANT TO LAW No. 36 OF 5 JANUARY 1994. ENTERED INTO BY

- Po River Basin Authority
- Department of Civil Protection
- Emilia-Romagna Region
- Lo
- Ve
- Ac
- Pi
- Interregional Agency for the Po River (AIPO)
- National Transmission Grid Operator (GRTN)
- Lake Regulation Consortia
- National Association for Land Reclamation and Irrigation (ANBI)
- Electricity Generation Companies (ENEL S.p.A., Edison S.p.A., AEM Milan S.p.A., AEM Turin S.p.A., EDIPOWER S.p.A., Endesa Italia, CVA S.p.A.)

ALL COUNTRIES AND ALL STAKEHOLDERS, ACTIVE IN A COLLABORATIVE PARTNERSHIP WILL IMPLEMENT THIS PLAN (from the 2030 Agenda for sustainable development)

MEMORANDUM OF UNDERSTANDING SUMMER 2003

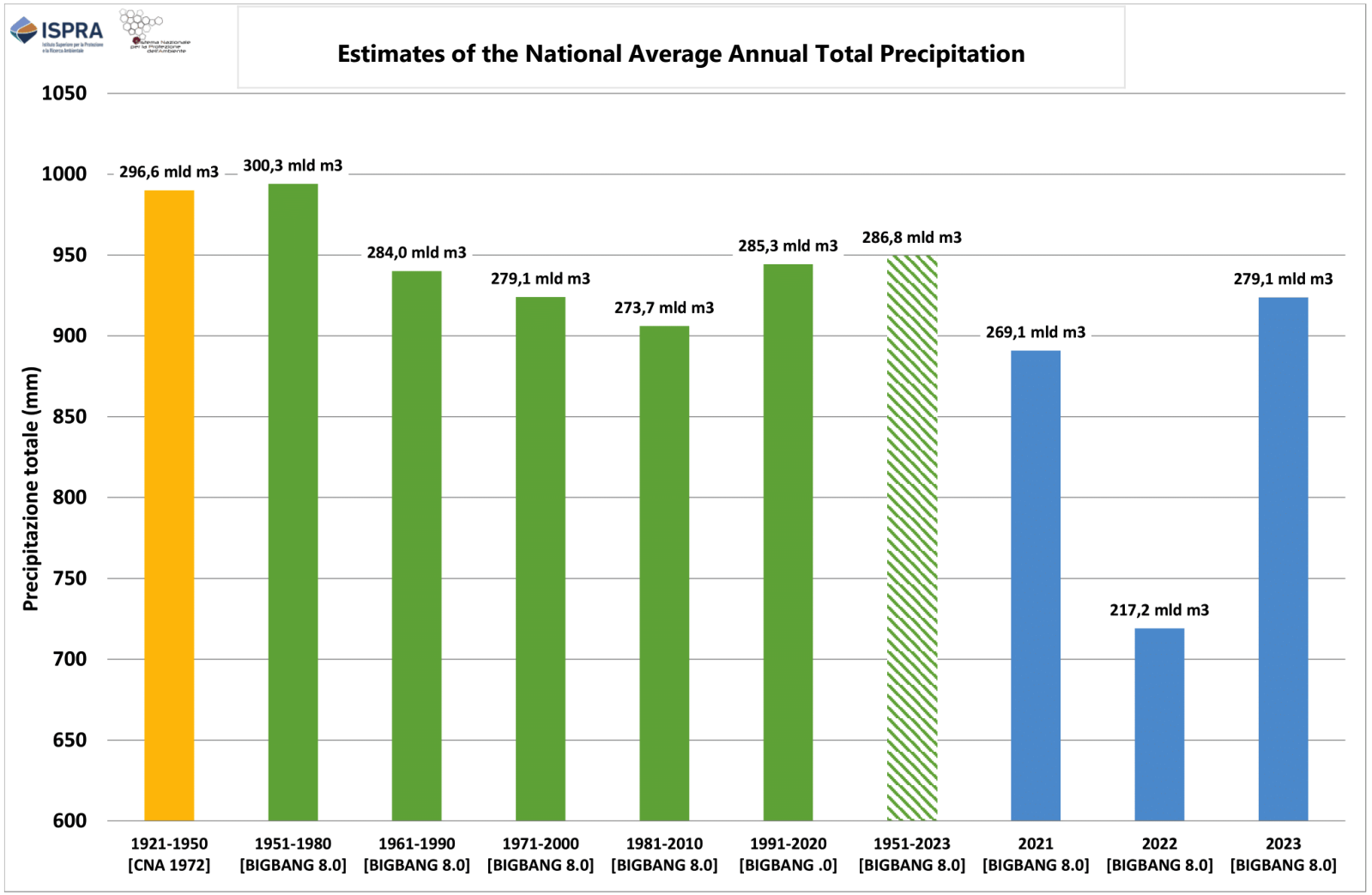


Increase in the flow releases required from Alpine reservoirs to support:

- Essential irrigation demands
- Drinking water supply requirements (Ferrara)
- Energy-generation requirements (thermoelectric power plants)

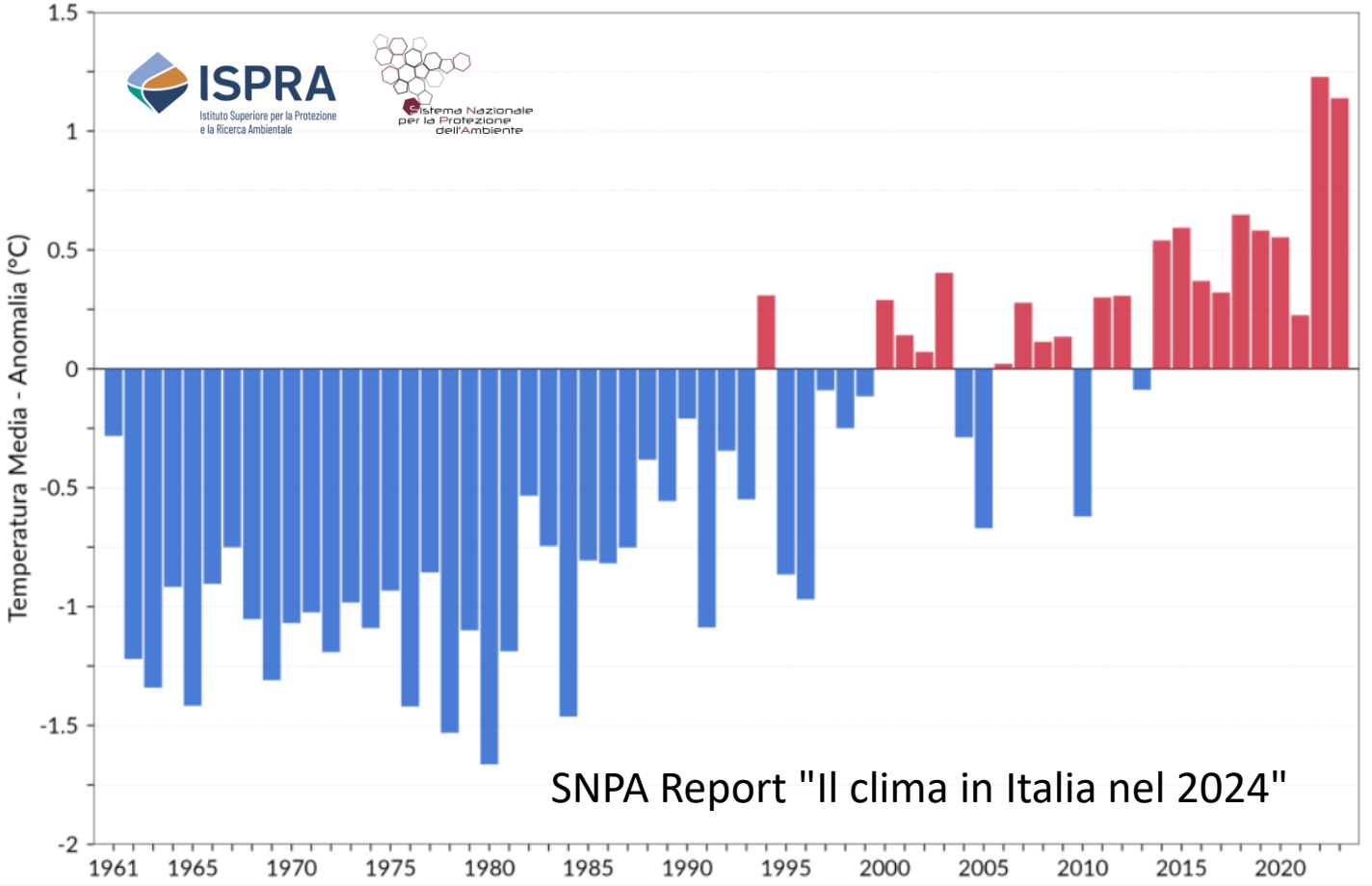
Agreement on 8 Mm^3/d made it available for downstream uses

PRECIPITATION TREND



- ✓ Significant decrease in the number of rainy days (Caporali et al., 2021)
- ✓ Trend towards an increase in the number of positive extreme events (Alpert et al., 2002; Di Lena et al., 2014; Piccarreta et al., 2013; Baronetti et al., 2024), although this trend is not always statistically significant.

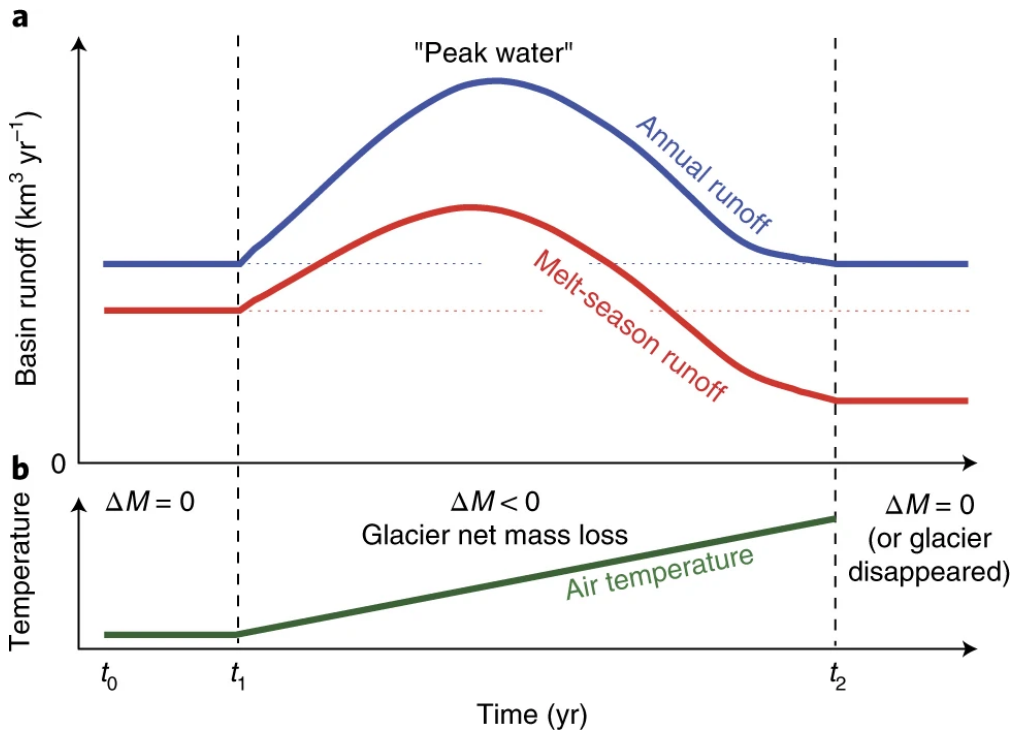
TEMPERATURE TREND



- Since 2000, mean temperatures in Italy have been almost consistently above the 1991–2020 climatological reference period.
- 2022 → Warmest year on record since 1961 (+1.23°C).
- 2023 → Warmest year on record for daily minimum temperatures (+1.40°C).
- 2024 → Warmest year ever recorded globally, and the first year to exceed the 1.5°C threshold in global mean temperature relative to the pre-industrial era.

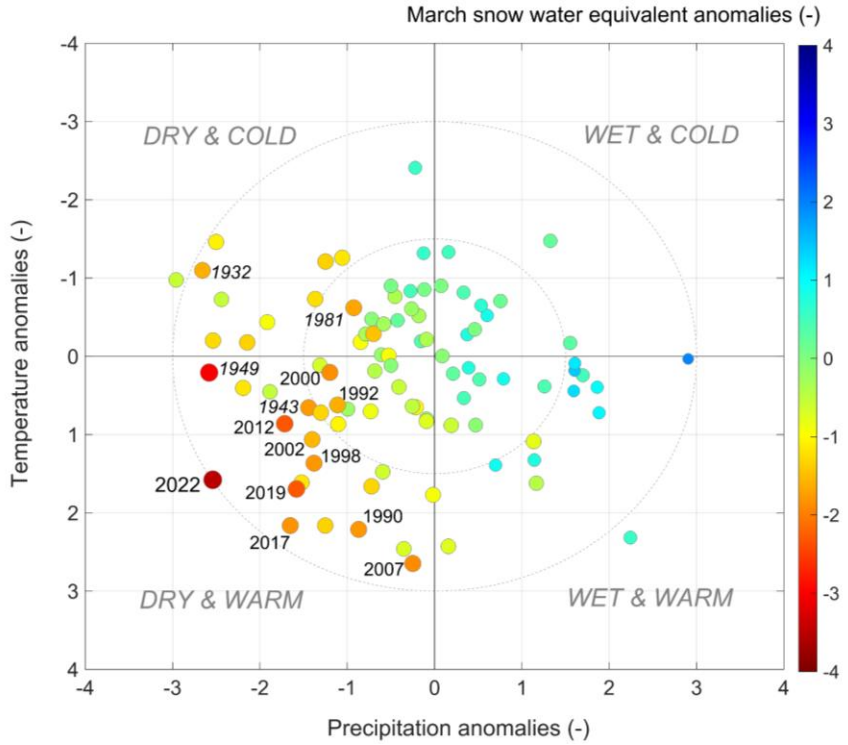
CRYOSPHERE - TREND

GLACIERS



A marked acceleration in glacier area loss has been observed over the last 20 years, reaching approximately a 60% reduction compared to the end of the Little Ice Age (Haeberli et al., 2019), resulting in increased runoff due to glacier melt

SEASONAL SNOWPACK

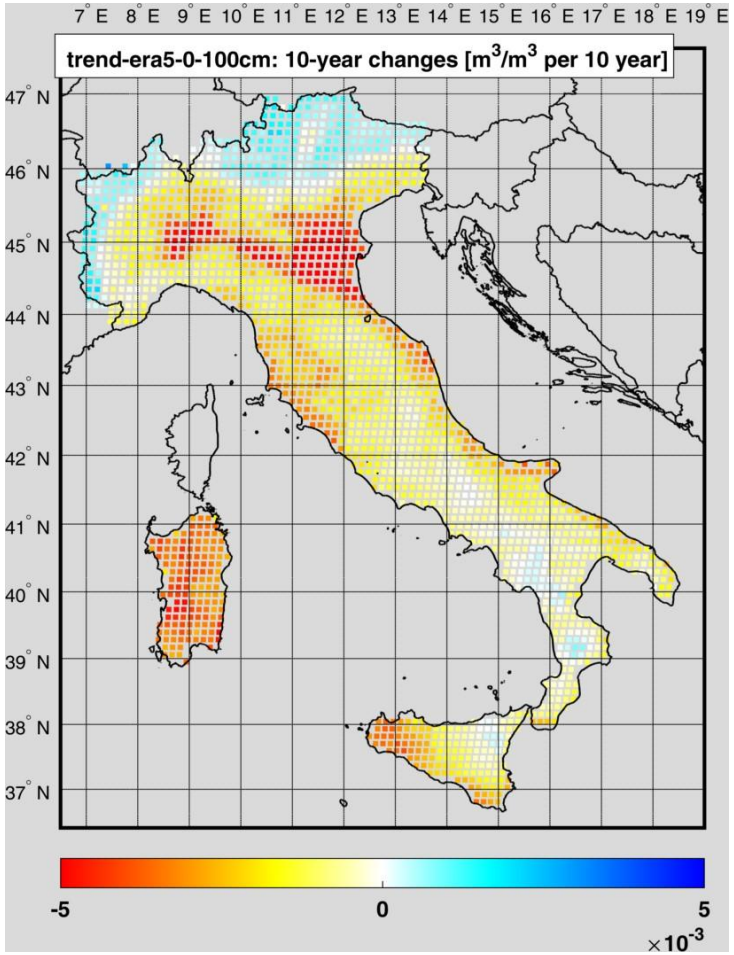


(Colombo et al. 2024)

a. Snow-covered area decreased by approximately 0.25% per year during the period 2000–2018 (Notarnicola, 2020).
b. Snow cover duration declined by approximately 0.5 days per year during the period 2000–2018 (Klein et al., 2016).
c. Average snow depth (HS) decreased by about 0.8% per year (Matiu et al., 2021; Monteiro & Morin, 2023).
d. A decreasing trend was observed in snow water equivalent (SWE), amounting to approximately −4 mm per year in April over the period 1967–2020 (Ranzi et al., 2024).

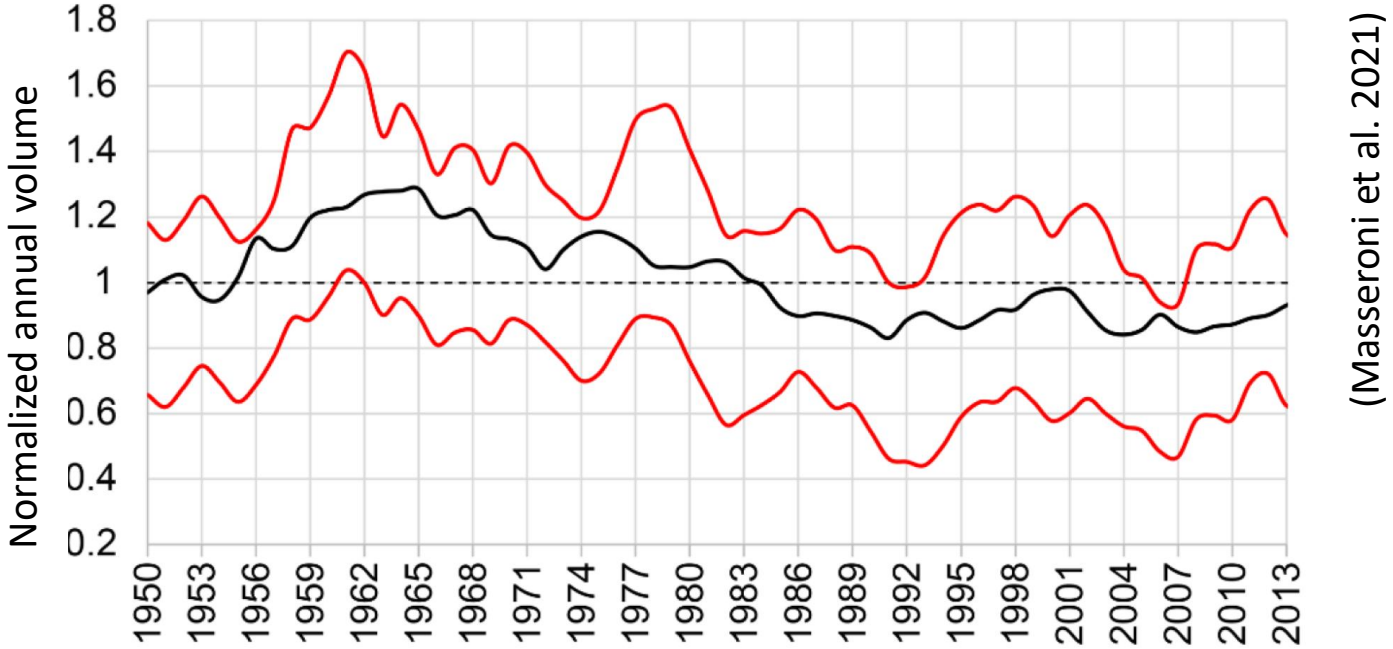
SOIL MOISTURE AND SURFACE DISCHARGE TREND

SOIL MOISTURE



Soil moisture trends (m^3/m^3 per decade) derived from the ERA5-Land reanalysis dataset for the period 1950–2023.

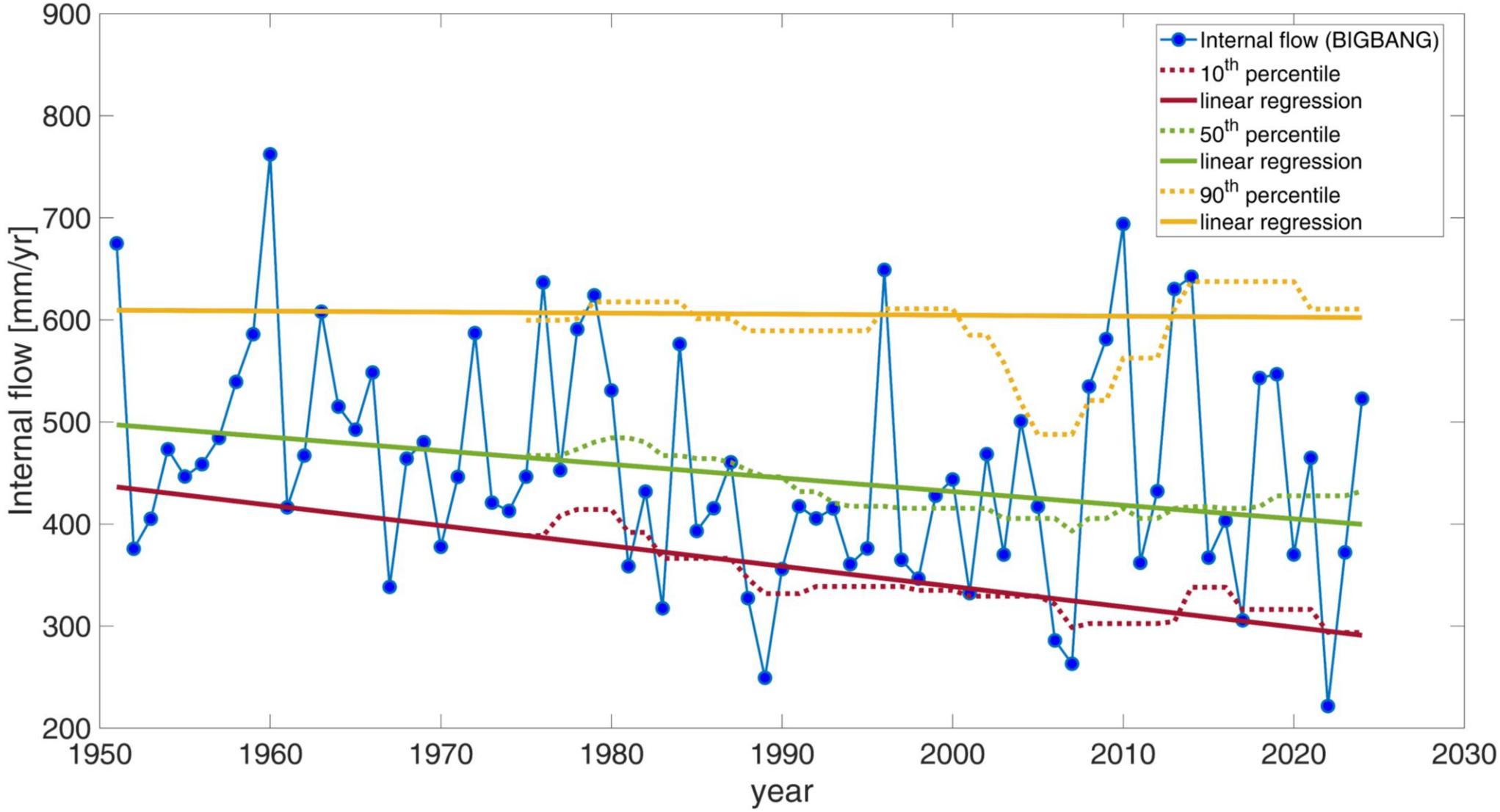
SURFACE DISCHARGE



(Masseroni et al. 2021)

Standardized annual runoff volume from 1950 to 2013: moving average of the standardized annual runoff volume across the entire Mediterranean region (black line), with the 25th and 75th percentiles shown by the red lines.

SURFACE DISCHARGE TREND



GROUNDWATER - TREND

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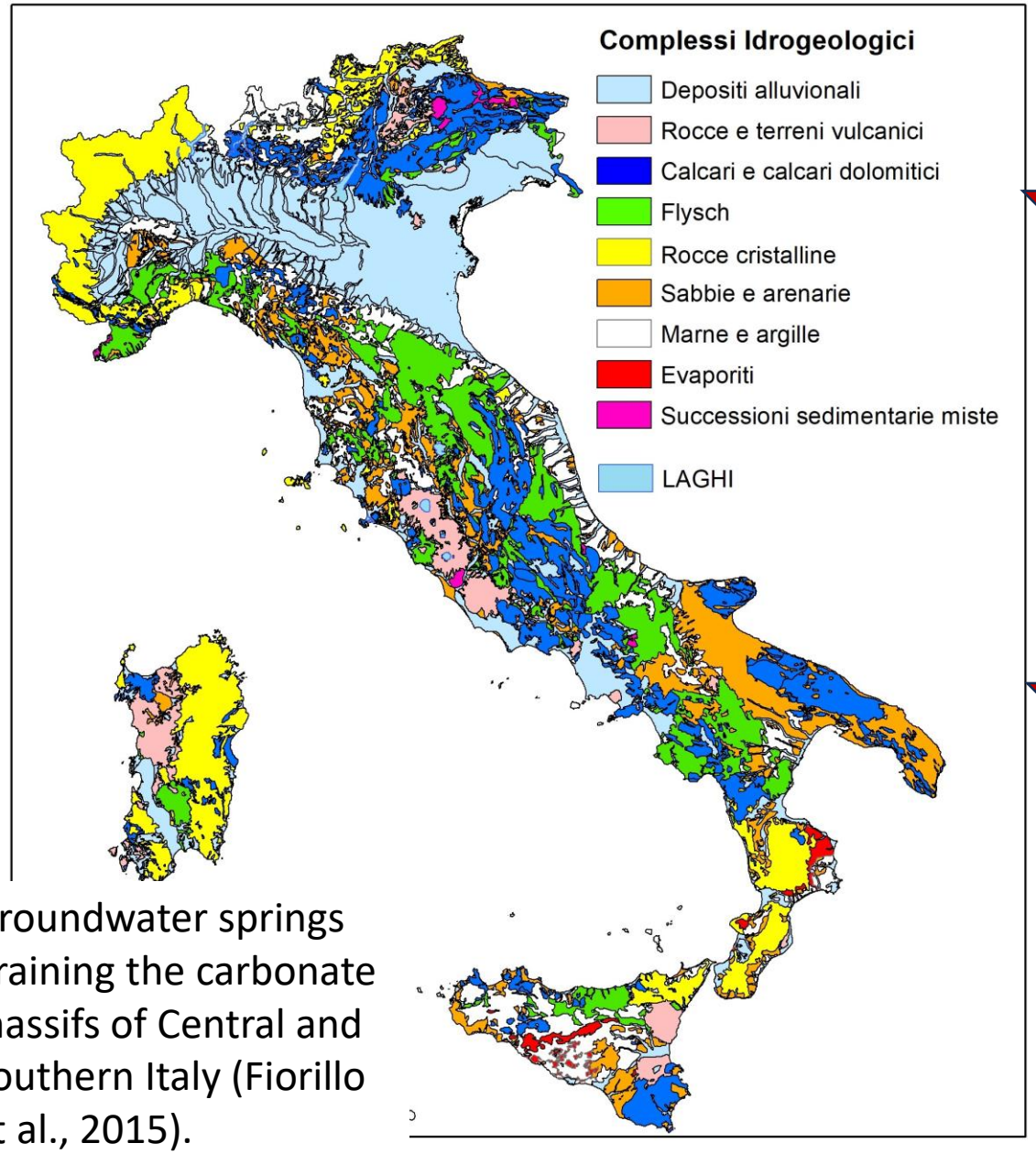
Only a limited number of studies have estimated trends in groundwater storage.



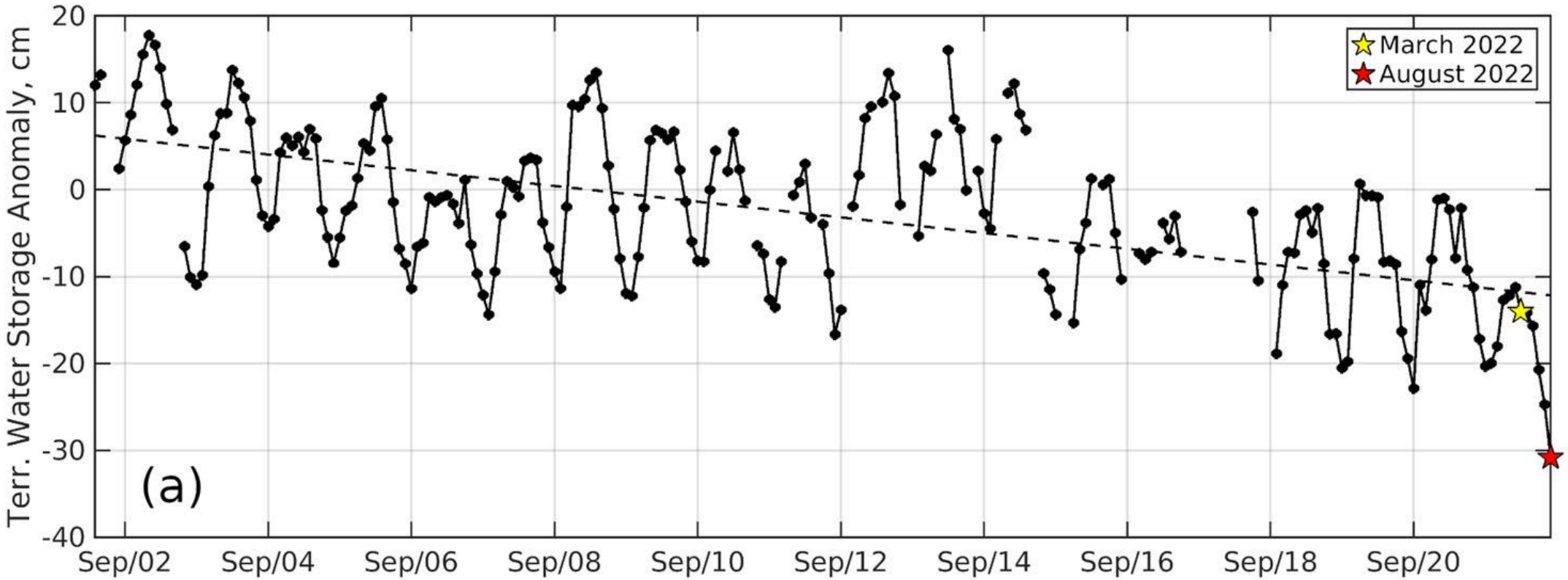
Nossana spring, Citrini et al. 2020.

Groundwater springs fed by the Apuan carbonate aquifer systems and the volcanic aquifers of Mt. Amiata (Tuscany) (Doveri et al., 2019a,b).

Groundwater springs associated with the Apennine aquifer systems of Umbria and Marche (Di Matteo et al., 2013).

Groundwater springs draining the carbonate massifs of Central and Southern Italy (Fiorillo et al., 2015).

GROUNDWATER - TREND



Terrestrial water storage anomalies according to GRACE (Gravity Recovery and Climate Experiment) for the Po-river-basin area, 2002 through 2022 (Avanzi et al., 2024, Carlson et al., 2024)

Drought risk assessment: a "systemic" perspective

TRENDS IN DROUGHT EVENTS AND WATER RESOURCE AVAILABILITY

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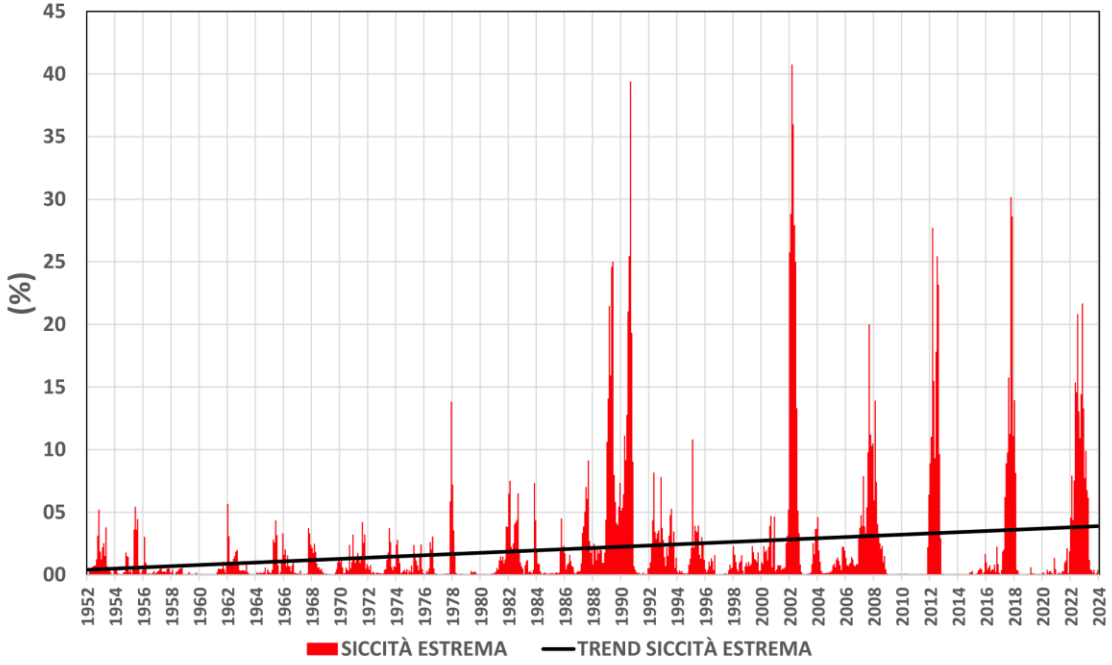
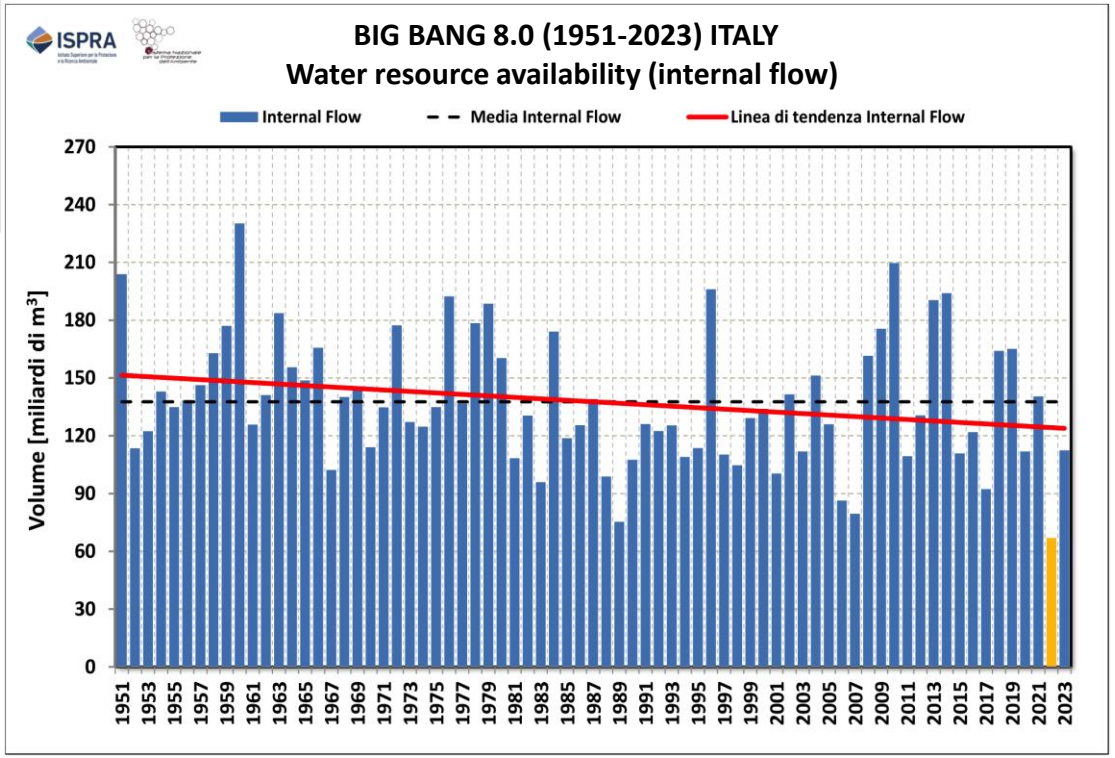
ISPRA

Percentage of the Italian territory affected by extreme drought (1952-2023)



Years in which extreme meteorological drought affected more than 20% of the Italian territory: 1989–1990, 2002, 2012, 2017, and 2022.



A statistically significant declining trend in the average annual availability of renewable water resources.

WATER CONSUMPTION MONITORING

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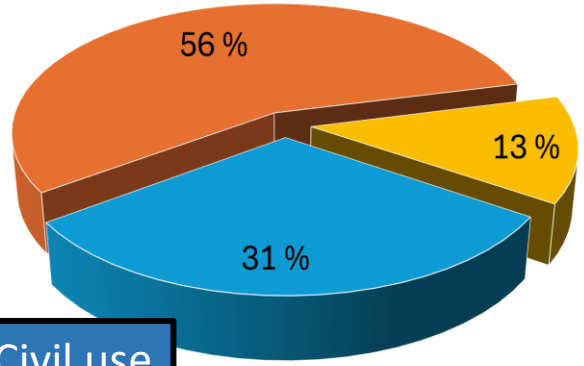
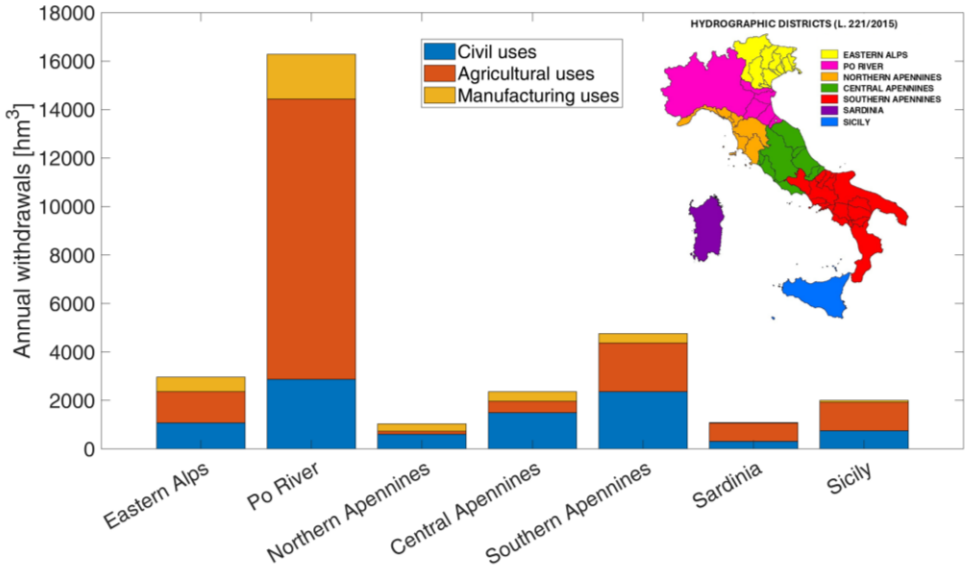
Agricultural use

Data are partly estimated and partly based on direct measurements



Civil use

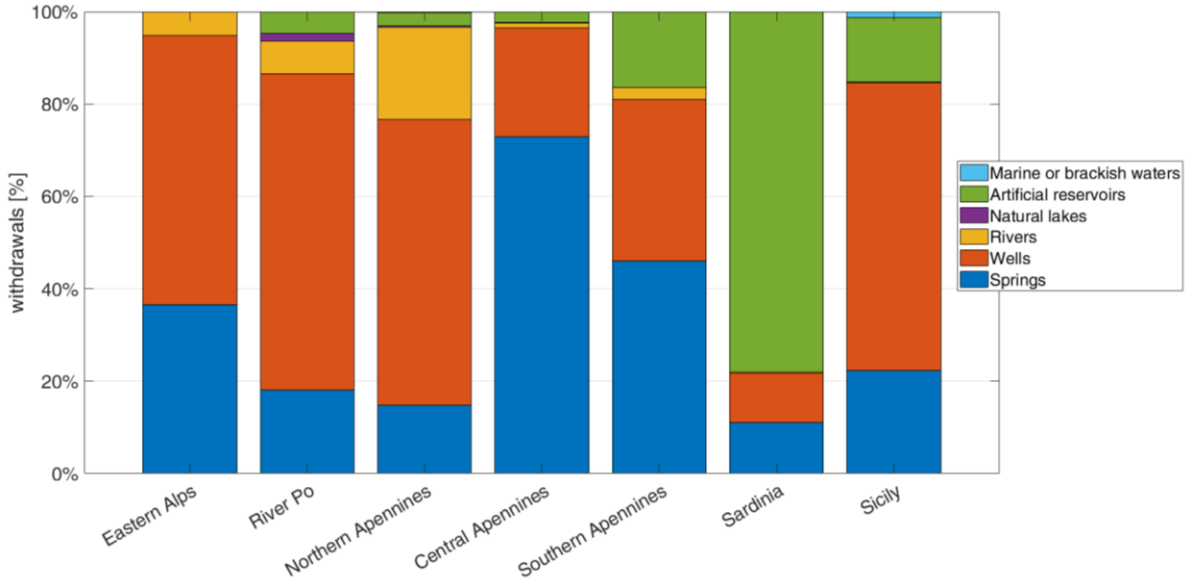
ISTAT Census of Water for Civil Use



Manufacturing use

Estimated data (Istat, 2019)

Uncertainty in water balance assessment at different spatial and temporal scales



Drought risk assessment: a "systemic" perspective

IMPACTS ON THE TERRITORY – VULNERABLE AREAS

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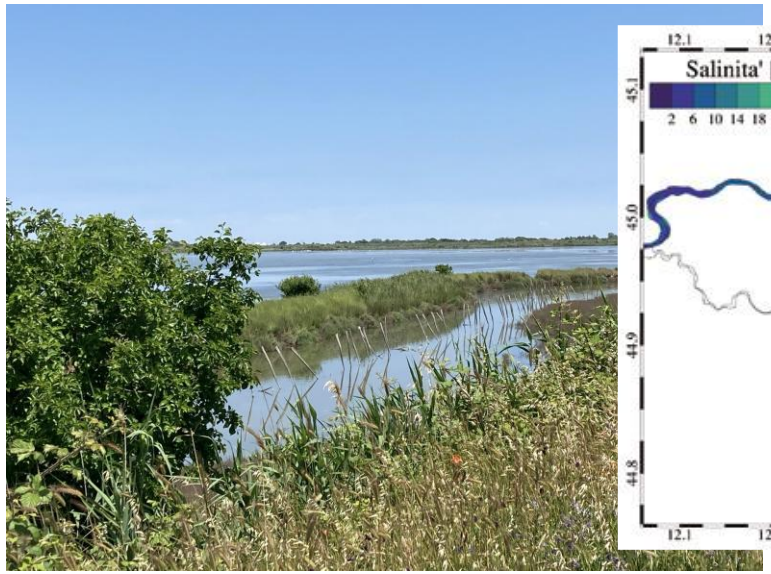
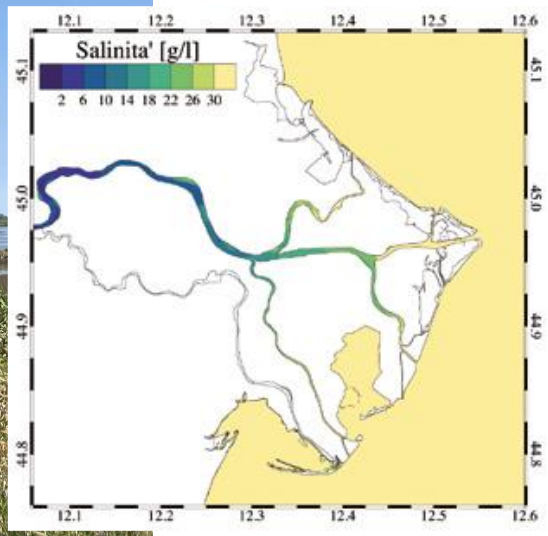
TRANSITION AREAS





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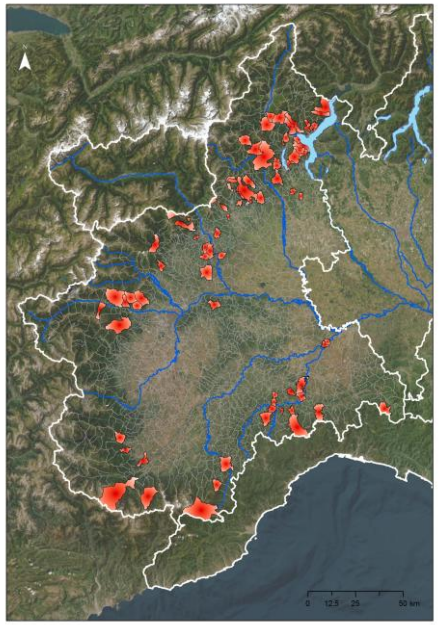
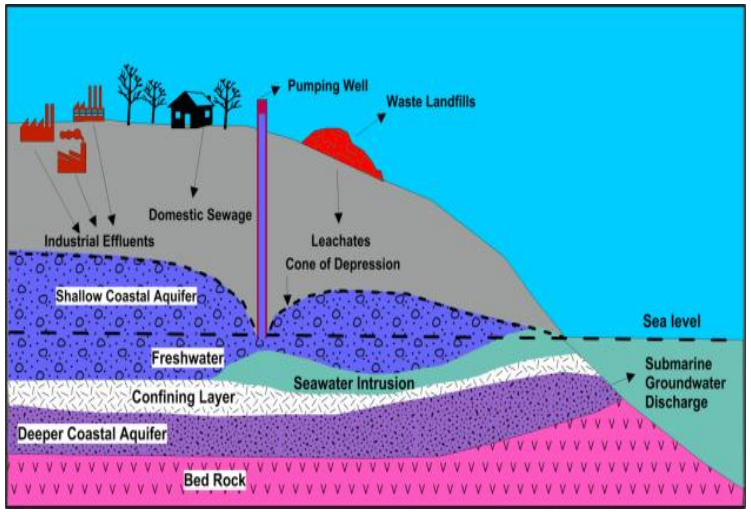


MOUNTAIN WATER SUPPLY SYSTEMS

Municipalities benefiting from "Water Supply Distribution by Tanker Trucks" interventions financed by the Piedmont Region

MOUNTAIN LAKES

INTERMITTENT RIVERS



COASTAL AQUIFERS

CLIMATE CHANGE – FUTURE SCENARIOS

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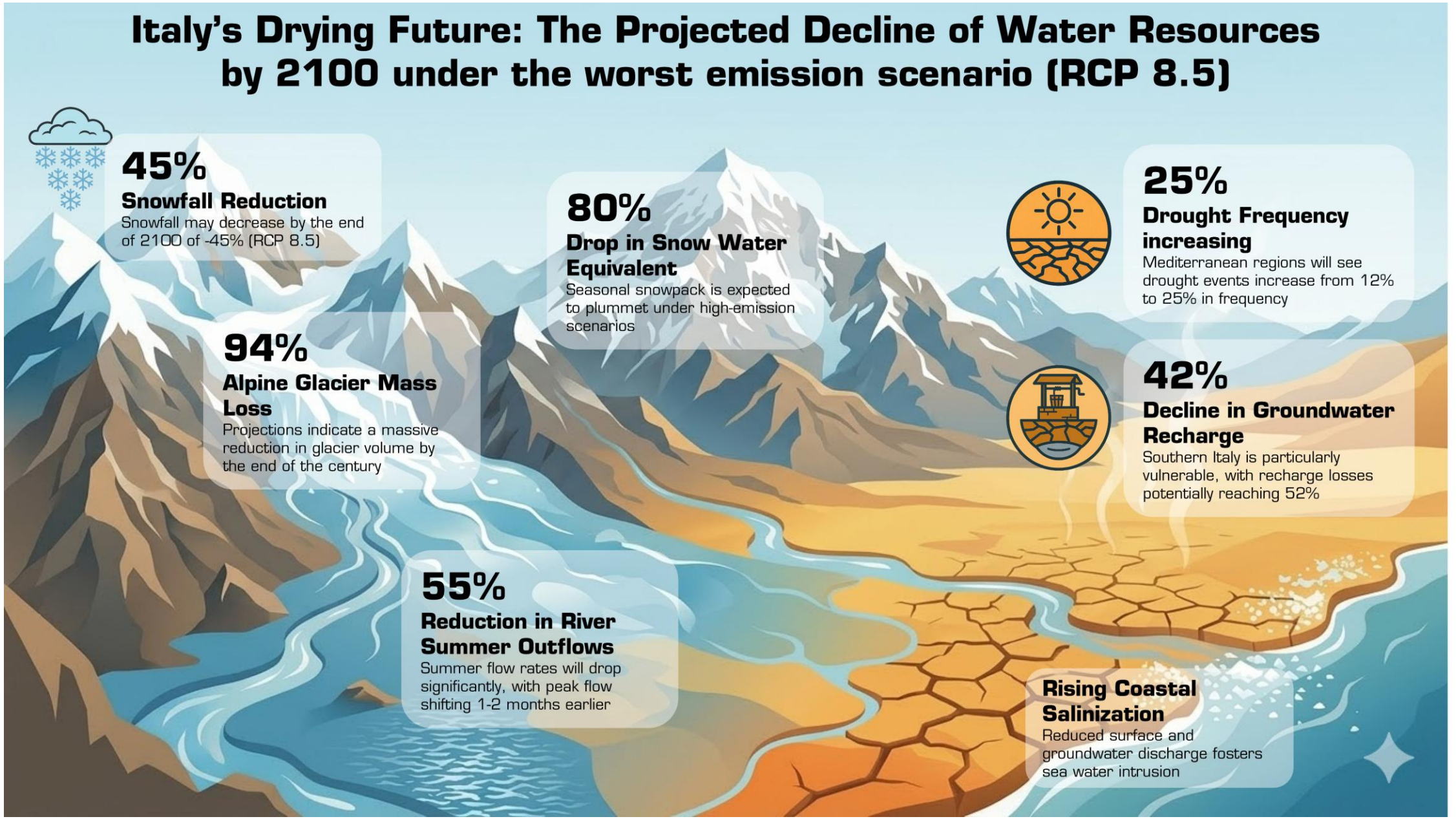

Drought risk assessment: a "systemic" perspective

CLIMATE CHANGE – FUTURE SCENARIOS

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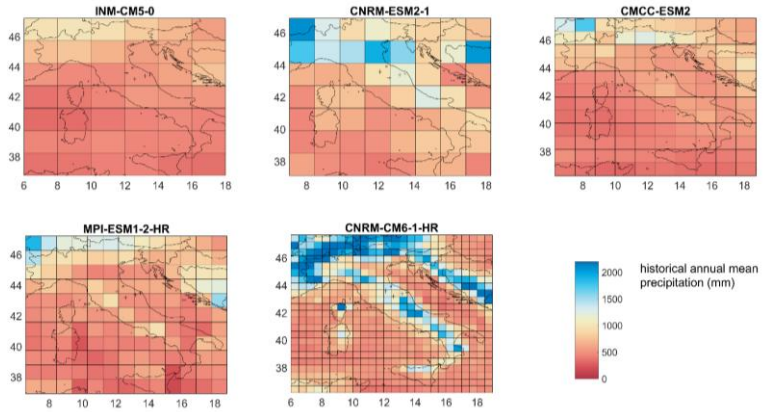
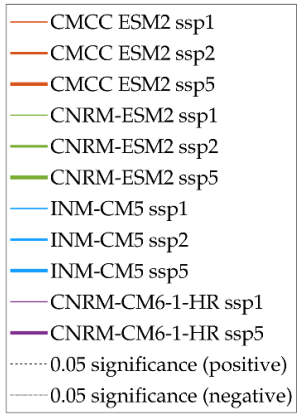
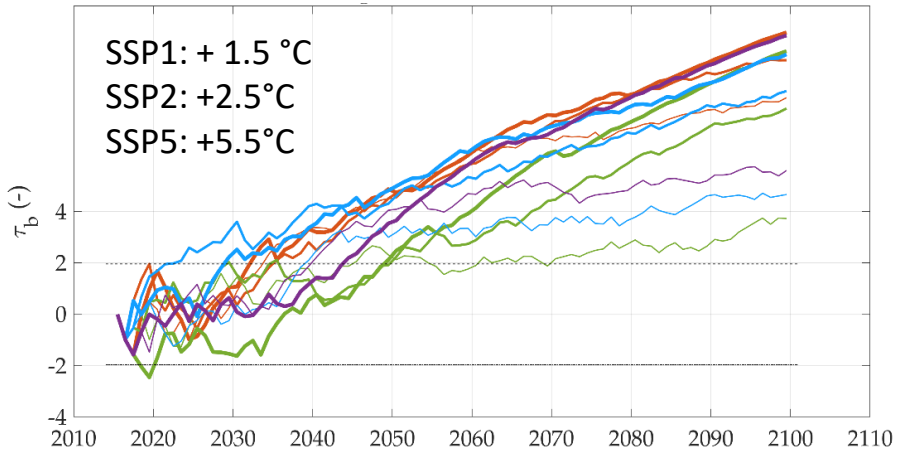
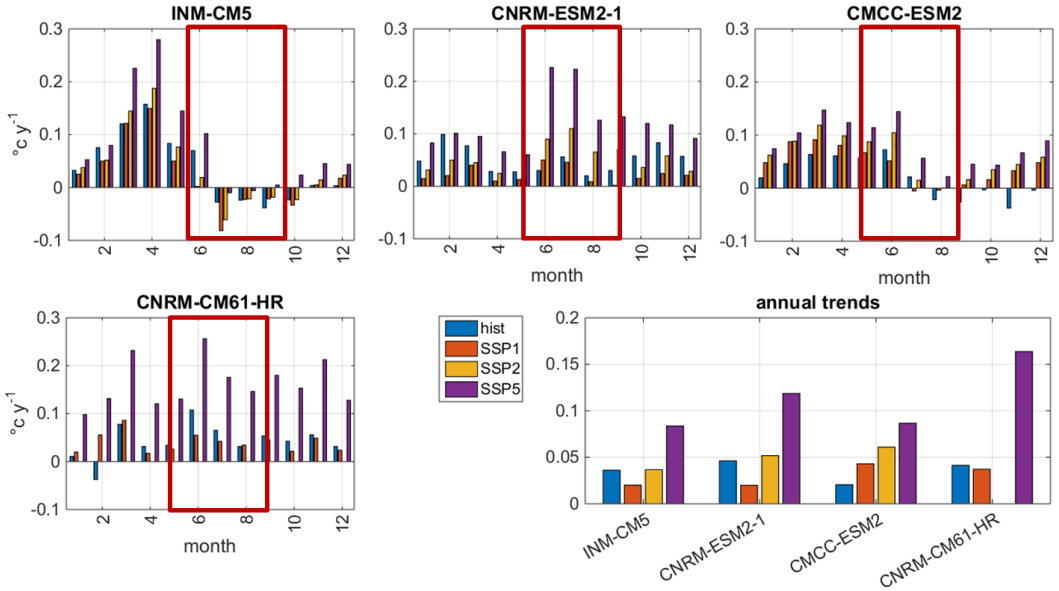




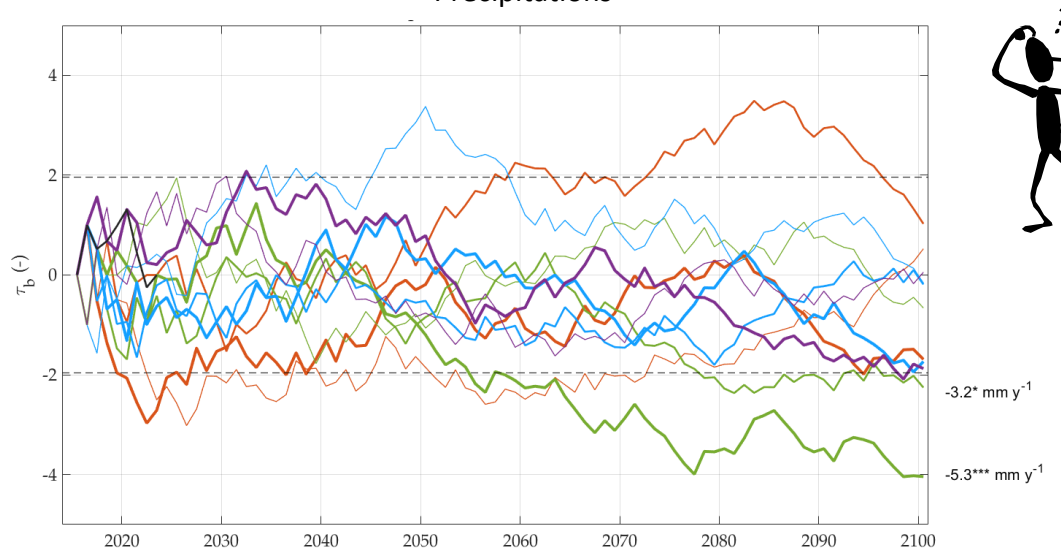
Mean annual temperature



Mean monthly temperature



Precipitations



The effectiveness of adaptation measures depends on the characteristics of future drought events

ADAPTATION MEASURES

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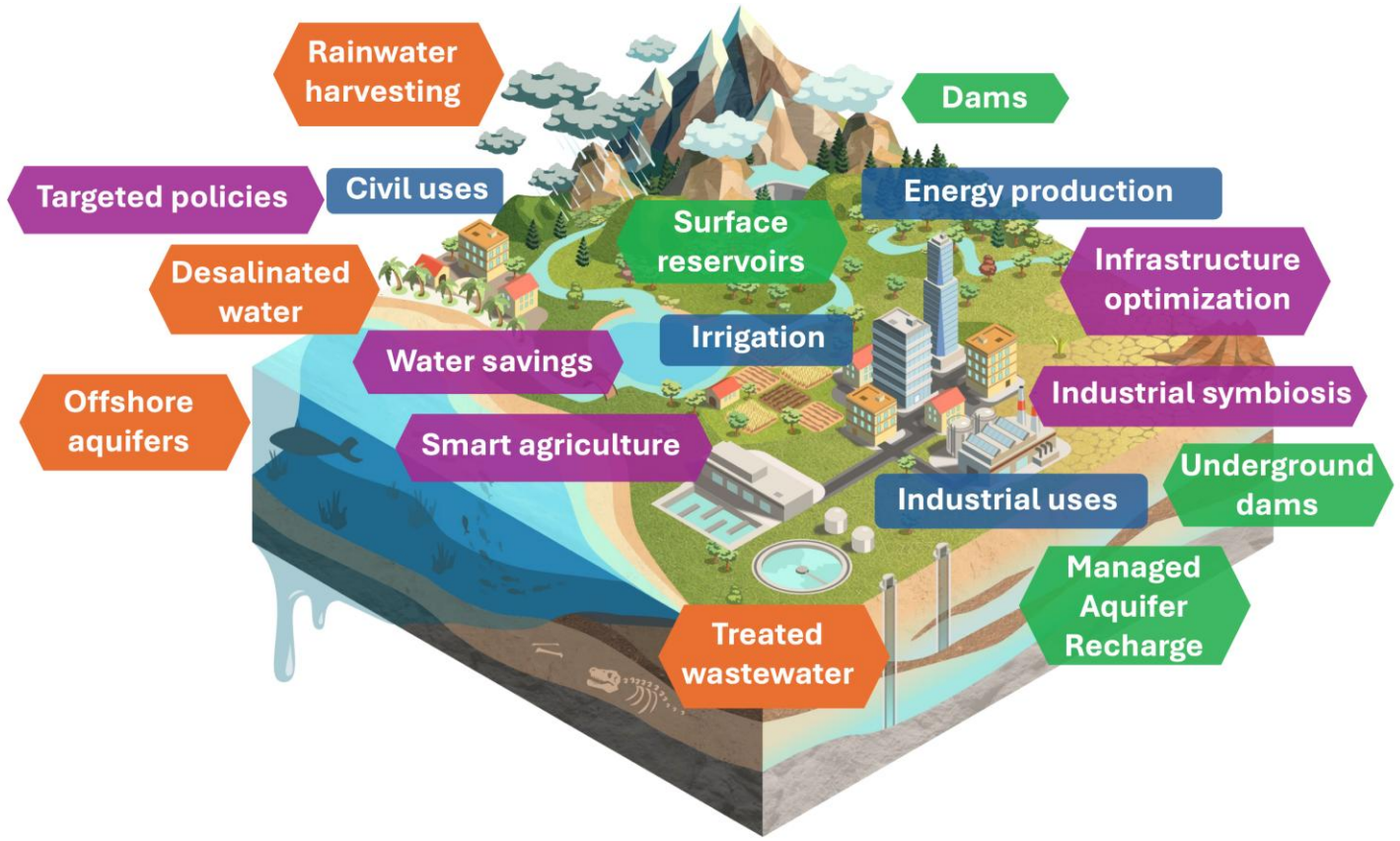
CNR IRSA



Uses — Water needs and abstractions in different sectors

Adaptation — Increasing water resource availability and storage

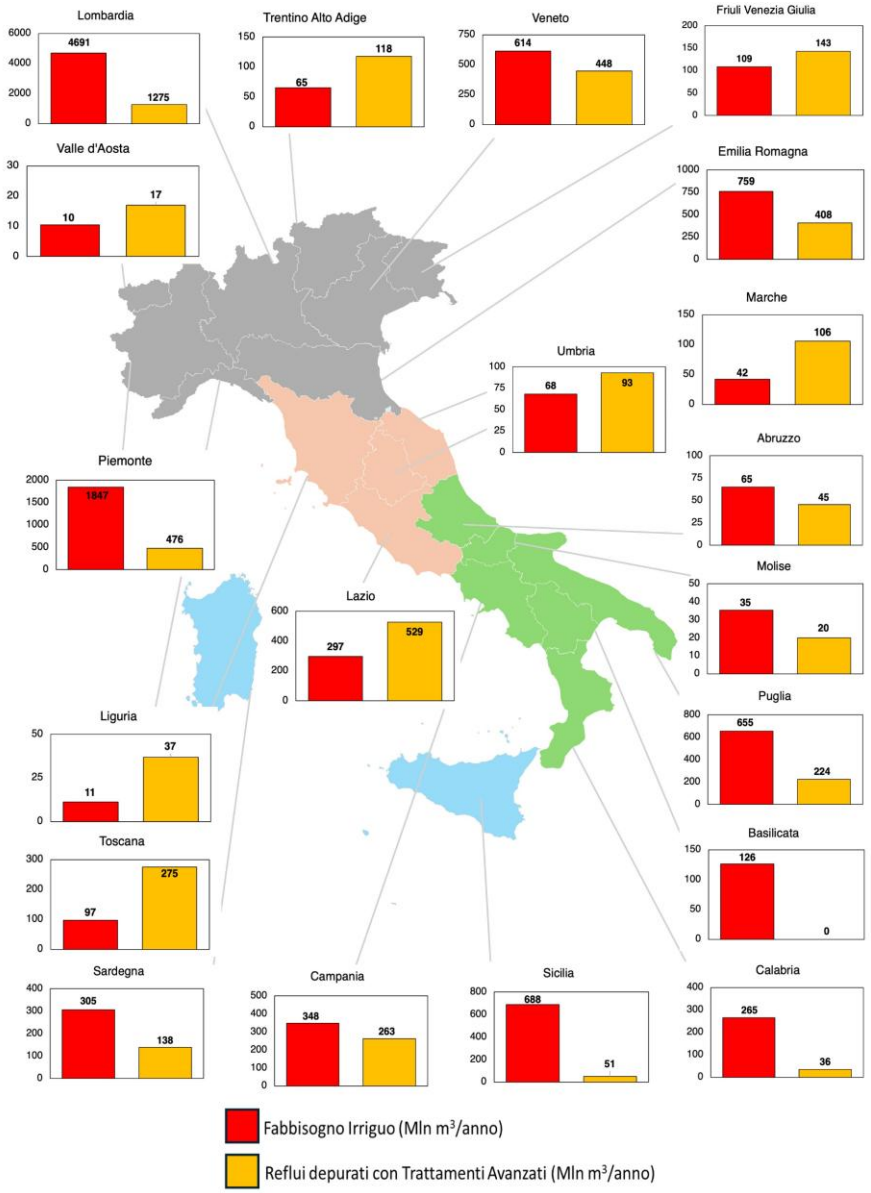
Adaptation — Exploiting new/alternative water resources

Adaptation — Reducing pressure on water resource and promoting efficient water use

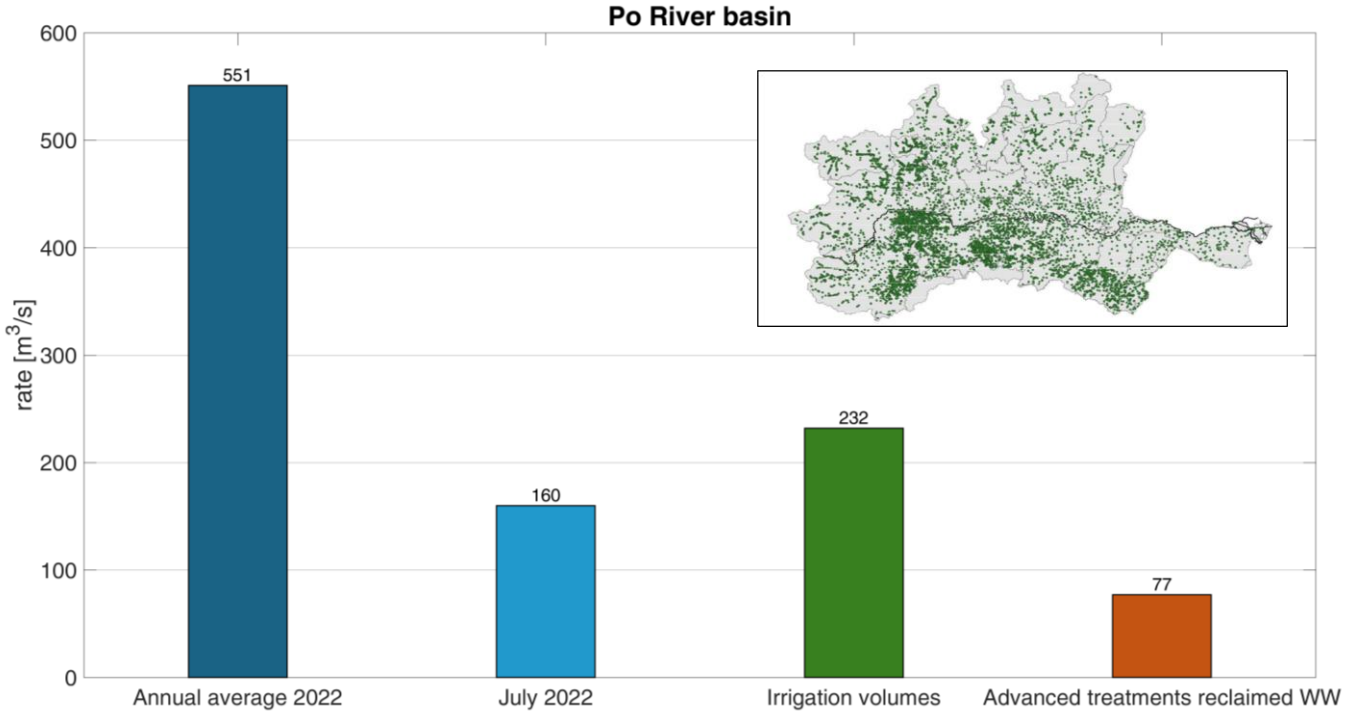
Which spatial and temporal scales are most suitable for evaluating the effectiveness and impacts of different adaptation options?

Drought risk assessment: a "systemic" perspective

ADAPTATION MEASURES: TREATED WASTEWATER REUSE FOR IRRIGATION



Area	Irrigation water needs [Mln m³/year]	Volumes of wastewater treated with advanced treatment processes [Mln m³/year]	Ratio
North	8.107	2.921	36 %
Center	504	1.003	200 %
South	1.495	589	39 %
Islands	993	189	19 %
ITALY	11.099	4.702	42 %



ADAPTATION MEASURES – INCREASING SURFACE WATER STORAGE CAPACITY

Plays a crucial role in ensuring water supply, particularly in Southern Italy, Sicily, and Sardinia.

Negative impacts on ecosystems, not only when ecological flow requirements are not met during operation, but also due to the inherent disruption of longitudinal river connectivity.

i. The usefulness of a reservoir for surface water storage should always be assessed at the **local scale**. Moreover, **its impacts on ecosystems may extend beyond that scale**, affecting downstream reaches and receiving catchments. Consequently, providing general guidance is of limited value and may even be counterproductive.

ii. For each planned reservoir project, future scenarios—although inherently uncertain—must be defined as clearly as possible. A reservoir is intended **to buffer periods of water deficit**, but a key question remains: how long can future deficit periods be expected to last?

iii. Observed data indicate a (weak) trend towards an **increase in extreme precipitation events**, highlighting the need for careful assessment of changes in the frequency of such events and in their associated return periods.

ADAPTATION MEASURES
MAKING USE OF SOLUTIONS FROM THE PAST TO OVERCOME WATER SCARCITY

SD-WISHEES

- Horizon Europe project, funded by the "Widening" work program
- Call HORIZON-WIDERA-2022
- Type of Action HORIZON CSA Coordination and Support Action
- Coordinator National Research Country of Italy (CNR)
- Duration 48 months
- Start date: January 2023 – End date: December 2026
- Estimated Project Cost: € 2,728,912.50
- https://sd-wishees.irsa.cnr.it/

The 17th-century underground reservoir of Victory (Birgu) Square (Malta) filled up with rainwater

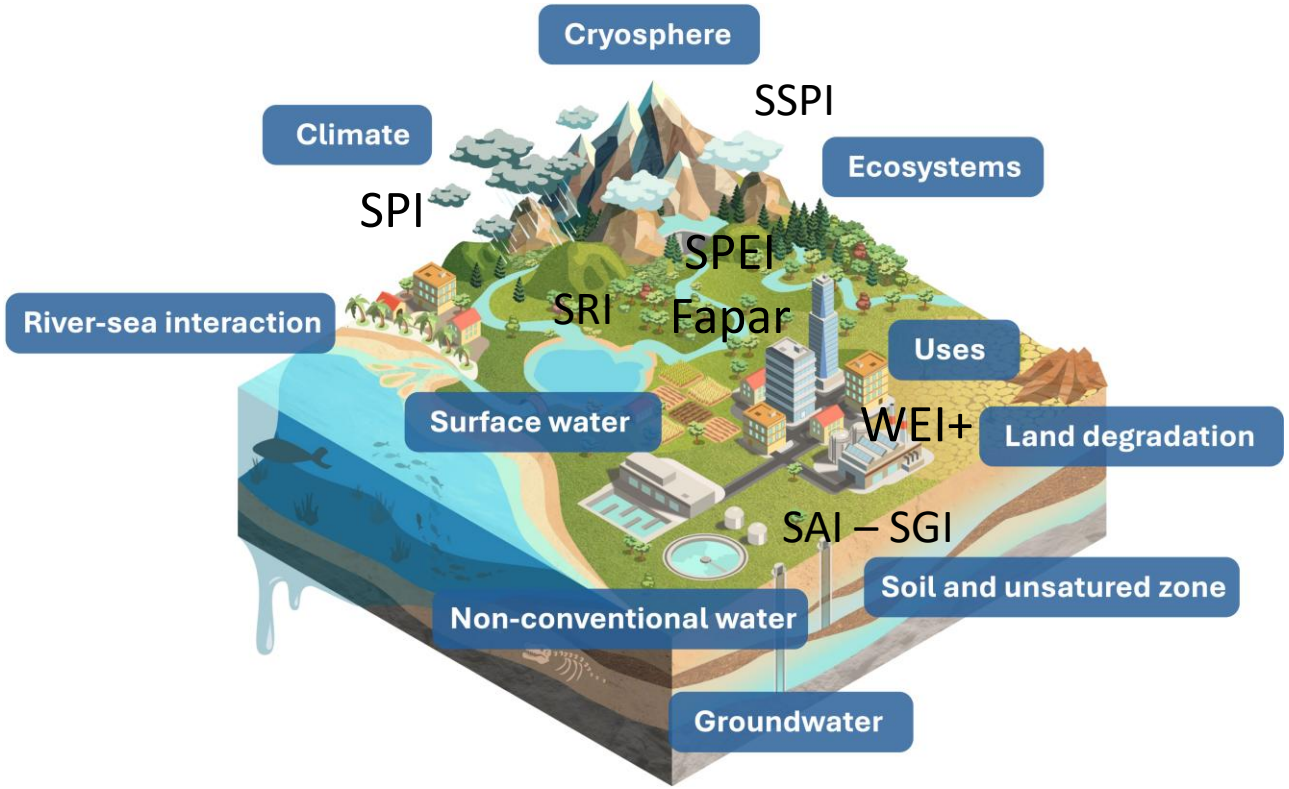
- The project Alter Aqua, as part of the Non-Conventional Water Resources (NCWR) Programme in the Mediterranean, aims to promote the use of NCWR for secondary uses and reduce the consumption of freshwater
- Rehabilitation and reinstatement of more than 15 rainwater harvesting reservoirs
- More than 20,000 m^3 of water is being harvested per year

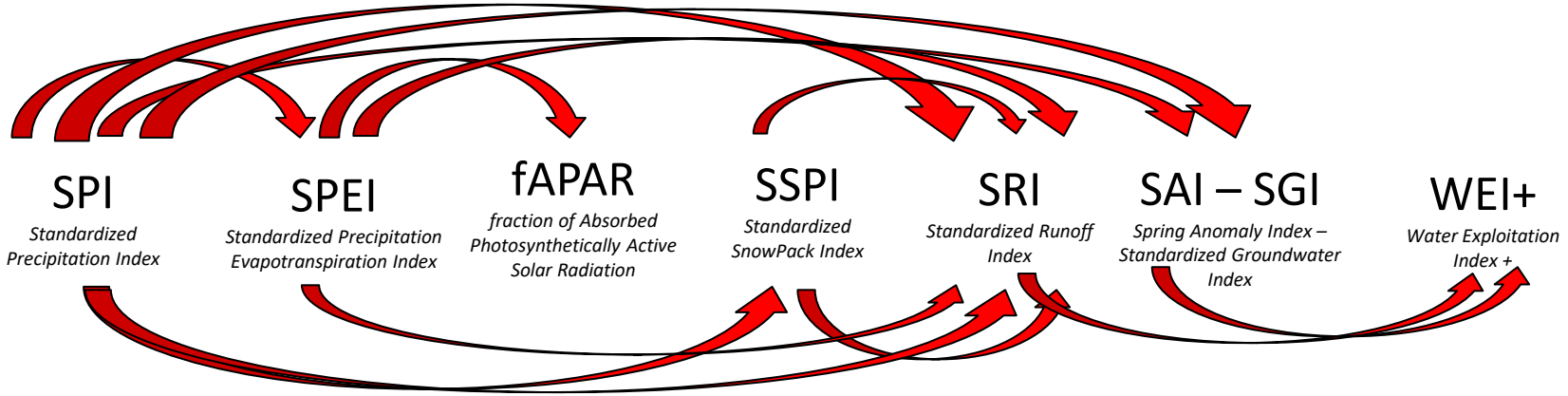
MANAGEMENT, EARLY WARNING, AND EMERGENCY RESPONSE

Consiglio Nazionale delle Ricerche
CNR IRSA

Law 142/2022

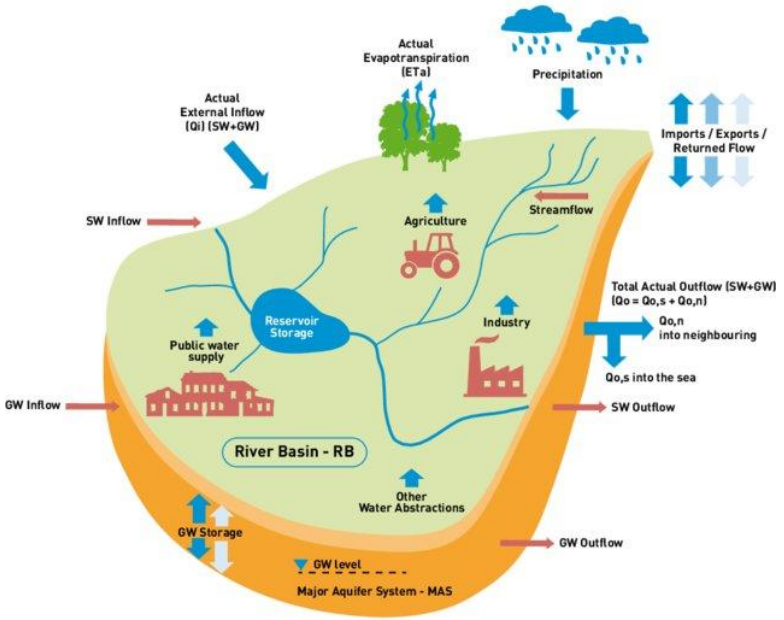
«To ensure greater operational effectiveness and response capacity with regard to the risk arising from water scarcity, the declaration of a national state of emergency pursuant to Article 24 may also be adopted in advance, where, on the basis of the available information and data—including climatological data—and the analyses produced by the District Basin Authorities and the Competence Centres referred to in Article 21, **it is possible to foresee that the ongoing situation may evolve into an emergency condition**»





MODELLING – DIGITAL TWINS

Need for an **integrated and shared modelling framework** that combines meteorological and climate data, hydrological and hydrogeological models, and water supply system models to assess the probability of unmet anthropogenic and environmental water demands



High level of (hidden) uncertainty

Need for long historical time series

Challenges in achieving stakeholder acceptance of the modelling tool

Top-down approach

Need to defend sector-specific interests under competing water resource uses

Difficulty in understanding the modelling tool and its underlying assumptions

Failure to properly recognize and interpret input data

STAKEHOLDER ENGAGEMENT: PARTICIPATORY MODELLING

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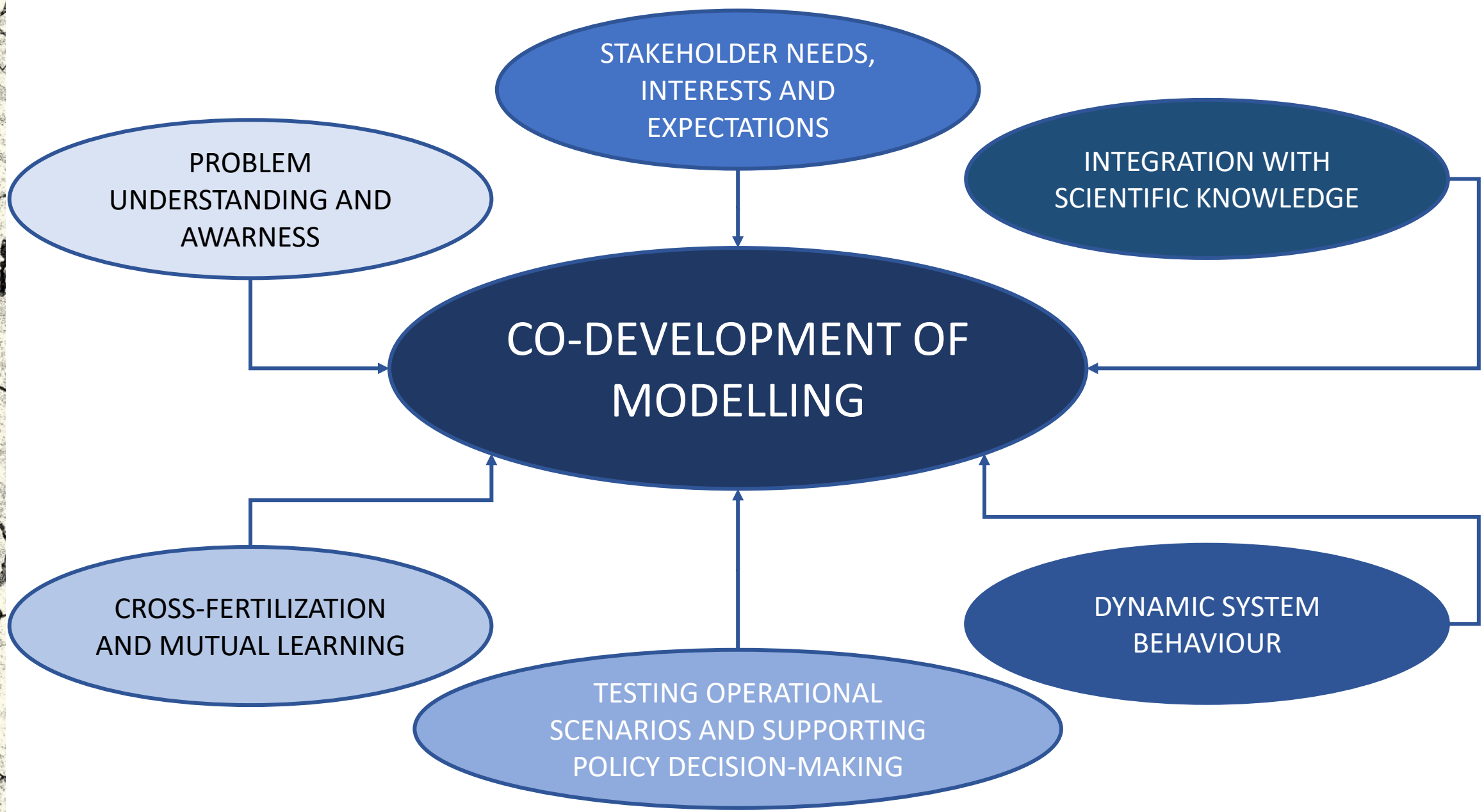


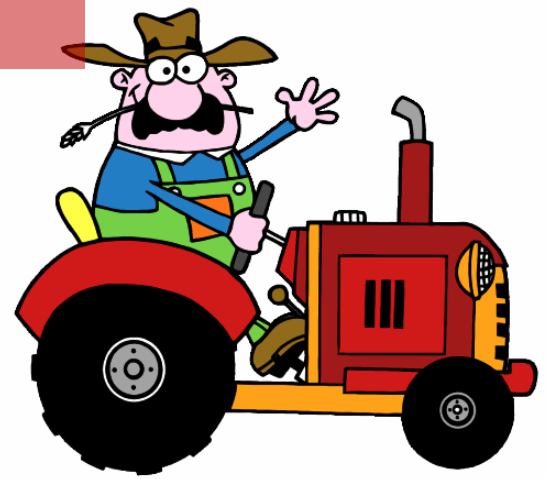
PARTICIPATORY KNOWLEDGE CO-PRODUCTION

NEED FOR AN INCLUSIVE PROCESS

PARTICIPATORY PROCESSES ARE OFTEN CONFINED TO THE LIFESPAN OF INDIVIDUAL RESEARCH PROJECTS

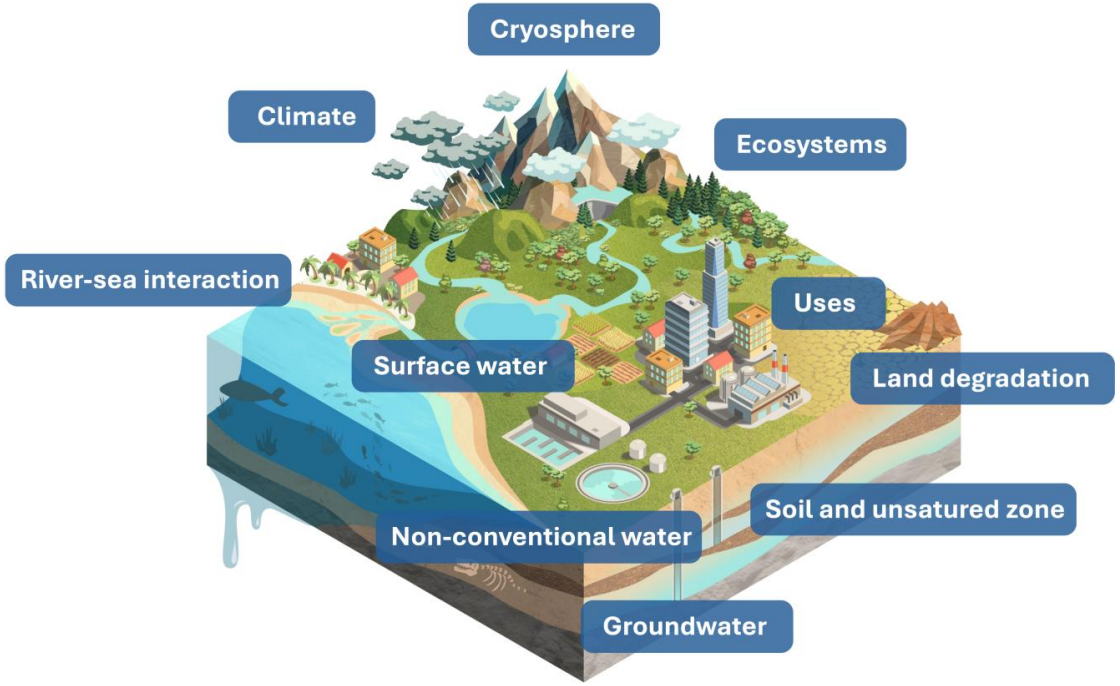
PARTICIPATORY PROCESSES ARE OFTEN PERCEIVED AS INEFFECTIVE AND TIME-CONSUMING

MUTUAL SKEPTICISM BETWEEN SCIENTISTS AND STAKEHOLDERS



THE ROLE OF THE SCIENTIFIC COMMUNITY

- ARE WE ADDRESSING REAL NEEDS, OR ANSWERING QUESTIONS THAT NOBODY IS ASKING?
- HOW CAN WE EMBED OUR ACTIVITIES WITHIN AN OPERATIONAL AND DECISION-MAKING FRAMEWORK?



https://www.cnr.it/sites/default/files/public/media/attivita/editoria/SiccitaInterattivo_ver2.pdf

Siccità, scarsità e crisi idriche

Il contributo della ricerca a supporto della definizione del bilancio idrico

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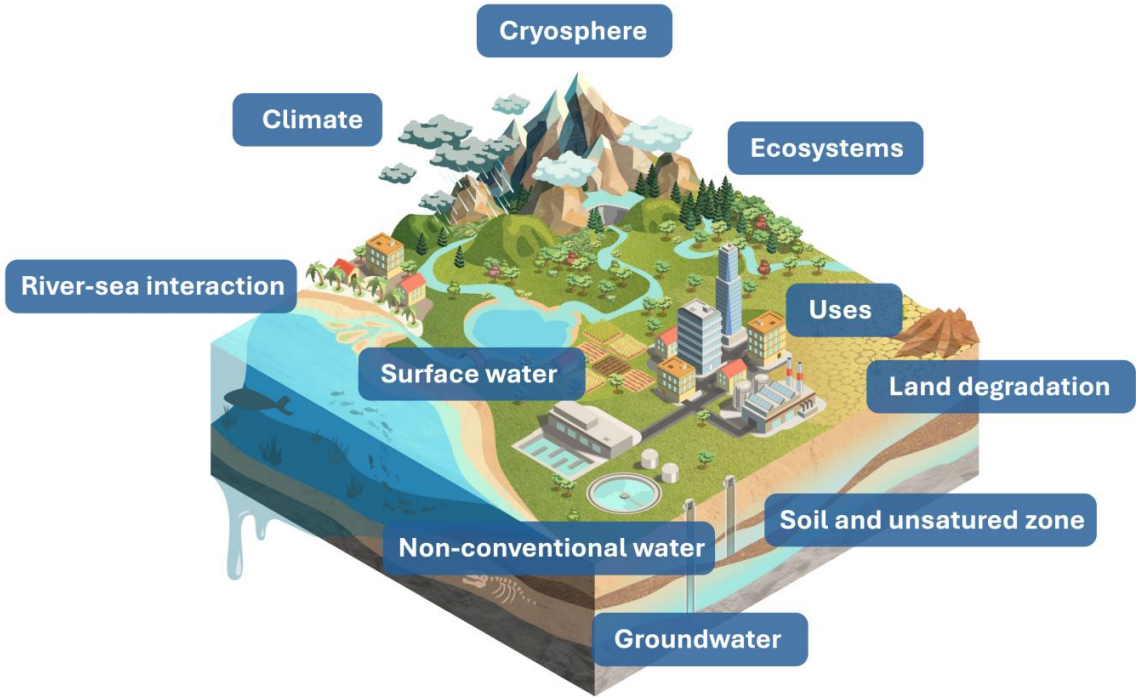
habitat signa Studi e ricerche su sistema terra e ambiente



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habitat sigma
Studi e ricerche su sistema terra e ambiente

Drought, water scarcity and water crises in Italy: an executive summary from a scientific perspective

Romano, E., Portoghese, I., Adamo, M., Berardi, M., Brocca, L., de Blasi, F., Di Salvo, C., Federico, S., Ferrarin, C., Imbrenda, V., Lauteri, M., Martinotti, M.E., Menichini, M., Mosca Angelucci, D., Pellegrini, C., Stefani, F.

habitat sigma

Executive Summary

edizioni