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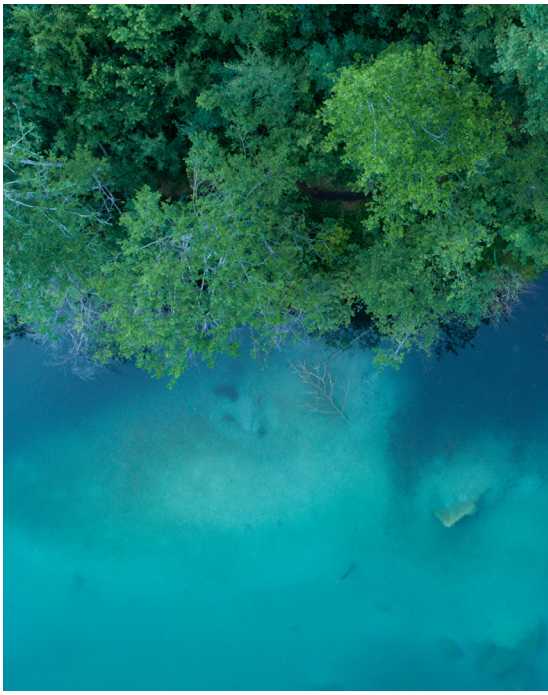
Water

Institute for Social-Ecological Research

Groundwater in Europe: Cornerstone for Resilience —



Groundwater is a key lever in achieving water resilience in Europe.

Authors: Fanny Frick-Trzebitzky, Robert Luetkemeier, Dženeta Hodžić, David Kuhn, Linda Söller, Anne Jäger

EXECUTIVE SUMMARY

Groundwater resources and groundwater ecosystems in Europe are under stress from climate change, water use and pollution; implementation of sustainable solutions is complicated by long-distance effects such as water transfers, trade and tourism. Research findings show that addressing new spatial relations via collaboration and integration across sectors and governance levels is key but requires the investment of time and resources. Strengthening groundwater as a cornerstone for water resilience in Europe must be a priority.

ACTIONABLE RECOMMENDATIONS

1 — Strengthening the European Water Resilience Strategy: The new European Water Resilience Strategy should prioritize both climate change mitigation and the reduction of local and long-distance anthropogenic stress on groundwater.

2 — Accounting for cross-regional effects in strategies and guidelines: Research funding should be allocated to further explore the effects of distal impacts from water transfers, tourism, and water footprints across Europe, and consolidate findings, thus ensuring better integration of this knowledge into policy documents.

3 — Safeguarding groundwater as an ecosystem: Indicators for assessing the health of groundwater ecosystems should be explicitly considered when setting groundwater management targets and monitoring frameworks.

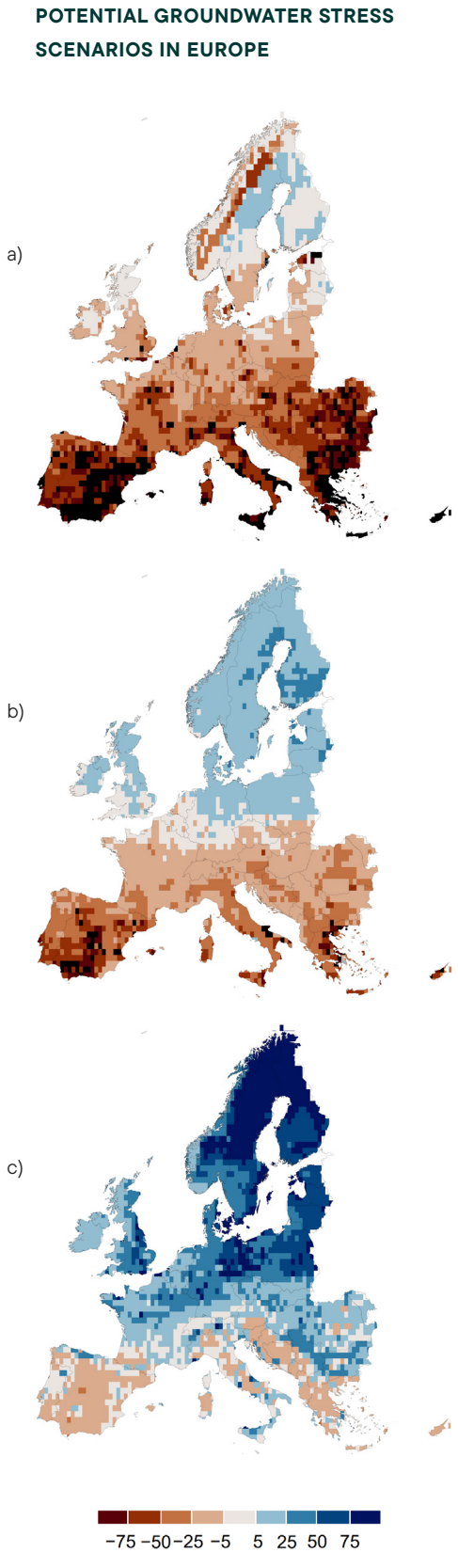
4 — Tailoring management strategies to aquifer-specific characteristics: Local and regional expertise alike should be covered by expert groups. Regulatory frameworks need to be adjustable to fit specific aquifer conditions, and must set clear benchmarks for groundwater protection, especially in sensitive areas.

5 — Enhancing collaboration and integration: Resources should be devoted to collaborative management in a way that allows for continuous engagement on the part of multiple stakeholder groups.

April 2025

Introduction and problem statement

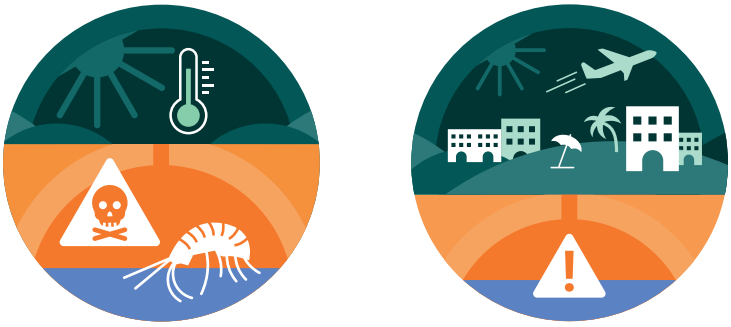
Groundwater is more important than ever for people, society, and ecosystems. However, as things stand, it is unlikely that the objectives of the Water Framework Directive (WFD) will be achieved by 2027. One reason for this is the lack of cross-sectoral integration. Furthermore, while groundwater serves as a buffer against increasing water extremes, the effects of climate change on groundwater resources remain largely uncertain. The same applies to emerging substances that threaten the resilience of groundwater bodies. Finally, despite the crucial role of healthy groundwater ecosystems in maintaining good groundwater quality, current monitoring practices do not consider ecological indicators. Why is groundwater so crucial to water resilience?



Simulated changes in groundwater discharge across Europe until the end of the century (in %) under: a) high-, b) intermediate-, and c) low-stress scenario. Reddish colors indicate a decrease, while bluish colors indicate an increase in groundwater discharge (Söller et al. 2024).

Analysis and Evidence

Threats to the quantity and quality of groundwater



Left: Climate change threatens groundwater
Right: Long-distance effects impact groundwater

Climate change, water demand and land use

Climate change and water abstraction are the main factors increasing groundwater stress in Europe. Projections of current trends indicate that reduced recharge and increased abstraction may threaten ecosystems and water supplies. The newly developed Groundwater Stress Indicator (GWSI) predicts future stress. It shows that under a high-emissions scenario, 58 % of Europe could experience a decline in groundwater discharge of at least 25 % by 2070 to 2099. Even under a lower-emissions scenario, 38 % of the continent remains at risk, with Southern and Southeastern Europe being particularly vulnerable.

Groundwater demand management alone cannot prevent this decline. In other words: climate change threatens groundwater both as a vital resource for drinking water supplies and as a unique, diverse habitat for groundwater organisms. Decline in groundwater levels not only leads to supply shortages but also increases qualitative risks, including rising pollution and biodiversity loss.

Besides climate change, land use is another key factor influencing groundwater ecosystem health. For example, intensive anthropogenic use, as found in urban areas or on agricultural land, negatively affects groundwater fauna and consequently the groundwater ecosystem, which is essential for maintaining stable groundwater quality. Against this backdrop, mitigating climate change, reducing water demand and managing land use is crucial to preserving groundwater as a major resource for the resilience of drinking water supplies, food production, and ecosystems.

New spatial relations

Local changes in water management can have unforeseen impacts on water security, biodiversity, and consequently on people and ecosystems in distant locations. Long-distance water transfers and tourism require infrastructure that sustains and reinforces mutual dependencies. For example, peak water demand in one location can alter groundwater systems in another location if they are connected via a long-distance water supply.

Long-distance water transfers can support adaptation to climate change by linking water-scarce and water-rich regions. However, the path dependency of large infrastructures also poses risks to groundwater and local water resilience. Seasonal water consumption on touristic islands such as in Croatia often relies on water transfers from the mainland. The history of a long-distance water transfer in Germany shows that these infrastructures continue to expand even when water demand decreases. One consequence is that local supply strategies such as water reuse or pollution control receive little attention. In addition, where local supply relies on water from distant sources, the maintenance of local resources and infrastructures turns into a resilience strategy involving costs, capacities and regulatory measures. Such resilience strategies are therefore bound to spark conflicts. More knowledge is needed on how long-distance effects impact groundwater in European regions, and how this can be assessed and managed with a view to achieving sustainable and fair relations.

Managing complexity and uncertainty

Left: Aligning sustainability indicators with hydrogeological conditions

Right: Cross-sector integration across levels

Adaptation to climate variability

Adaptation to climate change is already taking place in groundwater management. However, current examples show that sustainability indicators and strategies do not always align with hydrogeological, social and technical conditions.

Examples include:

1 — Allocation of water use rights: Administrations lack clear reference points for factoring in drought impacts and climate variability, and applying the precautionary principle when allocating water rights or implementing emergency measures such as water restrictions. Conflict between various uses of groundwater often only becomes visible over time.

2 — Public discourse and drinking water quality: Public debates strongly influence how limits on drinking water quality are interpreted and how technical adaptation measures are discussed. As a result, water managers must navigate between political and public interests, specific hydrogeological conditions, and technical adaptation options—for example, in response to heavy metal concentrations in groundwater.

3 — Challenges in karst areas: Karst regions, which are widespread in Europe, do not fit neatly into the groundwater and surface water categories defined by the Water Framework Directive (WFD). The groundwater directive allows groundwater bodies to be defined based on local conditions and thus provides a flexible framework within which to identify karst water bodies as either groundwater or surface water. This could become problematic if it were to lead to a categorization based on monitoring requirements rather than the target of obtaining a good qualitative status. Locally coordinated adaptation measures require the support of flexible strategies and improved data sets, in combination with a clear framework for prioritizing strong quality requirements.

Collaboration to manage uncertainty and complexity

Addressing uncertainty and complexity in groundwater management requires cross-sector and multi-level cooperation. Such collaboration fosters a deeper understanding of site-specific groundwater challenges and enables the development of tailored management measures to ensure the long-term reliability of groundwater for both ecosystems and people. For example, collaborative research in Germany has revealed a shared vision for water in the landscape as a core resilience strategy among regional and local actors from administration, water supply, agriculture, and conservation. Collaboration has led to the identification of specific measures such as groundwater protection zones. On Krk, Croatia, collaborative research has led to the definition of measures for enhanced circularity and a new water culture in touristic water use. Such collaboration demands time, resources, and diverse forms of local knowledge. Both locally and in the CIS Groundwater Working Group, collaboration currently relies largely on the voluntary engagement of individuals and organizations in contributing their expertise and resources in expert meetings and round tables. Greater investment in resources for collaborative groundwater management could strengthen such collaboration and knowledge integration more effectively and more equitably across stakeholder groups and regions.

Conclusion and further information

Groundwater is a key lever in achieving water resilience in Europe. It needs attention now, with an additional focus on new spatial relations and uncertain, dynamic future scenarios.

Groundwater is a unique habitat for endemic species and a key ecosystem. Its ecosystem functions likely play a crucial role in biodiversity conservation and drinking water quality. Management of groundwater security across Europe needs to build on a precise understanding of aquifer behavior.

Approaches that strengthen resilience – such as creating redundancy in infrastructure systems and conducting risk assessments – must consider cross-regional effects and conflicting interests. The strengthening of cross-sectoral and transboundary collaboration is essential for managing groundwater resources efficiently, equitably, and in alignment with biodiversity protection. Actionable recommendations include critical steps to design, implement and monitor approaches to safeguarding groundwater as a cornerstone for water resilience.

Groundwater amphipod populating Karst aquifers along the Adriatic coast.

About the project

regulate is a junior research group exploring challenges in groundwater management in Europe, focusing on long-distance environmental and societal feedbacks (telecouplings). The group examines groundwater quantity and quality dynamics, leading to risks like droughts, pollution, societal conflicts, and institutional settings, from natural and social sciences perspectives and stakeholder views at local and European levels. regulate is funded by the German Federal Ministry of Education and Research (BMBF) as part of the funding measure “Junior Research Groups in Social-Ecological Research”.

www.regulate-project.eu

Research and project partners

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Goethe University Frankfurt, Institute of Physical Geography

Goethe University Frankfurt, Department of Social and Cultural Anthropology

Trier University, Governance and Sustainability Lab

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