

POLICYBRIEF

October 2026

Why Groundwater Use Location Matters in Transboundary Aquifers

Executive Summary

Transboundary aquifers extend beneath nearly all international land borders and underlie approximately 35% of global groundwater-irrigated cropland. Yet cooperation over these shared resources remains limited: only 11% of country pairs sharing an aquifer report an operational cooperative arrangement, and fewer than 5% are covered by a formal treaty. In the era of Global Water Bankruptcy, strengthening cooperation over shared groundwater is an important policy priority.

Sharing an aquifer does not necessarily mean sharing the same groundwater problem. Pumping lowers groundwater levels most strongly near a well, creating a localized zone of decline rather than lowering levels uniformly across the entire aquifer. These effects generally diminish with distance and spread over time, with their extent and timing depending on local hydrogeological conditions. Where groundwater is pumped relative to the border therefore matters: intensive pumping near a border creates greater potential for cross-border effects than comparable pumping farther away. We have examined not only whether transboundary aquifers are being depleted, but where depletion and groundwater-dependent irrigation occur relative to international borders.

The policy problem

Groundwater supports agricultural production, cities, and livelihoods across much of the world. It also straddles political boundaries. The 426 known transboundary aquifers extend beneath nearly all international land borders (Figure 1), yet cooperative arrangements for shared aquifers remain rare. Strengthening transboundary groundwater cooperation is therefore an important international policy objective, reflected in Sustainable Development Goal (SDG) Indicator 6.5.2.

Expanding cooperation raises a practical question: where does groundwater use create a shared management problem, and what should countries cooperate over? Legal frameworks, political relations, and institutional capacity shape whether and how countries cooperate over shared groundwater. Yet the need for cooperation and the management options available also depend on how and where groundwater is used within a shared aquifer. Groundwater demand may be concentrated far from the border, distributed across the aquifer, or clustered close to the boundary, creating very different potential for pumping in one country to affect groundwater users in another.

The effects of groundwater pumping are spatially uneven. Water withdrawn from a well causes groundwater levels to decline most strongly in its

vicinity, with the influence of pumping generally weakening with distance and developing over time. The extent and rate of this response depend on factors such as aquifer properties and recharge. An international border cutting across an aquifer therefore does not automatically make all groundwater use on either side a shared management problem. Pumping close to the boundary has greater potential to influence groundwater conditions across it, while more distant pumping may remain effectively separated over relevant distances and time-scales. The location of groundwater use within a shared aquifer can therefore be as important for management as the fact that the aquifer itself is transboundary.

Treating the full extent of a shared aquifer as a single management problem can obscure these differences. Different parts of the same aquifer may present different potential for cross-border interaction and different management options. Where groundwater use remains separated from the border, spatial restrictions may help limit cross-border impacts. Where demand is already concentrated along the boundary, such measures may be less feasible and more direct coordination may be needed. Effective cooperation therefore requires understanding not only which aquifers are shared, but where groundwater use creates a shared management problem.

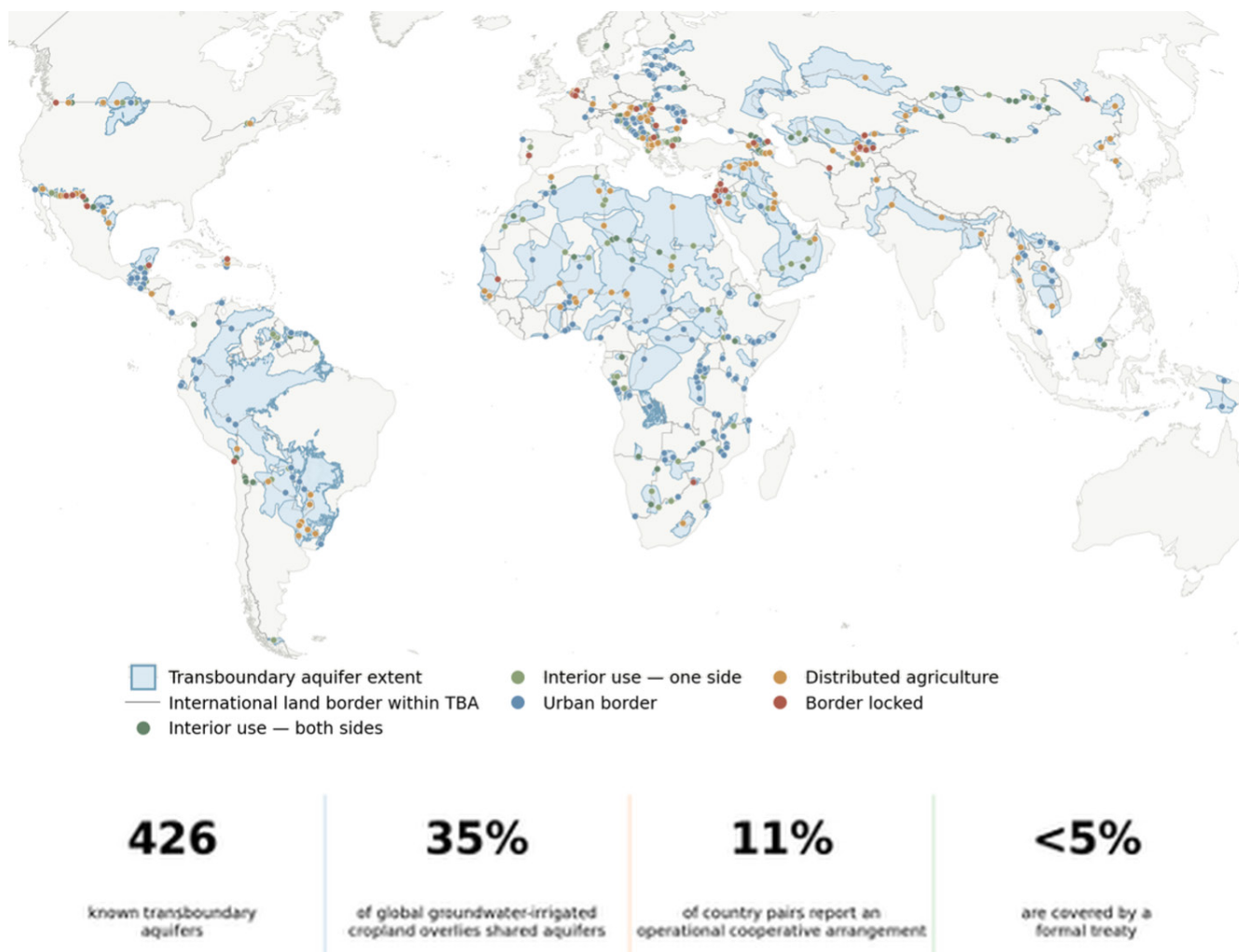


Figure 1. Global distribution and cooperation status of transboundary aquifers. Transboundary aquifers are widespread but cooperation remains limited: 426 mapped aquifers extend beneath nearly all international land borders and underlie approximately 35% of global groundwater-irrigated cropland, yet only 11% of the 568 country–aquifer pairs report an operational cooperative arrangement and fewer than 5% are covered by a formal treaty. Markers classify country–aquifer pairs by where groundwater-dependent demand occurs relative to the border; shaded polygons show aquifer extents. Marker locations are approximate and do not represent specific groundwater-use or impact locations. Country borders are shown for reference only and do not imply endorsement of any territorial status or claim. Data sources: IGRAC and UNESCO-IHP (2025), Transboundary Aquifers of the World Map; geoBoundaries.

Key findings

To understand where cross-border groundwater pressures are most likely to arise, we examined where groundwater depletion and groundwater-dependent demand occur relative to international borders. We combined groundwater-level observations with global irrigation data across 568 country-aquifer pairs and compared the resulting patterns with comparable domestic aquifers. Two findings stand out. First, average groundwater depletion is no greater in transboundary aquifers than in comparable domestic aquifers. Second, within transboundary aquifers, both depletion and groundwater-dependent irrigation tend to concentrate closer to international borders. Comparable domestic aquifers show no equivalent spatial concentration, suggesting that the pattern observed in transboundary aquifers is associated with the geography of groundwater use relative to international borders.

Proximity to the border does not, however, by itself mean that groundwater use in one country is causing measurable changes in groundwater levels or well yields in another. The location of groundwater use reflects many factors, including rivers, settlements, infrastructure, and local water availability. Border proximity can therefore help identify where closer assessment is warranted, but local hydrogeological analysis is needed to determine whether groundwater use actually creates cross-border impacts.

Even though groundwater use and depletion tend to concentrate closer to international borders overall, the geography of groundwater use varies substantially among shared aquifers. To capture this variation, we distinguish four groundwater-use configurations according to where agricultural and urban groundwater demand occurs relative to the border. Among the 568 country-aquifer pairs, 35% are Interior Use and 36% Urban Border, together indicating limited groundwater-dependent agriculture near the border. Another 22% are Distributed Agriculture, where agricultural groundwater demand extends across and beyond the border region, and 7% are Border Locked, where groundwater-dependent agriculture is highly concentrated near the boundary. These configurations represent distinct management situations: in some shared aquifers, intensive groundwater use remains spatially separated from the border; in others, agricultural demand extends across the border region or is concentrated directly along the boundary, leaving less scope to manage potential cross-border pressures through spatial separation.

These differences affect both the need for cooperation and the management options available. Where groundwater use can be spatially separated from the border, spatial measures can limit potential cross-border impacts without requiring uniform restrictions across an entire aquifer. The Agreement between the Hashemite Kingdom of Jordan and the Gov-

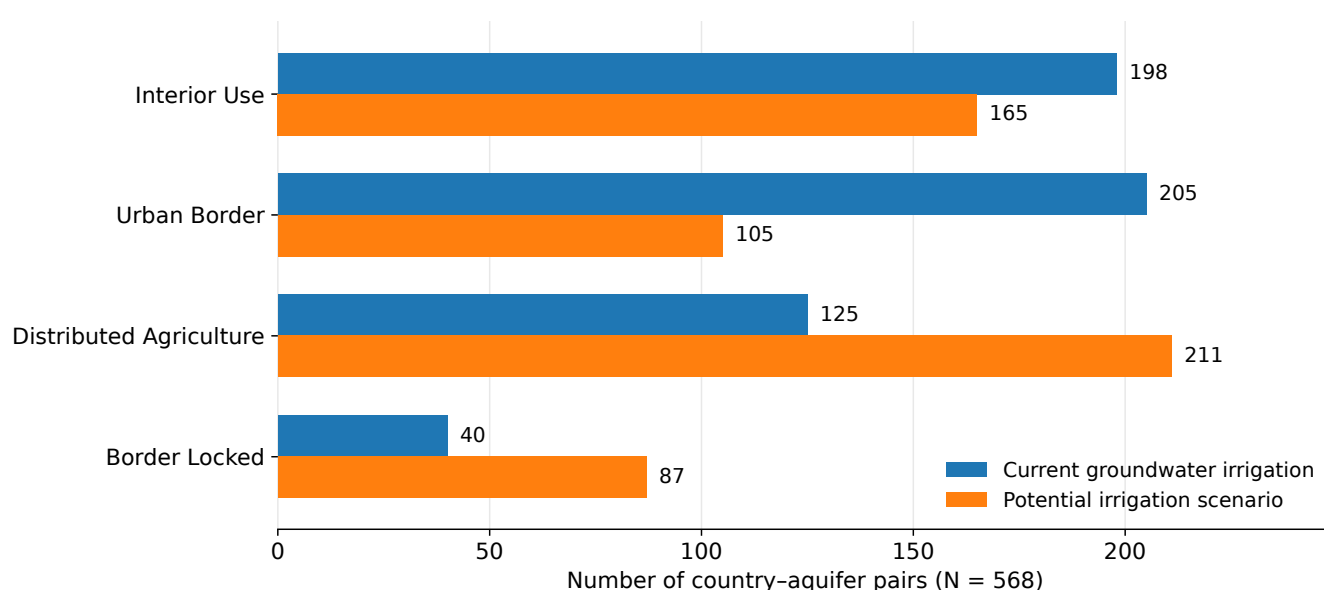


Figure 2. Current and potential future groundwater use configurations. Potential irrigation expansion shifts shared aquifers toward greater cross-border interaction. Under the potential-irrigation scenario, Distributed Agriculture country-aquifer pairs increase from 125 to 211 and Border Locked pairs from 40 to 87, showing how future development could shift more shared systems toward cross-border interaction and reduce the scope for spatial separation.

Table 1. Groundwater-use configurations in shared aquifers. Distances define the screening zones used in the typology: 100 km is the broader zone where cross-border effects may be possible; 10 km is the immediate border zone where substantial effects are more likely for most hydrogeological settings.

Configuration	Share of country-aquifer pairs	What the configuration means
Interior Use	35%	Little or no groundwater-irrigated agriculture or urban land within 100 km on one or both sides.
Urban Border	36%	Little agricultural groundwater demand within 100 km on at least one side, but urban areas reach the border.
Distributed Agriculture	22%	Groundwater-irrigated agriculture occurs across broader areas on both sides, including the border region.
Border Locked	7%	>99% of groundwater-irrigated cropland lies within 10 km on at least one side.

ernment of the Kingdom of Saudi Arabia for the Management and Utilization of the Ground Water in the Al-Sag/Al-Disi Layer establishes protected and management areas to regulate groundwater-dependent activities near the border. Along part of the United States–Mexico border, International Boundary and Water Commission Minute 242 – Permanent and Definitive Solution to the International Problem of Salinity of the Colorado River – takes a similar spatial approach, capping groundwater pumping in each country at 160,000 acre-feet annually within five miles (eight kilometres) of the Arizona–Sonora boundary near San Luis. Where intensive groundwater use is concentrated immediately along a border, however, spatial separation becomes less feasible and direct coordination may become more important. In the Genevois aquifer shared by France and Switzerland, groundwater use for urban supply on both sides has led to long-standing cooperation over groundwater abstraction and managed recharge.

The geography of groundwater demand can change as irrigation and urban water uses expand. Our potential irrigation scenario identifies water-stressed cropland in shared border regions where additional irrigation could increase groundwater demand and the potential for cross-border interaction (Figure 2). Under this scenario, Distributed Agriculture country-aquifer pairs increase from 125 to 211, while Border Locked pairs increase from 40 to 87. The scenario does not predict where irrigation and associated groundwater use will expand, but shows where current patterns could change. Anticipating new groundwater demand can help preserve management options before groundwater use becomes concentrated near the border.

Policy recommendations

The four configurations in Table 1 point to distinct management options. The closer

Key messages

- Groundwater depletion and groundwater-dependent irrigation tend to concentrate near international borders within shared aquifers, even though average depletion is no greater than in comparable domestic aquifers.
- Groundwater-use patterns vary widely across and within shared aquifers: 71% of country-aquifer pairs have limited groundwater-dependent agriculture near the border, while 22% have agricultural groundwater use extending across the border region and 7% have it highly concentrated near the border.
- Where groundwater is used should inform the form and spatial scale of cooperation; different parts of the same aquifer may require different management approaches.
- Expanding groundwater irrigation to water-scarce croplands could shift agricultural groundwater use toward international borders, increasing the number of shared aquifers where spatial separation becomes more difficult.

intensive groundwater use is to a border, the less scope countries have to avoid cross-border interactions through spatial separation and the greater the potential need for direct coordination. Three priorities follow.

1. Identify where groundwater use could create cross-border impacts

Countries sharing an aquifer should first map groundwater-dependent demand and depletion relative to the border and assess the hydrogeological conditions that determine whether pumping effects can propagate across it. They should also identify where future irrigation, urban growth, or other development could alter these patterns. This can help identify where closer assessment and cooperation are most needed.

2. Match cooperation to the potential for cross-border interaction

The form and extent of cooperation need not be the same across all shared aquifers or across different parts of the same aquifer. Where the potential for cross-border interaction is limited, joint assessment, monitoring, and data sharing may be sufficient. Where pumping has greater potential to affect groundwater users across the border, countries may need more direct coordination over groundwater abstraction and recharge. Political, legal, and institutional conditions will shape which arrangements are feasible.

3. Preserve spatial separation where feasible

Countries need not manage an entire aquifer as a single zone. Where intensive groundwater use remains away from the border, pumping setbacks, protected areas, or other zone-based measures can help maintain spatial separation and reduce the potential for cross-border impacts.

Final remarks

The boundaries of a shared aquifer do not necessarily define the extent of the shared management problem. Cross-border interactions may be concentrated in particular areas, vary within the same aquifer, and change as groundwater development expands. Legal, political,

and institutional conditions remain central to transboundary groundwater cooperation. Geography adds another dimension by clarifying where shared pressures may arise and how they can be managed. Effective governance should therefore consider not only which aquifers cross international borders, but where groundwater use may affect users across the border.

Further reading

1. Müller, M. F., Davis, K. F., Faure, J., Chiarelli, D. D., & Hung, F. (2026). Geography of groundwater use and depletion in internationally shared aquifers. *Proceedings of the National Academy of Sciences*, in press.
2. Penny, G., Müller-Itten, M., De Los Cobos, G., Mullen, C., & Müller, M. F. (2021). Trust and incentives for transboundary groundwater cooperation. *Advances in Water Resources*, 155, 104019.
3. Müller, M. F., Müller-Itten, M. C., & Gorelick, S. M. (2017). How Jordan and Saudi Arabia are avoiding a tragedy of the commons over shared groundwater. *Water Resources Research*, 53(7), 5451–5468.
4. Mullen, C., Müller, M. F., Penny, G., Hung, F., & Bolster, D. (2022). Hydro-economic asymmetries and common-pool overdraft in transboundary aquifers. *Water Resources Research*, 58(11), e2022WR032136.
5. Sanchez, R., Rodriguez, L., & Tortajada, C. (2020). Effective transboundary aquifer areas: An approach for transboundary groundwater management. *Journal of the American Water Resources Association*, 56, 360–378.
6. Sanchez, R., Kikoyo, D., & Yang, L. (2024). Effective transboundary aquifer areas between Mexico and the United States: A border-wide approach. *Journal of Hydrology: Regional Studies*, 56, 102003.
7. Maass-Morales, C., Stigter, T., Fraser, C., Van Breukelen, B. M., & Jewitt, G. (2024). Management zones in transboundary aquifers: A review of delineation methods under a new framework of cross-border groundwater impacts. *Journal of Environmental Management*, 357, 120677.
8. Sterckx, A., Maass-Morales, C., Fraser, C. M., Pietersen, K., Podolny, O., Samaniego, L., & Sanchez, R. (2026). Cross-border groundwater impacts and joint management interventions: An overview of case studies. *Journal of Environmental Management*, 401, 128644.

Authors

Dr. Marc F. Müller is an Associate Research Professor for water cooperation and conflicts at the United Nations University Institute for Water, Environment and Health (UNU-INWEH), and a Senior Scientist at the Swiss Federal Institute of Aquatic Science and Technology (Eawag), studying coupled human-water systems with a focus on issues related to global food, water, and energy security.

Dr. Kyle F. Davis is a Senior Research Fellow in Food Security Informatics at UNU-INWEH and an Associate Professor of Environmental Data Science in the Department of Geography and Spatial Sciences at the University of Delaware, working on food system sustainability and global environmental change.

Dr. Julie Faure is a scientist at Eawag studying coupled human water systems with a focus on mining and large scale land acquisitions.

Dr. Davide D. Chiarelli is an Associate Professor in the Department of Civil and Environmental Engineering at Politecnico di Milano. His research focuses on hydrology and water and food security, including the sustainable use of water and land resources within a NEXUS perspective.

Dr. Fengwei Hung is a hydrologic modeling analyst at the Colorado River Commission of Nevada. His work primarily centers at the intersection of water scarcity, sustainable development, and climate hazards within cross-boundary river basins and global urban centers.

Professor Kaveh Madani is the Director of UNU-INWEH and a Research Professor at the City University of New York's Remote Sensing Earth Systems (CUNY CREST) Institute with expertise in modeling complex human-nature systems to advise policy.

doi: <http://doi.org/10.53328/INP26MFM002>
ISBN: 978-92-808-6149-5

Disclaimer: The views and opinions expressed in this brief are those of the authors and do not necessarily reflect the official policy or position of the United Nations University.

How to Cite

Müller, M.F., Davis, K.F., Faure, J.C., Chiarelli, D.D., Hung, F. and Madani, K. (2026). Why Groundwater Use Location Matters in Transboundary Aquifers. United Nations University Institute for Water, Environment and Health (UNU-INWEH), Richmond Hill, Canada.
doi: 10.53328/INP26MFM002

