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Global groundwater depletion is accelerating, but is not inevitable

Groundwater is rapidly declining across the globe, often at accelerating rates. Writing in the journal Nature, UC Santa Barbara researchers present the largest assessment of groundwater levels around the world, spanning nearly 1,700 aquifers. In addition to raising the alarm over declining water resources, the work offers instructive examples of where things are going well, and how groundwater depletion can be solved. The study is a boon for scientists, policy makers and resource managers working to understand global groundwater dynamics.

“This study was driven by curiosity. We wanted to better understand the state of global groundwater by wrangling millions of groundwater level measurements,” said co-author Debra Perrone, an associate professor in UC Santa Barbara’s Environmental Studies Program.

The team compiled data from national and subnational records and the work of other agencies. The study took three years, two of which were spent just cleaning and sorting data. That’s what it takes to make sense of 300 million water level measurements from 1.5 million wells over the past 100 years.

Next came the task of translating the deluge of data into actual insights about global groundwater trends. The researchers then scoured over 1,200 publications to reconstruct aquifer boundaries in the regions of inquiry and evaluate groundwater level trends in 1,693 aquifers.

Their findings provide the most comprehensive analysis of global groundwater levels to date, and demonstrate the prevalence of groundwater depletion. The work revealed that groundwater is dropping in 71% of the aquifers. And this depletion is accelerating in many places: the rates of groundwater decline in the 1980s and ’90s sped up from 2000 to the present, highlighting how a bad problem became even worse. The accelerating declines are occurring in nearly three times as many places as they would expect by chance.

Groundwater deepening is more common in drier climates, with accelerated decline especially prevalent in arid and semi-arid lands under cultivation — “an intuitive finding,” said lead author Scott Jasechko, an associate professor in the university’s Bren School of Environmental Science & Management. “But it’s one thing for something to be intuitive. It’s quite another to show that it’s happening with real-world data.”

On the other hand, there are places where levels have stabilized or recovered. Groundwater declines of the 1980s and ’90s reversed in 16% of the aquifer systems the authors had historical data for. However, these cases are only half as common as would be expected by chance.

“This study shows that humans can turn things around with deliberate, concentrated efforts,” Jasechko said.

Take Tucson, Arizona for instance. Water allotted from the Colorado River is used to replenish the aquifer in the nearby Avra Valley. The project stores water for future use. “Groundwater is often viewed as a bank account for water,” Jasechko explained. “Intentionally refilling aquifers allows us to store that water until a time of need.”

Communities can spend a lot of money building infrastructure to hold water above ground. But if you have the right geology, you can store vast quantities of water underground, which is much cheaper, less disruptive and less dangerous. The stored groundwater can also benefit the region’s ecology. In fact, while preparing a research brief in 2014, Perrone found that aquifer recharge can store six times more water per dollar than surface reservoirs.

Tucson’s groundwater recharge is a boon for the local aquifer; however, withdrawals have caused the mighty river to dwindle above ground. The Colorado rarely reaches its delta in the California Gulf anymore. “These groundwater interventions can have tradeoffs,” Jasechko acknowledged.

Another option is to focus on reducing demand. Often this involves regulations, permitting and fees for groundwater use, Perrone explained. To this end, she is currently examining water law in the western U.S. to understand these diverse interventions. Regardless of whether it comes from supply or demand, aquifer recovery seemed to require intervention, the study revealed.

The authors complemented measurements from monitoring wells with data from the Gravity Recovery and Climate Experiment (GRACE). The GRACE mission consists of twin satellites that precisely measure the distance between them as they orbit the Earth. In this way, the crafts detect small fluctuations in the planet’s gravity, which can reveal the dynamics of aquifers at large scales.

“The beauty of GRACE is that it allows us to explore groundwater conditions where we don’t have in-situ data,” Perrone said. “Our assessment complements GRACE. Where we do have in-situ data, we can explore groundwater conditions locally, a crucial level of resolution when you’re managing depletion.” This local resolution is critical, as the authors found out, because adjacent aquifers can display different trends.

That said, groundwater level trends don’t present the whole picture. Even where aquifers remain stable, withdrawing groundwater can still affect nearby streams and surface water, causing them to leak into the subsurface, as Perrone and Jasechko detailed in another Nature paper in 2021.

The authors also analyzed precipitation variability over the past four decades for 542 aquifers. They found that 90% of aquifers where declines were accelerating are in places where conditions have gotten drier over the last 40 years. These trends have likely reduced groundwater recharge and increased demand. On the other hand, climate variability can also enable groundwater to rebound where conditions become wetter.

This study of monitoring wells complements a paper Perrone and Jasechko released in 2021. That study represented the largest assessment of global groundwater wells, and made the cover of the journal Science. “The monitoring wells are telling us information about supply. And the groundwater wells are telling us information about demand,” Perrone said.

“Taken together, they allow us to understand which wells have run dry already, or are most likely to run dry if groundwater-level declines occur,” Jasechko added.

Perrone and Jasechko are now examining how groundwater levels vary over time in the context of climate change. Connecting these rates of change to the depths of actual wells will provide better predictions of where groundwater access is at risk.

“Groundwater depletion is not inevitable,” Jasechko said. Fine resolution, global studies will enable scientists and officials to understand the dynamics of this hidden resource.

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