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A Discussion on the Global Groundwater Crisis: Potential Approaches to Groundwater Sustainability

In 2021, intense storm clouds traveled across Louisiana; rain rattled down the gutters of New Jersey; hail pummeled Nebraska; vicious floodwaters forced evacuations in California; a blizzard brought life to a screeching halt for several days in Texas. Seeing these headlines day in and day out easily places us under the assumption that we have more than enough water. But in the same year as these record-breaking weather events, several of these states issued severe warnings about the growing scarcity of groundwater. This came as a shock to many, but scientists saw it coming for decades. But, how?

The issues leading to our contemporary groundwater crisis can be traced to decades of overuse, unregulated pumping by industries and agriculture, and minimal oversight from legislative commissions rife with conflicts of interest. The groundwater stores in some of the largest aquifers globally, such as those in California's Central Valley, the southern Great Plains, northern India, and the North China Plain, are being utilized at rates significantly higher than can be replenished (Famiglietti, 2014). Even more worrying is the fact that these aquifers support the world's largest and most productive agricultural regions. Scientists at NASA have been monitoring and warning politicians about the decrease in groundwater for years using NASA's Gravity Recovery and Climate Experiment (GRACE) satellite mission, which tracks the changes in earth's mass over time and space, which includes the large changes in water stored underground. Using GRACE data, scientists predict that within just 50 years, groundwater will be reduced by more than a third in many regions in the U.S. (Wilkerson, 2019).

Even further, the acceleration of climate change has greatly impacted both precipitation and the demand for groundwater. As general trends show, the wettest regions of the U.S. are getting wetter, the drier areas are getting drier. It may seem to follow from this logic then, that water is being replenished, albeit in different regions than where it's used. However, it's not as straightforward; where precipitation is projected to increase (usually in the northern regions of the U.S.), the increase is so extreme that it is difficult to capture and use rainfall (Wendland and Ramsey, 2021). At the same time, groundwater reservoirs in the Southwest, southern Great Plains, and Florida are expected to be drier than ever before. Along with this decrease in precipitation comes rising temperatures. For example, the U.S. could be more than 5.7°F warmer in the next few decades; extreme heatwaves and drought could be more intense and more frequent, in turn increasing the demand for water, which would already be evaporating quickly from lakes, reservoirs, and rivers as temperatures rise (Heggie, 2020) .

There is no clear 'solution' to the global groundwater crisis. In the most populated countries in the world, the demand for water is simply greater than is available in groundwater reservoirs, much of which is nonrenewable. How, then, can we sustain global groundwater for future generations? The first step to comprehensive regional, national, and international planning is immediate recognition and acceptance of the severity of this situation by corresponding governments. This recognition allows public officials to give significant attention to this issue and respond to it like the global emergency it is (Llamas and Hera, 2006).

Next, strong leadership that regulates and imposes sanctions with a clear legal framework of rules for all water users is crucial. Government-sanctioned groundwater regulation and oversight are crucial because, in many countries, large agricultural exporters are powerful, but the organizations that defend the agricultural water rights of small- and medium-sized farmers to have access to groundwater are relatively weak (Gleeson et al., 2010). In this way, leadership on groundwater issues must provide a voice for an unseen, underrepresented, yet fundamental cornerstone of freshwater supplies and food production around the world.

Government-led groundwater oversight can look different in different countries and regions. For example, governments can promote the combined use of groundwater and surface water, require large-scale users to artificially recharge reservoirs from other water resources, such as flood and storm waters and treated wastewater, improve the efficiency of dam and canal infrastructure to avoid leakages and promote efficient water use, and/or establish protocols for reusing wastewater when applicable (Raghavendra and Deka, 2015). Similarly, councils and organizations must be established for groundwater oversight where all sectors in the watershed can participate, and which have technical staff with autonomous financing. This measure is crucial to ensure wide-scale compliance, such as by enforcing penalties for misuse by large corporate users previously not held accountable. Similarly, this legal framework for groundwater use can be extended and modified to be applied in groundwater-sharing agreements, whether they're intra-state, interstate, or international.

This is not to say that top-down approaches centered on government-sanctioned enforcement are enough to respond to our current groundwater crisis; bottom-up approaches are just as important

in groundwater sustainability. For example, in northern India, which is one of the world's largest and fastest-growing groundwater users, there is an emphasis placed on small-scale methods of improving irrigation (Azmi, 2021). Farmers are taking control of recharge efforts by using rainwater and runoff, building small percolation tanks, and checking dams to help improve groundwater levels (Famiglietti et al., 2020). These grassroots initiatives can be applied in various communities in addition to other tried-and-true methods like promoting groundwater recharge by local farmers and users, becoming involved in groundwater data collection, making groundwater data publicly available, encouraging groundwater management and conservation, and increasing the use of crops such as beans, lentils, and oilseeds, which require less water. A variety of culturally and geographically appropriate approaches to pioneering groundwater conservation can be driven from the grassroots, not from the top, to promote innovative and unconventional approaches to groundwater conservation.

If we are going to respond effectively to our contemporary groundwater crisis, it is imperative that we can monitor progress and adapt our strategies accordingly. In order to do this, we must bridge the gap between science and policymaking. Hydrological problems and solutions embody meticulous science, yet scientists usually aren’t the ones with the authority to implement solutions. Current technology affords scientists the ability to analyze the coevolving processes and scenarios between the surface water-groundwater systems, ecosystems, and human activities (Gleeson et al., 2020). By taking advantage of satellite imagery, ground data, and predictive models, various analyses can be conducted to facilitate adaptive management, or the process of assessing the success of different management methods, or lack thereof, and to perpetually update our arsenal of solutions (Evans et al., 2020). In order for these to have an impact on actual

groundwater conservation outcomes, participation must be such that 'the products of science must emerge from an iterative, collaborative, two-way exchange with management and policy communities' (Elshall et al., 2018). This collaboration can manifest in a variety of ways: government-funded organizations working on groundwater research and education, facilitation of discussion at recurring conferences, development of new tools for communicating information, the establishment of human resources necessary to carry out the strategy, and more.

While the severity of the groundwater crisis may lead us to believe in the inevitability of a future of unending droughts, global food shortages, and hefty water taxes, it is important to remember that this crisis is anything but inevitable. It's time we all take lessons from places with chronic water shortages: simply use less water. For example, Los Angeles has grown by more than one million people since 1980, but water usage is still the same due to collective consciousness and collective action (Tures, 2018). Whether or not you live in a region that is affected by groundwater scarcity, everyone can conserve water daily in multiple ways, such as taking shorter showers or not rinsing dishes before loading them into a dishwasher (a practice that wastes around 20 gallons of water for each load). These are relatively minor actions, but when adopted on a large scale, will result in the greatest conservation of water—and we are going to need every drop.

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