Stanford Woods Institute for the Environment

Research Brief

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Water Security and Development: Assessing Groundwater Management Strategies

Background

As the United Nations Millennium Development Goals effort comes to a close, attention has turned to lessons for the post-2015 development agenda. Freshwater sustainability and security are high on the list. According to the Rio+20 Summit document, The Future We Want, "water is at the core of sustainable development as it is closely linked to a number of key global challenges." The security of food, energy, the economy and the environment is highly dependent on reliable and sustainable freshwater supplies in the face of global change. About 800 million people still lack access to reliable, safe water supplies. Threats to water supply will only grow due to regional and global changes.

The U.N. is not alone in recognizing the priority of water security. For example, the World Economic Forum's 2015 Global Risks report ranks water security as the top global risk, and the U.S. Agency for International Development issued its Water and Development Strategy in 2013 for the very first time, recognizing the importance of freshwater to the development agenda.

The Threat

Global changes, such as increasing population, urbanization, irrigated agriculture, and transboundary conflicts, are severely stressing freshwater supply systems. With many major rivers fully exploited, the net global groundwater depletion rate has doubled since 1990. In the Middle East and Northern Africa, unsustainable mining of fossil groundwater is well underway. For example, 70 percent of Jordan's water supply is obtained from groundwater while long-distance transport of unsustainably mined groundwater provides essential supply to 2.5 million inhabitants of Amman, Jordan's largest city. The country already treats almost all wastewater from Amman and uses it for irrigation in the Jordan Valley.

About the Researcher

Steven Gorelick is Director of the Global Freshwater Initiative, a program of the Stanford Woods Institute for the Environment. He is a Woods senior fellow and the Cyrus F. Tolman Professor of Earth System Science at Stanford. A hydrologist by training, Gorelick studies ways to enhance freshwater security, improve water supply management, analyze urban water vulnerability, understand causes of water crises, identify ecosystem protection strategies, and remediate contaminated aquifers.

Solutions: Policy Evaluation Tools for Improved Water Management

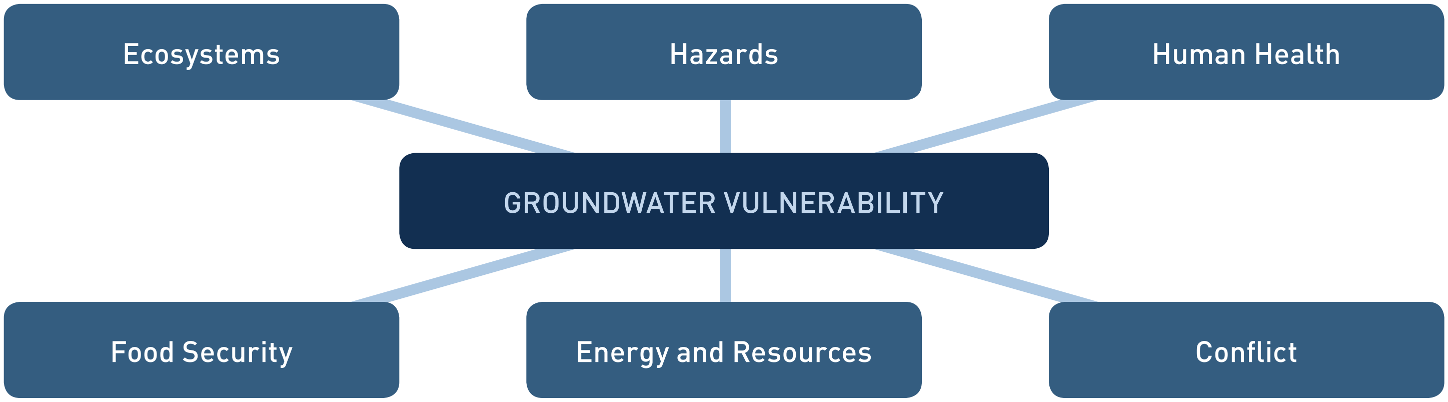
Stakeholders from the development community need modern scientific approaches to identify the most effective and viable strategies upon which to base water management decisions. Assessment tools are needed for managing groundwater, which is often coupled to surface water resources. This brief provides information about the latest developments in analytic tools for groundwater and groundwater–surface water policy evaluation and management. We discuss how policymakers in the water sector can use these tools as an important part of assessing impacts of proposed management instruments, ranging from quotas to water markets.

Water management and policy evaluation models can assess various options for managing water resources. Such hydroeconomic models represent water systems coupled with human behavior. Understanding the intricate interplay between hydrologic response and human activities is essential if groundwater resources are to be used sustainably or otherwise managed to reduce short-term vulnerability.

Because groundwater is largely unmanaged around the world, with little disincentive for users to take as much as they want, shared aquifer resources suffer aggregate impacts with consequent costs for humans and the environment. Solutions ranging from water markets to top-down governmental regulations can achieve equitable groundwater allocation. Such solutions require quantitative tools for planning and policy evaluation. These tools integrate modern hydrologic simulation with a new generation of management methods based on physical, institutional, environmental and economic metrics that reflect decision-making objectives and processes.

Developed by Stanford's Global Freshwater Initiative, predictive simulation models combined with economic optimization-management methods can help solve groundwater and coupled groundwater–surface water problems. The system models focus on six dimensions of groundwater vulnerability: ecosystems, hazards, human health, food security, energy and resources, and conflict.

- **Ecosystems** — Pumping from aquifers has affected groundwater-dependent ecosystems, resulting in pronounced effects on rivers, lakes and wetlands. Modern groundwater planning models provide a way forward by, for example, demonstrating that rotating among pumping locations can allow wetland water levels to recover and maintain necessary seasonal and inter-annual patterns of wetland inundation.
- **Hazards** — Hazards from overexploitation of aquifers include groundwater mining and depletion, land subsidence, triggered earthquakes, and seawater intrusion. Simulation-based system models can identify optimal, cost-effective groundwater pumping strategies to alleviate these hazards.
- **Human Health** — Optimal aquifer remediation design models are valuable for identifying cost-effective means of capture, containment, and treatment of groundwater contaminants.
- **Food Security** — Coupled surface water and groundwater system optimization models already have been used to determine optimal cropping, reservoir release and groundwater-surface water management policies in countries such as Mexico and India.
- **Energy and Resources** — Water is needed for virtually all aspects of energy and earth resource production, yet these activities threaten water resources. Producing shale gas, for example, can contaminate shallow



aquifers with gas leaking from wells. Surface water and shallow groundwater can be contaminated with shale gas production wastewater. No integrated simulation-management model formulations have been developed to help deal with these hazards.

- **Conflict** — Transboundary groundwater conflicts can be intraregional, interstate, or international. Groundwater exploitation on one side of a political or property boundary can affect water levels, pumping costs and flows on the other side. By developing predictive models and management strategies for communal use of water resources, future conflicts, particularly during periods of drought, can be avoided.

Freshwater Vulnerability: Points for Policymakers and Development Stakeholders

Groundwater is an important source of water for drinking and irrigation for hundreds of millions of people around the world. Its importance as a primary water source will likely increase due to growing populations, increasing urbanization, and other global pressures. As those in the development community seek to implement the Sustainable Development Goals and other aid efforts related to water security concerns, several factors merit consideration:

- Although freshwater sustainability is an ultimate goal, protecting against shorter-term vulnerability and promoting water management to avoid conflict are pressing matters in developing and underdeveloped regions that have received far too little attention.
- Hydroeconomic simulation-management models are essential tools for identifying freshwater solutions aimed at avoiding crises in vulnerable regions by ensuring that human and environmental needs are met while considering logistical, legal, social, economic and infrastructural constraints.
- By combining physically based hydrologic simulation with economic and institutional analyses, policy evaluation models can quantify the future effects of proposed interventions such as quotas, water markets, taxes, allocation systems, infrastructure, regulations, and alternative water rights systems.

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Websites

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