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Editorial: Limits and permanence of modern interventions in the water cycle

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Editorial on the Research Topic
Limits and permanence of modern interventions in the water cycle

The global water cycle is altered profoundly by societal demands for water, food, land, and energy [Albrecht et al., 2018; US Geological Survey (USGS), 2022]. As human activity and population growth increase demand for water beyond supply (Vörösmarty et al., 2000), water managers explore adaptation strategies (Brown et al., 2019). This elicits several questions: (1) How do modern adaptation strategies impact the water cycle regionally/globally, in the short-/long-term? (2) What are the hard limits of these adaptations? (3) Will these adaptations become adopted permanently?

Here, we present a collection of articles addressing these questions. It is diverse in methodologies, including original research, a community case study, and a literature review. It is also diverse in geographic/hydrogeophysical settings, including Maltese and Bahamian Archipelagos; the Horn of Africa; East and Southeast Asia; and the Pacific Northwest, USA. Thus, it sheds light on the global water cycle in urban and agricultural contexts, from perspectives of water managers, end-user consumers, and other stakeholders.

The first article is a case study of a small island nation (Malta), which, by definition, has a small catchment and therefore limited supply of freshwater. Typically, such a nation relies on large-scale interventions or supplemental sources for potable water. One is offshore freshened groundwater (OFG; groundwater less saline than seawater and stored in sub-seafloor sediments and rocks). De Biase et al. used 2/3-D numerical models to estimate that the present volume of OFG potentially provides an alternative supply to onshore groundwater for 75 years. However, future projections indicate that increased drought (under climate change) can decrease recharge and diminish OFG.

In another small island nation (the Bahamas), Welsh and Bowleg review multiple adaptation strategies over centuries. They discuss historic over-extraction of groundwater that led to severe salinization. Wellfields were abandoned, and freshwater was barged in from the larger Andros Island for ~40 years until it became insufficient. Then desalinated seawater *via* diesel-operated reverse osmosis plants became the primary source of potable water. Desalination was/is seen as a permanent solution, but it presents concerns due to greenhouse gas emissions by production plants and its inability to meet demand for the growing population. So, The Bahamas is investigating alternatives, particularly Ocean Thermal Energy Conversion, which uses deep seawater to co-generate clean energy and drinking water.

Demand for water does not increase alone, but interacts with that for energy and food (altogether WEF). In a case study for South Korea, which faces difficulties ensuring WEF security, An analyzed synergies and trade-offs between WEF security indicators (WEF security is most ensured if synergies are maximized and trade-offs are minimized). An found, for example, that indicators related to water supply services had synergies with the food production index, suggesting food production becomes more efficient when the water supply system is well-developed. This and other findings demonstrate that WEF security is an interconnected system—efforts in one part alone cannot improve WEF security as a whole.

Under the WEF framework, Zhao and Boll enhanced a water storage management tool to analyze proposed adaptations in alleviating drought impacts in an agricultural basin (Pacific Northwest, USA) under climate change scenarios for 2030–2090. Adaptations included greenhouses with efficient water application technology; crop planting time; irrigation technology; and managed aquifer recharge. They found that, for long-term impact, managed aquifer recharge is a cost-effective and easy-to-adopt option. However, implementing all adaptations together was the only way to alleviate most drought impacts, and it may take many years for these methods to be adopted widely.

In addition to agricultural systems, there is a need for effective water management in fast-growing urban centers. This is largely ignored and understudied in Ethiopia (the second most populous country in Africa). There, Abraha et al. found that water availability per person per year is 1,109 m^3, indicating water stress. The authors also found that 178 (15%) urban centers are in dry basins, 369 (33%) are in low groundwater potential zones, and 315 (28%) are in areas with <100 mm annual rainfall. To mitigate water risks, Abraha et al. advocate water-centric management strategies, such as water-smart community development, water-smart technology, water-sensitive physical planning, and a water-sensitive legal framework.

At the heart of "smart" water infrastructure is "smart" technology. One example growing rapidly in governance, transport, supply chain, and logistics is distributed ledger technology (e.g., blockchain), which stores data/transactions in a secure computing network, and thereby manages smart assets and smart contracts. Asgari and Nemati reviewed the literature to assess the potential of blockchain application in urban smart water management systems. They addressed technical, organizational, social, and institutional challenges that may hinder adoption of blockchain technology. For example, the technology is data-intensive and computationally demanding, so it has large/high requirements for data storage, bandwidth, computational speed, and electricity. As such, there are significant energy costs that impact the environment.

Water "-smart," "-intelligent," and "-wise" proposals to manage water more efficiently rely on data-driven machine-computing technologies (Abraha et al.; Asgari and Nemati). In contrast, some researchers turn to human mindfulness (direct human conscious experience). The premise is that adoption of water conservation technologies does not always increase efficiency of irrigation because the cost of water can be low, and farmers will take their full quota even if not required, thus causing water waste. So, irrigation efficiency can depend more on behavioral characteristics of the farmer. In a case study in Cambodia, where irrigation development projects are advancing at fast pace, Asthana found that mindfulness of farmers both directly and indirectly (through environmental concern) increased irrigation efficiency.

This collection of articles presents examples of modern water adaptation strategies that meet immediate demand and create buffers that provide security. Some were implemented on a temporary basis, and became long-term/permanent; others became unsustainable and threatened freshwater availability. This highlights the importance of water storage, whether on small islands (Welsh and Bowleg) or large agricultural areas that depend on highly seasonal runoff (Zhao and Boll). In increasingly technological systems, data storage is also important (Asgari and Nemati). Bridging the temporal scales in management of coupled human-natural systems remains a crucial scientific, technological, and social challenge.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

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