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EDITED BY

Murugesu Sivapalan,
University of Illinois at Urbana-Champaign,
United States

REVIEWED BY

Melissa Haeffner,
Portland State University, United States
Matthew R. Sanderson,
Kansas State University, United States
Maria Rusca,
The University of Manchester,
United Kingdom

*CORRESPONDENCE

Amber Wutich
✉ awutich@asu.edu

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Water insecurity is human: why social science must be at the core of water security research and practice

Amber Wutich*

School of Human Evolution and Social Change, Arizona State University, Tempe, AZ, United States

Many water scholars believe we are at an inflection point in which new approaches to water research and management are needed, and I agree. Water insecurity is fundamentally driven by human behavior and is socially determined. To address this, the emerging science of water security can build on well-established and theoretically-robust findings from social science. Foundational work establishes the formative role of human social structures in producing water insecurity, particularly for populations experiencing poverty, racial/ethnic minoritization, and political exclusion. While infrastructural and legal/regulatory reforms are essential to advance water security, they have failed vulnerable populations in patterned, predictable ways globally. New research highlights how social and engineered infrastructures that are hybrid, modular, adaptive, and decentralized can improve water security for the most vulnerable populations. However, reliance on such systems is inherently a feature of unjust, inequitable water governance. Social scientists have a valuable role to play in explaining these dynamics, addressing water system failures, and developing more equitable water solutions.

KEYWORDS

water insecurity, hybridity, MAD water, social science, social determinants

Introduction

Water insecurity is fundamentally driven by human behavior. Water overdraft, water overallocation, water pollution and climate change are, obviously, human-induced events that cause water scarcity—or scarcity of usable water. But even in places where water is abundant, decisions about how to invest in water infrastructure, where to build it, who will be served, the cost of water, and societal valuations of water uses (e.g., industrial over cultural needs) also produce water insecurity for some populations, but not others (Mehta, 2005). In all these ways, water insecurity is socially determined.

Many water scholars believe we are at an inflection point in which new approaches to water research and management are essential (Vicente-Serrano et al., 2024; Gleick, 2023; Falkenmark, 2020; Vörösmarty et al., 2018; Famiglietti, 2014; Rockström et al., 2014), and I agree (Wutich et al., 2023; Wutich et al., 2021). In addition to long-standing problems with groundwater overuse, aging infrastructure, and growing demands, new problems are growing: climate change-related disasters, widespread scarcity, pervasive water contamination, and skyrocketing water costs. Emerging solutions, such as desalination and wastewater reuse, are important but likely insufficient to solve water problems for many populations. And water insecurity is on the rise everywhere. It stubbornly persists in low- and middle-income countries (Birkenholtz, 2016; Young et al., 2022). Water intermittency is newly emerging in urban households once believed water-secure (Beard and Mitlin, 2021; Kumpel and Nelson, 2016). And there is a growing realization that millions of people in high-income countries like the U.S. and Canada experience

water poverty (Meehan et al., 2020a, 2020b). As such, it is increasingly important to understand who is affected, how, and why—and what solutions exist for people whose water needs cannot be met by large-scale infrastructure investments alone.

In this commentary, I take as my starting point the definition of water insecurity developed in the Water Insecurity (WISE) Research Network (American Association of Geographers, 2024), which I helped build over the last decade. Water insecurity happens when water is insufficient for human needs, including drinking, cooking, sanitation, hygiene, livelihoods and culturally-valued uses (Jepson W. et al., 2017; Mehta, 2014). The field of water insecurity remains focused on individual needs, health, and experiences (Rosinger, 2023), while also recognizing that people, households, and communities are situated in vast networks of agriculture, industry, exchange, culture, hydrology, and ecology (Meehan et al., 2023; Budds et al., 2014). In this commentary, I draw on well-established findings and cutting-edge research to demonstrate the unique value social scientists bring to global efforts to achieve water security.

Settled science: what social science tells us about water insecurity

Water insecurity is often experienced in households, as households are the most basic unit that humans use to acquire and distribute resources across cultures (Brewis et al., 2020; Netting et al., 1984). Every member of a household has a social position that shapes their experiences of water insecurity. This can be quickly demonstrated with a thumbnail analysis, drawn from the large and complex literature on gender and water insecurity (Brewis et al., 2024; Shah et al., 2023; Dickin and Caretta 2022; Harris, 2009; Sultana, 2009). Foundational research indicates that women and girls are most often responsible for acquiring and distributing water, and tend to be most impacted when water becomes scarce (Zwarteveen and Meinzen-Dick, 2001; Crow and Sultana, 2002; Ray, 2007; Pouramin et al., 2020; Tallman et al., 2022). Building on these findings, recent work points to livelihood structures and cultural settings in which men, boys, and gender-diverse people experience significant water insecurity and water-related suffering (Ilboudo Nébié et al., 2024; Adams, 2023; Truelove and Ruszczyk, 2022; Wilson et al., 2021; Geere and Cortobius, 2017; Gaillard et al., 2017). Like gender, other social structures that vary within households—such as age, kinship, wealth, and citizenship—shape individual experiences of water insecurity (Harris et al., 2017; Maxfield, 2020; Sultana, 2020). The broader social structures in which the household is situated matter too. Households that lack land tenure or home ownership, experience disaster risk, are not well-integrated into cash economies, or have other livelihood limitations, for example, tend to be particularly at risk of household water insecurity (Roque A. et al., 2023; Roque A. D. et al., 2023; Cole et al., 2020; Shah, 2021; Jepson W. et al., 2017; Pearson et al., 2015).

Within societies, empirical research on the social determinants of water insecurity is now advancing rapidly (Drakes et al., 2024; Thomson et al., 2024a; Rosinger et al., 2022; Stoler et al., 2020; Young et al., 2019). These cross-cultural studies and others have determined that key predictors of water insecurity include poverty, racial/ethnic minoritization, and political marginalization (Ranganathan and Balazs, 2015; Pulido, 2017; Brown et al., 2023). My collaborative research on water insecurity with U.S. colonias residents illustrates

how these processes intersect and work (Wutich et al., 2022; Gu et al., 2023; Roque et al., 2024). Colonias are informal settlements within 150 miles north of the U.S.-Mexico border that were historically founded by migrant farmworkers from Mexico (Velez-Ibanez et al., 2003). In addition to suffering low incomes and ethnic minoritization in the United States, colonias residents may experience political exclusion due to their families' mixed immigration status (Jepson and Vandewalle, 2016). Many colonias were cut off from municipal services offered in nearby cities—this common exclusionary political process is known as “municipal underbounding” and it tends to target racial/ethnic minority communities (Durst, 2014; Mukhija and Mason, 2013). Lacking municipal services, colonias residents were left to self-fund and self-construct small-scale water infrastructure, including unregulated or underregulated local wells and septic tanks, or to subsist on bottled or vended water (Jepson, 2014; Jepson and Brown, 2014). Over the long term, this resulted in water insecurity, health inequalities, economic hardship, and personal suffering for colonias residents (Zheng et al., 2022). While the specific contexts of poverty, race/ethnicity, and political marginalization vary across communities and countries, the basic dynamics of environmental injustices that produce water insecurity seem to be fairly universal (e.g., Pellow, 2017). This well-developed area of research provides a solid foundation for understanding the social determinants of water insecurity in any global site.

At a societal scale, foundational work established the formative role of power dynamics in producing water insecurity (Johnston and Donahue, 1998; Swyngedouw, 2004, 2009; Sultana and Loftus, 2019; Wilson et al., 2021), particularly in low- and middle-income countries and Indigenous nations. Colonialism, dispossession, and capitalism produced a legacy of international development inequalities (Walsh, 2022), which have long driven inequitable water infrastructure investments. Decades of research examined the shift toward water management using markets and privatization (often called “neoliberalism”), especially as tools proposed to increase investments and efficiencies in water infrastructure (Bakker, 2004; Budds and McGranahan, 2003; Budds, 2020; Budds, 2004). My work in Cochabamba, Bolivia in the aftermath of its “Water War” over a failed privatization deal is just one of many examples of the negative long-term consequences of this approach (Wutich, 2009). Recent research examines how ongoing processes of colonialism produce water insecurity and environmental injustices, especially for Indigenous people (Montoya, 2017; Curley, 2019, 2021; Liboiron, 2021; Wilson et al., 2021, 2024). This work is important for understanding material inequalities, but also problems caused by the social meanings assigned to water (called “ontology,” Yates et al., 2017) and resulting ways of managing water. It suggests that current dominant ways of thinking about water (called “modern water,” Linton, 2014, Spackman, 2020; Meehan et al., 2020a; Meehan et al., 2020b) overlook the potential value of Indigenous approaches to water management—which center respect, caretaking, interconnectedness, and reciprocity (McGregor, 2008, 2015, 2021). Led by Indigenous scholars, recent work argues that overcoming legacies of colonialism in water management means more than just recognizing long-denied water rights and investing in equitable access to clean water and piped infrastructure, but also rethinking water relations in more profound ways.

Research on social construction of water insecurity has yielded many theoretically-robust findings. These broad-scale findings are largely settled science, though much work remains to be done to

characterize local, contextual, cross-cultural, and cross-national variability and trends. As such, I argue that these findings are an essential foundation to any interdisciplinary effort to understand and address water security.

What's next: halting steps toward water security

Now is a time of halting steps toward water security. Innovative water infrastructure planning and development, which has been the bedrock of public health advances for the last 200 years (Hall and Dietrich, 2000), continues apace (Vörösmarty et al., 2021). New legal agreements, policy instruments, and regulatory reforms are improving water conservation, allocation, quality, and management (Hoekstra et al., 2018; Pacheco-Vega, 2020; Pierce et al., 2021; Dobbin et al., 2023). Of course, the more successful infrastructural developments and legal/regulatory reforms are, the less we should need to worry about human water insecurity. But we should probably keep worrying. Water insecurity today emerges from the patterned, predictable failure of these large-scale infrastructural developments and legal/regulatory reforms (Meehan et al., 2020a, 2020b, 2023). Given the abundant challenges we face moving forward—in climate change, political instability, economic (de)growth—it would be unwise to assume we'll enjoy anything like continued linear progress toward water security (Birkenholtz, 2016). To address these risks, there is now a movement among water researchers to understand the conditions under which progress in water security might reverse and to plan for interventions that can help humans survive (Stoler et al., 2022; Wutich et al., 2023; Thomson et al., 2024b), even in the face of major infrastructural and regulatory failures. This is my area of expertise, and it is the focus of my WISE colleagues' research around the world.

The hybridization of water systems is one major approach that emerges from empirical evidence globally (Rusca and Cleaver, 2022). For people who experience water insecurity, living with hybrid water systems is normal: intermittent piped water service can be supplemented with vended water and rainwater harvesting, for example. Research that studies water systems “beyond networks” shows how the hybridization of pipes, people, and ecologies helps enhance water security in households and communities (Furlong and Kooy, 2017). Such research is fluorescing under host of names in the social sciences, including informality, hybridity, meshwork, alternative water systems, and everyday water infrastructures. Sociotechnical tinkering and institutional bricolage, or localized changes made to water infrastructures and institutions to improve functioning, can further improve these hybrid systems (Kemerink-Seyoum et al., 2019; Cleaver, 2002). And, research on polycentricity helps us understand how multiple overlapping systems of governance can be used to enhance water security (Garrick and Hahn, 2021; Schipanski et al., 2023). Put together, this research shows how embracing hybridization can increase human survival and community resilience, even when serious water insecurity challenges are present.

Human survival is always best understood at the individual and household level. MAD water is a field of scholarship that explores how integrated engineered and social infrastructures that are modular, adaptive, and decentralized (“MAD”) can help

improve self-reliance and survival in water-insecure households (Stoler et al., 2022; Wutich et al., 2023; Thomson et al., 2024b). This research is inspired by innovative technologies that can improve water supply or safety, such as nanotechnology enabled water treatment systems or atmospheric water capture (Feng et al., 2022; Qu et al., 2013). Such technological innovations can be important, but they work best when they are integrated into the social infrastructures that people already rely on for survival in water-insecure communities (Wutich, 2024). Social infrastructures like water sharing (or inter-household water transfers) (Rosinger et al., 2020) and informal water markets (Garrick et al., 2023) seem to be a near-universal coping strategy in water-insecure conditions. When engineered innovations are integrated with social infrastructure, MAD water systems have the capacity to safeguard household water security (Beresford et al., 2024; Empinotti and Garjulli, 2024; Dobbin et al., 2024).

Yet, it's important to acknowledge that community and household water self-reliance is inherently unjust. Research finds it pushes the responsibility, cost, and burden of survival on the most vulnerable people, while typically granting the privilege of well-functioning water systems to the more wealthy and powerful (Lloréns, 2021; Roque A. et al., 2023; Roque A. D. et al., 2023). So, while there is much truth in the Puerto Rican rallying cry “*solo el pueblo salva al pueblo*” [only the people can save the people] (Rodríguez Soto, 2020)—by providing water service through mutual aid and self-supply (Roque, 2021)—such arrangements are not a feature of functioning, equitable, just societies.

Water security futures: new research, innovations, and community-based collaborations

Global research points to serious challenges that may impede efforts to achieve global water security, or even reverse them. To maximize the success of water security gains—through, for example, infrastructure innovations, legal and regulatory reforms, hybridization, and community and household self-reliance using MAD water systems—it is important to consider what new approaches are needed. What's worked before is not working anymore. This is where social scientists can help.

One pervasive problem in the water sector is the increasing distrust of water institutions, managers, and systems. Based in real betrayals of trust, such as the highly-publicized cases in Flint and Jackson in the U.S. (Pauli, 2020; Wilson et al., 2023), distrust in water systems has long been linked water inequity and exclusion born of systemic racism and divestment (Jaffee, 2024). Now, distrust in water systems is being further amplified by people's political polarization and social isolation. This distrust is spurring skepticism about public health mechanisms, including public water service, that have made significant improvements and human health over the last two centuries (Teodoro et al., 2022). Further intensifying these dynamics is the ongoing climate crisis and its sequelae, including migration, conflict, and political destabilization (Stoler et al., 2021). These are not problems that water managers or engineers or hydrologists can overcome alone.

All these barriers to water security—and many more—are fundamentally social phenomena. This is why it would be a mistake

to build a future field of water security without social science at its core. Social scientists are needed to collaborate with biophysical scientists and engineers to develop new research and innovations. Social scientists have training and expertise in water governance (Zwarteveen et al., 2017). We know how to manage the complex cultural, political and social dynamics that shape water insecurity and related disasters (Peek et al., 2020). We bring skills in community-based research (Pacheco-Vega and Parizeau, 2018; Castro-Diaz et al., 2024), inductive theory-building through listening (Kearns, 2021), and grounded local water collaborations (Roque et al., 2024). Past failures in water interventions can often be attributed to the exclusion of social, cultural, and local knowledges in project planning and implementation—precisely those contributions that social scientists may be best positioned to make. The theoretical, analytical and practical skills that social scientists can contribute are essential for advancing water security in marginalized and water-insecure communities.

I am not naïve about the difficulties of this kind of action-oriented transdisciplinary research. I have been involved, sometimes centrally and sometimes peripherally, in collaborations around water insecurity (Jepson W. et al., 2017; Jepson W. E. et al., 2017), sociohydrology (Sivapalan et al., 2014), the hydrosocial cycle (Budds et al., 2014), participatory convergence (Castro-Diaz et al., 2024; Roque et al., 2022), and water institutions (Ostrom, 2009), to name a few. Such collaborations can, of course, be troublesome, with people struggling to work across differences of training, assumptions, scale, values, incentives, and power (Klenk and Meehan, 2015). For example, I worked with Sivapalan's group on an early paper describing the promise of sociohydrology (Sivapalan et al., 2014)—but later I was not able to contribute very much because I am trained as an anthropologist to theorize culture (shared norms and knowledge), and sociohydrology tends to be at different scales (e.g., Van Oel et al., 2024, Table 1). I do not see this as a problem. Diverse ways of thinking and theorizing only strengthen our work.

We know there is no one solution to water security. Working together—even when it is hard, even when it is uncomfortable—is the only way I can see to move forward toward water security. And I mean really together; not just across academic disciplines, but also with communities, activists, bureaucrats, and industry. We must and we will progress together because, without water, there is no human life.

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Data availability statement

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author/s.

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