WATER MANAGEMENT

Water Security: Research Challenges and Opportunities

New strategies for analyzing water security have the potential to improve coordination and generate synergies between researchers, policy-makers, and practitioners.

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An estimated 80% of the world's population faces a high-level water security or water-related biodiversity risk (*1*). The issue of water security—defined as an acceptable level of water-related risks to humans and ecosystems, coupled with the availability of water of sufficient quantity and quality to support livelihoods, national security, human health, and ecosystem services (*2*, *3*)—is thus receiving considerable attention. To date, however, the majority of academic research on water security is relatively poorly integrated with the needs of policy-makers and practitioners; hence, substantial changes to funding, education, research frameworks, and academic incentive structures are required if researchers are to be enabled to make more substantive contributions to addressing the global water crisis.

Key Issues Driving Recent Interest

More than 400 peer-reviewed publications on water security have appeared across the social, natural, and medical sciences in the past 20 years (more than 50% of which have been published in the past 5 years) (*4*) (see the graph), and several universities have recently launched water security initiatives. Water security—the focus of the 2013 Stockholm World Water Week and the next World Water Forum in 2015—has also attracted considerable attention from policy-makers, practitioners, and government organizations, including the U.S. Environmental Protection Agency and National Intelligence Council, the Australian government, the World Economic Forum, the Global Water Partnership (GWP), the World Bank, the North Atlantic Treaty Organization (NATO), the G8, and the United Nations [e.g., the World Water Assessment Program (WWAP)] (*5*–*10*).

This increase in research and policy activity reflects growing concerns—particularly among practitioners, who have been at the vanguard of this agenda—over water-related human and ecosystem vulnerability, notably:

(i) threats to drinking water supply systems [e.g., from contamination, human impact on aquatic ecosystems and lack of water access (*11*), or terrorist attacks (*12*)], implying the need for enhanced monitoring and emergency preparedness, as well as investment to meet the needs of the more than 1 billion people worldwide without access to safe drinking water (*10*, *11*);

(ii) threats to economic growth and human livelihoods from water-related hazards (e.g., floods and droughts), water stress, and water scarcity, notably with respect to food security (*13*) and energy security (*9*), implying the need for technological innovation and water conservation (*14*);

(iii) threats to water-related ecosystem services due to point- and non–point source pollution as well as increased water consumption (*3*), associated with increased use of ecosystem services and biodiversity loss (*1*, *15*), implying the need to comanage water for human and ecosystem needs, particularly given potential "tipping points" in socioecological systems (*16*);

(iv) increased hydrological variability (*17*) in the context of climate change (notably increased amplitude and frequency of droughts and floods), implying the need to develop innovative strategies for dealing with uncertainty (*18*) that move "beyond infrastructure" (*19*) to include governance and social learning as key strategies for more effective water management (*20*).

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Drought on the Colorado River. Drought has reduced water levels in Lake Mead, behind the Hoover Dam.

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A central theme of these water security threats is the challenge of balancing human and environmental water needs while safeguarding essential ecosystem services and biodiversity. Water security research thus incorporates and extends key aspects of Integrated Water Resources Management (*21*), notably an emphasis on linkages between land-use change and hydrological systems, between ecosystems and human health, and between political and scientific aspects of water management (*1*, *11*). Innovative aspects of the water security agenda include a conceptual focus on vulnerability, risk, and resilience; an emphasis on threats, shocks, and tipping points; and a related emphasis on adaptive management given limited predictability.

Notably, water security research also emphasizes a policy challenge: Achieving economic goals and sustainable development objectives (e.g., the Millennium Development Goals) may require contentious trade-offs—notably between agriculture, the largest water user globally, and other sectors—that generate both violent and nonviolent conflicts (*22*), as demonstrated by recent debates over water-related implications of the global "land grab" (*23*). This underscores the need for robust, polycentric governance mechanisms designed to resolve (or at least mitigate) conflicts between users, sectors, and nation-states (*20*).

Challenges for Water Security Research

The water security research agenda is faced with three challenges that represent potential opportunities for synergies among researchers, policy-makers, and practitioners:

(i) Multiple, and at times incommensurate, definitions of water security are used by academics and practitioners (*4*). It is unsurprising that multiple definitions of water security exist, given that perspectives vary between academic specializations (and indeed between stakeholders and sectors). Specialization has its advantages; however, effective water management and policy-making require shared conceptual common ground as a prerequisite to interdisciplinary analyses of the complex interac-

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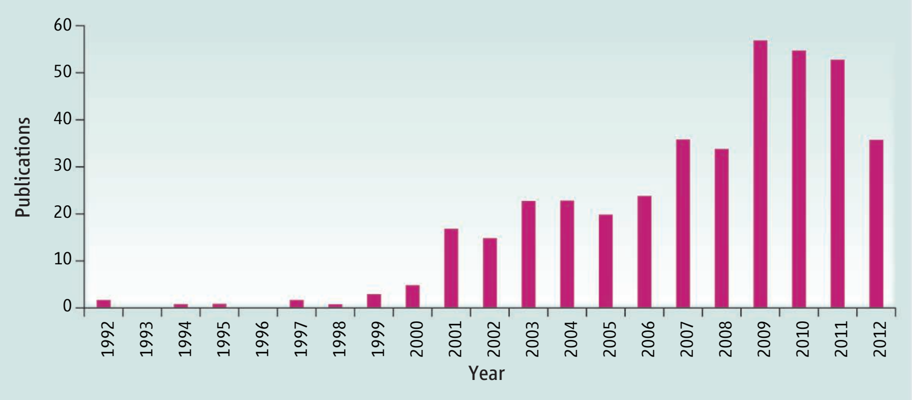

Water security publications (1992–2012). Updated from (4), based on methods described in (4). Data from Web of Science, accessed 15 June 2012; http://wokinfo.com/products_tools/multidisciplinary/webofscience/.

tions between humans, ecosystems, and the hydrological cycle (*24*). Promising examples do exist, such as the emerging subdiscipline of socio-hydrology (or eco-socio-hydrology) (*25–27*). Fully developing this (and other, similar conceptual frameworks) requires new approaches to research funding, research design [e.g., the Global Water System Project (*28*)], and student training [e.g., Harvard's Water Security Initiative, which trains water-related researchers as "specialized integrators" across a broad range of disciplines (*29*)].

(ii) Analyzing the socio-environmental implications of the changes now under way in the global water cycle in support of science-informed policy (*30*) requires interdisciplinary, collaborative research, transcending "broad" versus "narrow" and "academic" versus "applied" distinctions, in line with the integrative definition of water security provided above. As with other examples of "sustainability science," this requires engagement with "peer expert" networks that bring together both practitioners and academics (*31*). Such research strategies currently face substantial barriers, including disciplinary biases, funding constraints, and institutionalized incentives for tenure and promotion. Thus, the growing emphasis by research funders on collaboration with—and "impact" on—practitioners [e.g., the UK's Water Research and Innovation Framework and the U.S. National Science Foundation's (NSF's) Science, Engineering, and Education for Sustainability program] is welcome, although this should be complemented by changes to incentive structures within universities. In addition, project-based funding should be complemented by the creation of long-term networks [e.g., Oxford University's Water Security Network] and research units that bring together interdisciplinary researchers and practitioners on a longer-term basis (*32*), e.g., NSF's Decision Center for a Desert City, which bridges science and policy to create analytical tools used in water decision-making.

(iii) Researchers in different disciplines tend to conduct water security research at distinct scales (*4*) (e.g., whereas hydrologists tend to focus on the watershed, political scientists tend to focus on the nation-state), mirroring—and perhaps reinforcing—the "scalar mismatch" that characterizes on-the-ground water governance. This situation is unsatisfactory for several reasons: the inherently multiscalar nature of intersectoral food–energy–water security trade-offs (*19*); the increasing importance of "virtual water" flows, particularly those associated with global trade (*32*); the need to redress poor governance often generated by the "scalar mismatch"; and the fact that subsurface hydrological gradients may not correspond with surface topography (*33*). Accordingly, a river basin–focused approach, although important, must be complemented by analyses at other scales, in support of water-related decision-making and the development of adaptation strategies (*34*). Risk analysis frameworks are promising in this regard, because they can incorporate multiple, nested spatial and temporal scales. An additional potential advantage arises from the fact that the concept of risk is deployed across the biological, social, physical, and medical sciences, and is hence compatible with an interdisciplinary approach to analyzing water security, specifically with respect to trade-offs between multiple and competing objectives (*18*, *35*).

Conclusion

Interdisciplinary research on water security faces considerable challenges, given the complexity of analyzing interrelationships between vulnerability, risk, and resilience across scales, sectors, and disciplines in the context of limited predictability. Additional challenges arise from current barriers to creating constructive synergies between policy-makers, practitioners, and researchers. Promising examples exist of potentially useful innovations in funding, research design, institutional incentives, and graduate education; these must be systematically tested, refined, and replicated if researchers are to make more effective contributions to addressing global water insecurity.

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