Title: Advancing methods for research on household water insecurity: Studying entitlements and capabilities, socio-cultural dynamics, and politics

Short title: Household Water Insecurity Methods

Household water insecurity (HWI) has serious implications for the health, livelihoods and wellbeing of people around the world. Recent scholarship qualifying the World Health Organization's traditional metric of "access to an improved water source" suggests that water insecurity is far more pervasive than official estimates suggest, particularly in low and middle income countries (Satterthwaite 2016, 2003, Nganyanyuka et al. 2014, Onda et al. 2012, Wescoat et al. 2007). The tasks of defining and measuring water insecurity are critically important for understanding the social, cultural, economic and political processes that marginalize some communities from access to water, and ultimately undermine developmental efforts to reduce household water insecurity (Loftus 2015, Swyngedouw 2013).

The concept of insecurity to reflect the under-provision of domestic water has gained much traction in both academic literature and global development institutions. Household water insecurity has been defined, largely, as "inadequate, unreliable, and unaffordable water for a healthy life" (Jepson 2014). However, a definition of water insecurity that focuses solely on availability or quality may obscure important dynamics (Nganyanyuka et al. 2014, Obeng-Odoom 2012, Subbaraman et al. 2015), such as social, cultural, and political relations (Jepson et al. 2017b), as well as the processes that affect ecological dynamics (e.g., Kujinga et al. 2014). Scholars emphasize the importance of conducting research on water in the context of broader, relational frameworks, such as the hydrosocial cycle (Linton and Budds 2014) and sociohydrology (Srinivasan et al. 2017). While researchers are creating more comprehensive and broadened metrics to measure household water insecurity (e.g., Boateng et al. 2017, Tsai et al. 2016, Stevenson et al. 2016), in general, they do not yet address the socio-economic, cultural, and political relations at work in producing household water insecurity. To accomplish this, we suggest, researchers must develop better methods for research on household water insecurity.

Household-level research is notoriously complicated by the problem of defining the household, and most social science disciplines have established, well-justified approaches. Following Netting et al. (1984: xxii), we define a household as "a fundamental social unit…for pooling and sharing of resources." Yet, factors operating at other levels of analysis shape household water insecurity as well. For instance, households vary in their capacity to obtain water based on factors such as family size, acute/chronic illness and disability, and age composition (Geere et al. 2010), and the negative physiological impacts of water insecurity, such as dehydration, might be felt more acutely by some demographic subgropus, or even by some individuals within the household (Wutich and Brewis 2014). At the societal level, cultural and political structures embed social relations with differential power dynamics that in turn may differentially expose households to water insecurity. For example, processes of land tenure, disinvestment, spatial exclusion, and dispossession can elevate racial/ethnic-minority households' risk of experiencing water insecurity (Loftus 2011). Household water insecurity research thus requires attention to processes at multiple levels of analysis, and with specific interest and attention to variability and socio-spatial differentiation.

This paper has two goals. First, we briefly review current methodological approaches for studying household water insecurity, assessing their inadequacy in evaluating a broader notion of household water insecurity, including factors such as reliability, sources, quality, quantity, affordability, and health impacts. Second, we identify opportunities to develop methods to better assess the entitlements and capabilities, social and cultural dynamics, and political institutions and processes that influence household water insecurity, with attention to the need for systematic, cross-cultural and cross-site comparative analysis. Water insecurity has been

studied by researchers across the social and life sciences and humanities with little consensus on standard definitions or methods. Here, we articulate water insecurity as a concept that comprises both a *state* and a *relation*, which in turn requires a holistic approach to assessment and measurement. While other aspects of water insecurity merit further consideration (e.g. ecological considerations), our review of existing and emergent methods in this piece is most interested in the socio-cultural and institutional dynamics important for a relational understanding of water insecurity.

Established Methods for Assessing Household Water Insecurity

For 20 years, household water insecurity researchers have largely followed some variant of Webb and Iskandarani's (1998) definition: "water security is access by all individuals at all times to sufficient safe water for a healthy and productive life" (e.g., Mason 2012, Stevenson et al. 2012, Hadley and Wutich 2009). Four derivative concepts—water quality, quantity or adequacy, source or reliability, and affordability—have been subsequently included in most definitions of household water insecurity (Jepson 2014). Leading international and national agencies have set standards for approaches to assess human water requirements, including the United Nations, World Health Organization, U.S. Environmental Protection Agency, and American Public Health Association (e.g., Bridgewater & APHA, 2012; WHO, 2011), although guidelines, recommendations, and legislation vary widely. Here we review established methods to assess household water insecurity broadly speaking, as well as opportunities and challenges for methods to better assess household water insecurity within these approaches.

Water Quality

For domestic purposes, water quality typically refers to the safety of water for human consumption and, in some cases, washing and hygiene (considering water-borne and water-washed diseases, respectively). Water quality is measured by microbiological and physico-chemical contaminants that either pose direct health risks, or are proxies for dangerous pathogens or chemicals. Microbiological water quality is most commonly assessed by testing for the presence of fecal indicator bacteria such as *Escherichia coli* or thermo-tolerant coliforms. Fecal contamination in low- and middle-income drinking water supplies is often seasonal (Kostyla et al. 2015) and persists globally (Bain et al. 2014). The physico-chemical quality of drinking water is commonly assessed using metrics such as total dissolved solids, pH, turbidity, specific heavy metals, or levels of residual/free chlorine. Water quality is traditionally tested by sampling and measuring indicators of contamination at a point of consumption in the household, within a distribution network, and/or at the water source. Many techniques have been developed to monitor microbial and chemical water quality (Allan et al. 2006, Bain et al. 2012), though not all are transferable to low-income settings, in part due to wide variation in levels of bacterial contamination (Pearson et al. 2008). Low-cost field assessment of modern water contaminants such as bisphenol-A, phthalates, and agricultural nitrates remains a significant research gap. New concepts, such as the source-to-tap framework and one health concept, combined with new techniques, such as metagenomics technology, hold promise in terms of radically revisioning our approach to water quality—including the potential for innovative methods that could radically refashion how we understand, and test, for water quality (e.g. Dunn et al, 2015).

Water Quantity or Adequacy

Household water insecurity is most often measured in terms of quantity. Estimates of human daily drinking water requirements vary widely (Gleick 1996), and can depend on age, gender, breastfeeding status, physical activity, and culture. Public health concerns may be particularly salient when water usage falls below 5 liters/person/day (Howard and Bartram, 2003). Water quantity is gauged most easily when household water meters are employed. In the absence of metering, ecological measures of water availability (such as rainfall, as in Pande and

Savenijie 2016) are sometimes used as proxy measures of household water availability, although this is generally recognized to often be disconnected from actual access in households. Household water quantity may be measured directly (e.g. liters collected), though the volume of water brought to a household does not necessarily inform on the nature of water usage. Methods for assessing sufficiency of water quantity include assessment of urine specific gravity, GPS tracking, and self-reports from household members (Majuru et al. 2012, Wutich 2009). The volume of household water usage can also be estimated though observational surveys that incorporate container measurements and household reporting of water collection frequency (Geere et al. 2010; Pearson 2016). Mobile device-enabled data collection has also been explored to measure the effect of travel distance during fetching on water quantity (Geere et al. 2016).

Water Source or Reliability

The type of water source and its distance from the household have long been used as indicators of water access or quality (WHO/UNICEF 2015, 2017, Bain et al. 2012; Onda et al. 2012; Satterthwaite 2003). Household water insecurity is generally mitigated when piped water is available in the dwelling or compound (WHO/UNICEF 2017). Yet even the gold standard of water service delivery—in-home piped water from a municipal provider—may be unreliable if intermittent (Lee and Schwab 2005). Water procured outside of the home may be periodically inaccessible due to a broken pump handle, disputes between neighbors, climate change or environmental vulnerabilities, or other disruptions. In 2017, the WHO/UNICEF Joint Monitoring Program launched a new drinking water service ladder to facilitate monitoring during the Sustainable Development Goals era. This ladder of five service levels moves beyond the simple improved/unimproved classification to include criteria of drinking water accessibility, quality, and availability, and is operationalized according to source type (including on or off premises), collection time including queuing, presence of fecal contamination, and intermittency (WHO/UNICEF 2017). This classification scheme still struggles to classify newer water services, such as tanker or packaged water, which are becoming important services despite highly variable quality and reliability in some places. Better measurement precision is needed to assess the reliability of water sources in cross-cultural contexts.

Water Affordability

The most common measure of household-level affordability is the cost of water as a percentage of household income. Analyses of affordability in the United States, for instance, typically calculate average water residential bills as a percentage of median household income, with values of less than 2.5% declared “affordable” (e.g., Janzen et al. 2016; Mack and Wrase 2017). Internationally, the United Nations Development Program defines affordable water as that which costs no more than 3-5% of a household’s income (Hutton 2012, Smets 2012). Although these approaches enjoy intuitive appeal, they have been criticized as misleading and inaccurate (EFAB 2014; Davis and Teodoro 2014). Specifically, the binary nature of these conventional approaches—either “affordable” or “unaffordable”—is problematic because affordability is rarely a strictly either/or phenomenon; water is affordable relative to the costs of other things and the household’s economic resources. Simple income percentage-based metrics are not sensitive to other essential household costs (e.g., food, housing, medicine, home energy, taxes), and so income percentage standards can lead to over- or under-statement of affordability. More accurate and comprehensive (but seldom used) affordability metrics account for not only the direct costs households pay through water bills, but also direct capital costs (e.g., water tanks or on-site purification technology) and the opportunity costs associated with water acquisition, including time spent traveling to and from water sources (Hutton 2012). But even the broadest (and, incidentally, least used) cost measures still exclude costs such as the physical impacts of hauling water and missed opportunities for work or school

due to water carriage, although these are issues at times taken up in qualitative and critical water security studies. .

Challenges in Well-established Methods for Studying Household Water Insecurity

These methods for assessing household water security often fail to capture the everyday realities of water insecurity. For example, variation in needs and physical capacity to fetch water are not considered. In addition, differences between and within households, differences across seasons, intermittency of sources, and variation over time are largely ignored. The definition of 'sufficient' water quantity required to meet household needs varies with family size, livelihood, health status, acute/chronic illness, and disability, and is temporally dynamic. Household water insecurity metrics also often ignore the reality that water sources outside of the home may vary in inaccessibility due to factors such as poorly-maintained equipment, chemical contamination, seasonal evaporation, or the disappearance of sources because of climate change. Traditional, established approaches have the important advantage of offering relatively simple, quantifiable, and cross-culturally comparable measurements, but they may also oversimplify household water insecurity and obscure its global burden. Moreover, these methods all concentrate on measuring the material state of water insecurity, but do not currently extend to evaluating the non-physical dimensions that can also generate or constitute water insecurity. These comprise the underlying economic drivers of water insecurity, cultural meanings and expectations, and the governance of water access and services (Jepson et al. 2017b). These issues are widely addressed within existing literature, yet are seldom linked to methodological approaches for assessing insecurity in practice (Jepson 2014). It is to this lacuna that we now turn.

Developing Methods for Assessing Relational Dimensions of Household Water Insecurity

Recent research on household water insecurity suggests that conventional approaches are inadequate to capture core dimensions of the experience of water insecurity (Linton and Budds 2014, Yates et al. 2017, Norman 2017). These findings warrant an expanded conceptualization of household water insecurity to include three relational dimensions in addition to traditional measures: entitlements and human capabilities, socio-cultural dynamics, and political institutions and processes that produce water-related inequities (Jepson et al. 2017b). Although these dimensions have long been recognized as relevant (e.g., White et al. 1972), and increasingly are emphasized in the literature more broadly, researchers have been slow to incorporate them into a formal definition and operationalization of household water insecurity. The methods related to this expanded notion is also particularly difficult, in part because these dynamics are difficult to measure, let alone compare across sites. Here we identify three areas in which existing methods can be further developed to advance a broader set of methods with an eye towards these dynamics as crucial to household water insecurity.

Entitlements and Human Capabilities

Methods for studying household water insecurity tend to focus on the ways in which water insecurity impacts a household's economic wealth, with implications for status, function, and wellbeing. This entitlements approach examines how people obtain water through relations that legitimize ownership claims or use rights, through trade, production, labor, inheritance, or transfer (Sen 1981). The human capabilities approach focuses on the broader impacts of water insecurity on human wellbeing (Sen 2001, Jepson et al. 2017b). Existing methods for studying household water insecurity are more developed in the older and better-understood realm of entitlements than in the newer realm of capabilities.

Methods for studying market-based water entitlements are well-developed in economics, public policy, and allied fields. The simplest and most direct way to operationalize market-based entitlements to water is through the household affordability measures as discussed in the

previous section (Hutton 2012, see Davis and Teodoro 2014 for an extensive review). Anand (2010) has long shown leadership in methodological work on water and entitlements, demonstrating how economic methods, such as water expenditures analysis (Anand 2001) and multiple choice contingent valuation (Anand and Perman 1999), can help scholars understand the adequacy of water acquired at the household level. As Mehta (2006) explains, however, market-based approaches to entitlements must go beyond affordability to address broader market dynamics including issues of governmental involvement, development policies, and market exclusion. In an analysis of peri-urban water insecurity, for example, Mehta et al (2014) demonstrate how it is water related market dynamics are shaped by elitist policies, resource capture, and environmental injustices. Such work points to the necessity of including non-market dynamics, even within the analysis of the role water markets play in shaping household water insecurity.

Entitlements need not be limited to market exchanges and may include gifts, reciprocity, self-provision, and other kinds of transfers (Mehta 2014). Methods for measuring non-market entitlements are less developed than for marked-based entitlements. Nevertheless, well-established methods can be used to research a household's non-market and hybrid entitlements to water. Participant observation and semi-structured interviews are commonly used to discover and describe local forms of water acquisition, as in the role of *yapa* (bonus gift) in Bolivia's informal water markets (Wutich et al. 2016). Observation, diary methods, and structured recall can be used to systematically assess how much water is obtained through a single or complex combination of non-market water entitlements, as in Eichelberger's (2010, 2017) use of participant observation and direct observation to discover reciprocal and community forms of water acquisition in Alaskan villages. Others have suggested a social capital framework for improving access to water and sanitation, as well as water-related knowledge, attitudes, and practices (Bisung and Elliott 2014, Bisung, Elliott et al. 2014). Yet more robust methods are needed for systematic, comparative research relevant to the many research contexts in which non-market entitlements play an important role in household water insecurity dynamics. First, there is a need for a comprehensive analytic framework for cross-cultural identification and assessment of non-market water based entitlements. Beyond this, there is a need for standard or comparable toolkit of methods for measuring non-market entitlements to water that can be widely adopted across research contexts.

The entitlements approach, while broader than the affordability approach in that it can more easily accommodate non-market exchanges, is still fundamentally an economic approach that may exclude important social and psychological dimensions of household water insecurity. The capabilities approach offers a potential alternative for addressing this critique. According to Goldin (2013: 315), there are ten dimensions of human capabilities relevant to the water sector: health and basic goods, education and literacy, basic mental and physical capabilities, self-respect and aspiration, autonomy and self-determination, awareness, understanding, significant relations with others, participation in social life, and accomplishment. Existing methods for assessing the opportunity costs of disruptions to water access, e.g. school attendance (Cooper-Vince et al. forthcoming) or labor market participation (Sorenson et al. 2011), provide a proxy measure of the impact of household water insecurity on literacy/education and autonomy/accomplishment. Some newer metrics attempt to account for opportunity costs by measuring water affordability relative to other essential household costs and disposable income, or expressing water costs as hours of low-wage labor value (Davis & Teodoro 2014). Existing health and physical impact measures can also be leveraged to understand some dimensions of health and mental/physical impacts (Jepson et al. 2017a), though the link between capabilities and mental health and prevent health-related activities (e.g. healthy infant feeding, Young et al. 2011) remains under-examined. Beyond this, the link between household water insecurity (HWI) and other dimensions of capabilities (e.g., awareness, understanding) remain largely unexamined and unoperationalized. The challenge for future research is to design a more

comprehensive methodological approach that assesses the human capabilities that are explicitly linked to household water insecurity.

Title: Advancing methods for assessing entitlements and capabilities as dimensions of household water insecurity

Concept	**Market-based entitlements**	**Non-market entitlements**	**Human capabilities**
Area of HWI	Entitlement	Entitlement	Capabilities
Common methods	Economic methods, such as those discussed in "Water Affordability" section	Acquisition data, recorded using observational & interview methods; Descriptive and statistical analysis	Measures of HWI impacts on health and basic goods; education and literacy; mental and physical capabilities
Purpose or use of common methods	Is used, though data limitations often lead to measurement at higher levels of aggregation.	Describes and quantifies non-market water acquisition (e.g., reciprocal exchange & common-pool institutions)	Quantifies 3 aspects of capabilities (health, education, mental/physical) in cross-cultural context
Is the household (HH) typically the unit of analysis?	Yes. Also common at higher levels.	Yes, typically the household head reports on HH data.	Individual or household. Data can be aggregated to HH.
Recommended HWI approaches & methods that need further development	Broader assessments of the monetary cost of water, including opportunity costs and physical risks	Better conceptual definition of the range of non-market exchanges used to acquire water	Conceptual definition & measures to assess less-documented and poorly-understood dimensions of HWI impacts on capabilities
Why new approaches or methods are needed	To estimate more accurately the economic cost of water and how it contributes to HWI	To develop a valid & comprehensive framework for categorizing or quantifying non-market water exchanges	To assess the other dimensions of HWI & capabilities in ways that are valid for cross-cultural contexts & comparisons

Social and Cultural Dynamics

Social and cultural dynamics are crucial for understanding household water insecurity. Socio-cultural factors include the social and power structures that shape household water insecurity, the values and symbolism attributed to it, and how all of these impact lived experiences. Methods for understanding these phenomena at the social or cultural level are well-established, but vary in terms of their applicability and adaptability to understanding household-level variance. As well, issues of cross-cultural and multi-sited comparability remain difficult, given the empirically based, context rich, and ethnographic orientation of much of this work.

Social and power structures contribute to household water insecurity and exacerbate its consequences. For example, a social processes (gender), cross cut with additional dynamics and differences (race, class, caste, education, religion, rurality) and can impact choices individuals and households have with regard to access, participation and acceptable use. Political ecological research on social and power structures typically uses qualitative data (obtained from archives, interviews, observations) with critical discourse analysis to expose the nature and implications of power relations, vested interests, and dominant discourses (e.g., Boelens and Seemann 2014, Eichelberger 2014, Mehta 2014, Loftus 2015, Zwarteveen 2015, Staddon et al 2012, O'Reilly 2006, Harris 2005). Such research addresses multiple scales, from individual to society, and can offer insight into household-level dynamics, as well as issues of health intertwined with the social and cultural dimensions of water insecurity (e.g. Eichelberger 2016, Manderson and Huang 2005, Whiteford and Cortez-Lara 2005). More recently, the hydrosocial cycle approach (Linton and Budds 2014) builds on this scholarship and has the potential to incorporate household-level analysis into dynamic and critical longitudinal analyses of water insecurity. Both political ecological and hydrosocial cycle approaches excel at integrating households into multi-scalar analyses of water insecurity, but new concepts and methods more focused on household-level dynamics are needed. Such new methods could enable researchers, for instance, to assess longitudinally how households move in and out of water (in)security, depending on how each household's unique profile of individuals interfaces with powerful social groups, dominant discourses, and complex ecosystem dynamics. As well, there is little in the way of tracking or identifying unique or shared dynamics or attributes that might be important to characterize household water insecurity in diverse times and places.

Research on lived experiences of household water insecurity largely describe, track, and explain impacts on household (and individual) wellbeing. Drawing on local foundational work (typically based on participant observation, interviews, and/or focus groups), researchers identify core themes in lived experiences of household water insecurity, such as lack of funds or time to obtain water, constrained food and drink availability, poor hygiene, and health impacts. Researchers then develop and test survey items to assess household heads' reports on experiences of water insecurity. Ethnographic methods (including participant observation and surveys) have yielded case studies that describe the intersecting factors shaping the lived experiences of water insecurity, water-related health concerns, household coping mechanisms to insecurity, and cultural roles and knowledges involved in water insecurity at individual, household and community levels (e.g. Eichelberger 2016, 2017, Ennis-McMillan 2001, Ferguson 2005). Using scaling methods, such as Guttman scaling or split-half reliability tests (Jepson et al. 2017a), these efforts have yielded a number of locally-adapted household water insecurity scales for research in Kenya (Boateng et al. 2017), Uganda (Tsai et al. 2016), Ethiopia (Stevenson et al. 2016, 2012), Nepal (Aihara et al. 2015), the United States (Jepson 2014), the Philippines (Mason 2012), and Bolivia (Hadley and Wutich 2009, Wutich and Ragsdale 2008). While these scales are well-suited for assessing within-group and longitudinal variation in household water insecurity using parametric statistical tests (e.g., t-tests, OLS regression), most have limited applicability for cross-cultural and cross-site (e.g., urban/rural) research (Jepson et al 2017a). Future efforts should focus on the development of a broadly-applicable cross-cultural scale for assessing household water insecurity.

Water security research, to date, includes relatively little consideration of sacramental and symbolic meanings of water. Yet the wider literature on water and society demonstrates how important these considerations can be (Strang 2004). For instance, in Hindu societies, water, caste, and purity are inextricable, and as such caste inequality can be reproduced *through* water access or lack of access (O'Reilly and Dhanju 2014). Better understandings of water security can be supported through the valuation of water's symbolic qualities of purity, sustainer of life and livelihood, and representation of the gods. These symbolic meanings may influence water source choices, and how households evaluate the quality of natural drinking

water sources (e.g. Eichelberger 2017). In addition, peoples' material needs may be addressed by, or inflected through, non-material processes or phenomena such as the use of water for symbolic purposes (Staddon and Everard 2017, Norman 2017). One example is the conspicuous consumption of water for landscaping, in which households dedicate enormous water expenditures toward supporting ornamental greenery as a marker of class and status (Larson et al. 2009, 2016; Feldman 2017). Some progress has been made in developing methods to explore cross-cultural disgust, shame, and stigma related to water and hygiene using focus groups and essays (Curtis and Biran 2011), behavioral observation, storytelling, and word elicitation (Curtis et al. 2009) and judgements of visual cues (Curtis et al. 2004); this work could be built upon to yield methods for exploring disgust, shame, and stigma as dimensions of household water insecurity. Yet sacramental and symbolic aspects of water insecurity are enormously complex, and research on household water insecurity would need a range of contributions (foundational conceptual work, new analytic frameworks, new methods for description and measurement) to truly advance understandings of their role in household water insecurity.

Title: Advancing methods for assessing socio-cultural dynamics as dimensions of household water insecurity

Concept	**Social Structure**	**Lived Experience**	**Symbolic/Sacramental**
Area of HWI	Socio-Cultural Dynamics	Socio-Cultural Dynamics	Socio-Cultural Dynamics
Common methods	Archives, Interviews, Participant-Observation	Surveys, Interviews, Participant-Observation	Interviews, Visual Methods, Material Culture, Review of Secondary Data
Purpose or use of common methods	Identify key social structures, assess how they impact people and societies	Ethnographic case studies, survey items & scales to describe, assess, quantify lived experiences of HWI, including health concerns and outcomes	Describe symbolic and sacramental uses of water; Interpret their role in HWI
Is the household (HH) typically the unit of analysis?	No, but HH level effects can be tracked with a variety of methods.	Yes, typically the household head reports on HH data.	No. Data is typically thematic or cultural. Need new methods to disaggregate to HH.
Recommended HWI approaches & methods that need further development	Need clearer methods for research on HWI within hydro-social cycle approach; May be possible to do this by refocusing existing methods	Need more foundational research; Need development & testing of cross-cultural scale(s)	New HWI concepts to include symbolic & sacramental values; Refocus existing methods for cross-cultural description & comparison
Why new methods are needed	To improve inquiry into temporal, spatial, and socio-	To describe & assess lived experiences of HWI	To develop analytic frameworks & research methods to link HWI to

	ecological dynamics	in ways that are valid in cross-cultural contexts & comparisons	symbolic and sacramental uses

Political Institutions and Processes

Political institutions and processes greatly influence the production and distribution of household water security across systems, cities and regions (e.g., Birkenholtz 2013, Meehan 2013). Water governance arrangements can create, sustain, overlook, exacerbate, and/or ameliorate structural injustices that underpin conditions of water insecurity. In most cases, the household is not the focus of research on political institutions and processes, though these processes are vital for understanding household water insecurity (Fam et al. 2015). In this section, we address methods to locate household water security within larger political institutions and processes.

Many efforts to understand water insecurity have focused on large-scale modeling of complex ecological, economic, and political processes (e.g., Vörösmarty et al., 2010; Srinivasan et al., 2013; cf. Grey et al., 2013). The most distal assessments rely on analytical and comparative frameworks being applied to water governance characteristics (Pahl-Wostl et al. 2010, Gober et al. 2016, 2015) and water security indicators (Norman et al, 2013, Collins and Woodley 2013), and often employ modeling approaches such as simulation modeling, system dynamics modeling, qualitative scenario analysis, constructed governance scenarios, and coupled modeling approaches. Spatial analysis and mapping also provide important contextual information within which to understand gaps, challenges, and limitations in provisioning domestic water (Jiménez and Pérez-Foguet 2008). Recent scholarship emphasizes thatwater governance regimes must span multiple scales, including the household-level, given the complex and *dynamic* social and ecological processes that influence water security (e.g., Romero-Lankao et al. 2016, Varady et al. 2016, de Grenade et al. 2016, Lemos et al. 2016). Research in the United States has linked rates of drinking water contamination to the intersections of race, ethnicity, and socioeconomic status across municipal governments (Switzer & Teodoro 2017), and to governance of American Indian lands (Teodoro, Haider & Switzer 2016). These approaches can help provide an institutional context in which domestic water is provided to households; though they may aggregate household-level data, they are rarely used to disaggregate data at the household level. To advance our understanding of household water insecurity, there is a need for such models to be interpretable at the household level and to examine at how large-scale institutions foster or frustrate, and engage or alienate households in the governance of their water. Q-Methodology is a relative simple quantitative technique (a factor analysis of interview data) that enables researchers to systematically determine different perspectives among key actors involved in water and natural resource management (Eden et al. 2005, Vugteveen et al. 2010, Lynch et al. 2014), and may help elucidate the links between larger institutions and household-level impacts.

The water security concept is, in many ways, tied to legal processes that seek to secure a right to water (Cook and Bakker 2012). As a result, legal analysis plays an important role in understanding how water security is defined, where a right to water security exists, and how this plays out at the household level (Wouters 2005, Bluemel 2005, Gerlak and Wilder 2012). In addition, a large body of research aligned with the Institutional Analysis and Development Framework has developed methods for identifying the rules and norms that govern rights to environmental resources, often as they pertain to water, in the context of irrigation systems, and at the household level (Ostrom 2005, Poteete et al. 2010). In this context, agent-based modeling has emerged as a potentially fruitful method for understanding how ecological contexts, institutional rules and individual decision-making can produce household water insecurity (Srinivasan et al. 2017). Cultural consensus analysis, a factor analysis of shared

agreement on cultural knowledge and norms, is another emerging method that can be applied to analyses of household water insecurity. This method can measure the strength of agreement about how norms impact household and individual outcomes (Weller 2007). Cultural consensus analysis has been applied to water institutions at higher levels of analysis (e.g., Stone-Jovicich et al. 2011) but has not yet been applied in research on household water insecurity.

Beyond legal protections and institutional norms, informal processes can play an important role in shaping household water insecurity. Ethnographic research and interpretative analysis are common in the study of intermediaries in the water system, who are positioned in-between other actors, institutions, processes, or interests in the waterscape (Björkman 2015). For example, ethnographic study of intermediaries dominates research on informal or alternative water providers, as the coexistence of different socio-technical water provisioning systems is often more efficient at satisfying demand than planners or policy makers admit (e.g., Meehan 2014). Critical approaches to the study of water governance often employ interpretive or narrative analyses based on qualitative data such as semi-structured interviews or policy documents (Pearson and Muchunguzi 2011). Participatory methodologies allow researchers to tease out complex dynamics of water governance regimes and implications for domestic water service provision that are not readily captured in traditional assessments or indicators. More importantly, participatory research offers alternative modes to study domestic water service from the perspective of water users (Sultana 2007, Margerum and Robinson 2015). Ethnographic and participatory research methods extend to household and water-user participation and inform our understanding of household water insecurity and notions of citizenship and water users as political agents (O'Reilly and Dhanju 2012, Morinville and Harris 2014, Loftus 2011, Vandewalle and Jepson 2016). Social network analysis can leverage ethnographic and structured data (survey or observational) to analyze informal water governance structures (Cutts et al. 2015) as well as informal flows of resources, influence & knowledge (Borgatti et al. 2016). The application of social network analysis to household water insecurity research could improve precision and prediction in the analysis of political processes, non-monetary negotiations, and intermediaries that impact households.

Title: Advancing methods for assessing political institutions and processes as dimensions of household water insecurity

Concept	**Water governance**	**Laws & Institutions**	**Informal Processes**
Area of HWI	Political Institutions & Processes	Political Institutions & Processes	Political Institutions & Processes
Common methods	Complex systems modeling; Spatial analysis	Methods aligned with Institutional Analysis & Development Framework; Legal & institutional analysis	Ethnography, Interviews; Narrative, Interpretive & Critical Analysis; Participatory methods
Purpose or use of common methods	Examine different water governance regimes & complex systems; Understand & predict water security dynamics	Determine how formal laws & institutions contribute to or mitigate HWI	Determine how informal rules or intermediaries contribute to or mitigate HWI
Is the household (HH) typically the unit of analysis?	No. Data is typically at higher scales. Some methods can	No, but HH level effects can be tracked with a variety	No, but HH effects can be assessed; May need new

	disaggregate to HH.	of methods.	methods to improve HH measures.
Recommended HWI approaches & methods that need further development	Q-Methodology	Agent-based modeling, Cultural Consensus Analysis	Social Network Analysis
Why new approaches or methods are needed	To systematically track perspectives among key governance actors; Need to disaggregate to HH level	To produces data on hard-to-document norms and shared knowledge; Need to disaggregate to HH level	To improve precision on analysis of informal flows of resources, influence & knowledge; Need to disaggregate at HH level

Discussion and Conclusion

This paper critically evaluates existing methods for assessing household water insecurity and provides guidance on further methodological development needed to advance a broader and more holistic definition of household water insecurity. Existing methods focus largely on assessing the state of household water insecurity in terms of water quality, quantity or adequacy, source or reliability, and affordability. These methods have significant advantages in terms of their simplicity and comparability, but are widely recognized to oversimplify and underestimate the global burden of household water insecurity and its causes (e.g., Satterthwaite 2016). In contrast, a broader definition of household water insecurity should include entitlements and human capabilities, socio-cultural dynamics, and political institutions and processes that produce water-related inequities. A major future challenge will be to develop methods and metrics that can be widely adopted across cultural, geographic, and demographic contexts.

Households comprise diverse individuals, and are nested within communities and societies. The implications of this are that the 'household' is not necessarily a unit at which analysis should remain fixed. Rather, households are governed by societal norms and state policies and located within broader ecological processes; thus, any holistic analysis of household water insecurity implies a consideration of multi-scalar processes. But a more granular analysis of intra-household difference, as well as broader structural analysis of the factors that shape household differentiation and experiences of water insecurity, remain central to 'household' level analysis of water insecurity. Water maintenance, upgrades, water quality monitoring schemes, and infrastructure may relate to the levels of political freedoms and engagement, and the self-determination of individuals, households and wider communities. These societal features and governance structures often reflect existing socioeconomic, ethnic and gender inequalities, whereby some groups are advantaged while others are excluded. Therefore, we recommend that future research strive to locate the household within a multi-scalar approach, employing methods that enable us to attend to subjectivities, experiences, culture, and the wider politics and governance that shape water access, as central to research into the causes and effects of water insecurity that become manifest at the household level.

While our focus in this paper has been on socio-economic, cultural, and political dynamics, we also recognize the crucial role that ecosystem dynamics play in shaping household water insecurity. Recent scholarship has made important progress in advancing our understanding of water insecurity as emerging from multiscalar ecological and political-economic processes (e.g. Romero-Lankao et al. 2016, Varady et al. 2016, de Grenade et al. 2016, Lemos et al. 2016). Scholars have described how climate change and seasonal environmental factors affect household water security, as well as related coping mechanisms and cultural dimensions (Eichelberger 2017; Pearson, Mayer, and Bradley 2015; Pearson,

Zwickle et al. 2016; Wutich and Ragsdale 2008). Yet there remains a need for more conceptual work that unpacks ecological dynamics as a component of household water insecurity. Such studies would enable researchers to develop methods that are capable of assessing ecological dynamics of water security at the household level. Newer conceptual frameworks that encompass complex, multiscalar socio-ecologoical dynamics, such as the sociohydrology (Srinivasan et al. 2017) and the hydrosocial cycle (Linton and Budds 2014), may offer the best ways forward to develop such work.

The challenges of defining and measuring household water insecurity in a contextualized yet cross-culturally relevant way remain substantial. We aim to meet this challenge with multidisciplinary debate and a systemic perspective, as divergent operational concepts and measures impede cross-study comparisons. Traditional metrics do not fully reflect the unique socio-hydrological conditions or historical marginalization that produce water insecurity. However, we argue that adopting a more holistic conceptualization of water security, accompanied by an expanded toolbox of methods that includes a wider array of qualitative methods, will enable researchers to advancing methods to assess and to measure the drivers, nature, and impacts of household water insecurity.

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