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Frontiers of household water insecurity metrics: severity, adaptation and resilience

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ABSTRACT

The measurement of household-level and individual-level water insecurity has accelerated over the past 5 years through innovation and dissemination of new survey-based experiential psychometric scales modelled after food insecurity scales. These measures offer needed insight into the relative frequency of various dimensions of water problems experienced by households or individuals. But they currently tell us nothing about the severity of these experiences, mitigating behaviours (ie, adaptation) or the effectiveness of water-related behaviours (ie, resilience). Given the magnitude of the global challenge to provide water security for all, we propose a low-cost, theoretically grounded modification to common water insecurity metrics in order to capture information about severity, adaptation and resilience. We also discuss ongoing challenges in cost-effective measurement related to multidimensionality, water affordability and perception of water quality for maximising the impact and sustainability of water supply interventions. The next generation of water insecurity metrics promises better monitoring and evaluation tools—particularly in the context of rapid global environmental change—once scale reliability across diverse contexts is better characterised.

SUMMARY BOX

- ⇒ The current generation of household-scale and individual-scale water insecurity metrics are helpful screeners that provide increased resolution of how local communities around the world experience water insecurity, but with limitations.
- ⇒ Next-generation water insecurity metrics should incorporate assessments of severity, adaptation and resilience to inform targeted water supply interventions. We propose an adapted household/individual water insecurity survey module, with multiple scoring options, to measure these dimensions.
- ⇒ We suggest shorter participant recall periods, such as 4 weeks, in local settings with dynamic changes in water availability and use, and avoidance of binary classifications of water security.
- ⇒ This analysis identifies additional considerations for future developments in water insecurity metrics, such as multidimensionality, affordability and perceptions of water quality.

INTRODUCTION

Recent innovation around measuring household-level water insecurity has filled an important gap.[1] Previously, water insecurity was primarily measured at national or regional scales and tended to focus on water volumes or other physical, hydrological conditions.[2 3] The innovation around household-level scales, particularly those that capture people's water-related experiences, reflects a needed shift toward a human-centred approach that is better aligned with human capabilities and activities.[4]

Most currently used household water insecurity metrics are scales constructed from a series of short survey questions that assess perceived components of water insecurity such as access, affordability, quality or quantity.[2] Early versions of experience-focused scales tended to be tailored to particular settings, and could thus capture the effects of water insecurity in ways that take into account local language and cultural contexts.[5–8]

The Household Water Insecurity Experiences (HWISE) scale was created as the first cross-culturally validated household-level scale through a concerted effort to develop an experiential scale that could be used across water-insecure contexts.[9] Candidate survey items were collected at 27 different locations, and scale development led to a final set of 12 items that comprise the original HWISE scale. These items were derived from 11 sites and capture household-level disruptions related to water availability, consumption, personal hygiene and psychosocial distress using a 4-week recall period. The HWISE scale was intended as a rapid screener of household- and community-level water insecurity and as a potential monitoring and evaluation tool, and it was eventually adapted into a 4-item short form version.[10] In multisite studies, variations

of the 12-item HWISE scale have been associated, as hypothesised, with measures of food insecurity,[11] mental health,[12] water expenditures,[13] interpersonal conflict[14] and water borrowing.[15]

The HWISE scale was subsequently adapted into an *individual* water insecurity experiences (IWISE) scale[16] and 4-item short form[17] to facilitate rapid water insecurity screening in other health and development surveys. The IWISE scale recognises that individuals are best able to characterise their own experiences, and that household-level metrics can obscure intrahousehold variation in water insecurity related to age, gender, household responsibilities and other sociodemographics.[4 16] The IWISE scale thus lends itself to measuring intrahousehold water dynamics by surveying multiple household members to understand within-household differences in the impacts of water insecurity, a potentially important innovation for both research and intervention. But this is not how it has been implemented to date. Rather, it has been deployed in more global settings than any other water metric due to its inclusion in the 2020 Gallup World Poll in 31 countries, a national-level sample of individuals who were not nested in households.[16] This deployment—intended to generate national estimates of water insecurity—made two important compromises.

First, this cross-national implementation of the IWISE scale used a recall period of 12 months with items scored from 0 to 3 as never (0); 1–2 months (1); some, not all, months (2); or almost every month (3). This diverges from the 4-week recall period of the original HWISE scale. This change mirrored the standard recall period of other measures in the Gallup World Poll,[16] and was suggested by the scale developers to better capture the impacts of seasonal variation in precipitation and temperature on water access.[17]

But the temporal aggregation of experiences over 12 months ignores evidence about how water insecurity experiences can fluctuate as frequently as daily due to seasonality, water system intermittency and social factors.[18–21] This effectively decreases the resolution of water insecurity measurement and introduces significant interpretative limitations. HWISE/IWISE scale data collected using a 4-week recall period could potentially be compared within or across seasons. But the 12-month recall period and scoring system can yield similar scores for a set of seasonally acute water problems and a single chronic year-round water problem—situations which beckon very different interventions. Even more problematically, the 12-month recall period ignores a large and well-documented literature showing that recall-based data at long time scales are highly inaccurate, especially for chronic conditions.[22] While some loss of precision and accuracy may be acceptable for the purposes of informal stakeholder monitoring, it poses significant challenges to valid research.

Second, recent IWISE implementations have classified individuals as water insecure if their IWISE score was 12 or higher on the scale ranging from 0 to 36.[23 24] This cut-off score of 12 was generated using data-driven approaches during the original HWISE scale validation[9] and effectively reduces the complex experience of water insecurity to a binary attribute. The IWISE methodology thus classifies an individual who experiences 11 of the 12 IWISE items during 1–2 months a year—or any other configuration that produces an IWISE score of 11— as water secure.

This is inconsistent with one of the most commonly cited notions of water insecurity, that is, that approximately two-thirds of the global population experience severe water scarcity at least 1 month of the year.[25] Such a reductive view of water insecurity is also inconsistent with a broad literature that theorises household-level and individual-level water insecurity as comprising many interconnected experiences that are best conceptualised as a matter of degree.[1 26] But we suggest that this use of a binary cut-off point, especially at a national level, may also be harmful in more serious and systemic ways. It can easily render less visible—or even invisible—the experiences of non-majority groups who are already more likely to be water insecure, and in ways that can perpetuate or even create new water, sanitation and/or hygiene (WASH) stigmas.[27] The use of a cut-off point to interpret the HWISE or IWISE scale is thus problematic because it very easily fundamentally distorts the interpretation of water insecurity. That is, a respondent's best estimation of whether a single IWISE item was experienced during 2 versus 3 months over the prior year—which manifests as a 1-point difference in scoring—can ultimately determine whether an individual (or the demographic segment that they represent) is classified as water insecure or secure.

The reconceptualisation of the IWISE scale as a set of annual experiences—combined with little evidence of test–retest reliability, which is essential for a monitoring and evaluation tool[28]—raises other questions about whether these new scale variants inadvertently risk generating what Satterthwaite called 'nonsense statistics' (in that case, in the context of the Millennium Development Goals)[29] that are difficult to meaningfully interpret or use in scientific terms. As scientists, it is critical that we acknowledge the limitations and even dangers of these increasingly popular tools. We need to envision and develop a next generation of water insecurity metrics that reflects the complexity and variance of water insecurity experiences (including embedded inequalities) and provides refined tools to further examine the causes and consequences of such experiences scientifically.

So, how can we extend these water insecurity tools to provide richer information about the types of water system improvements that would make the biggest impact at household and individual scales? To this end, next we

identify three core aspects of water insecurity—severity, adaptation and resilience—that should be prioritised for future assessment as new monitoring, evaluation, and scientific tools across diverse contexts.

MEASURING WATER INSECURITY IN A CHANGING WORLD

There is increasing interest in the resilience of WASH systems in the context of climate change adaptation.[30] The ongoing expansion of access to safe water (and sanitation) in the post-Sustainable Development Goal era will be—and arguably already is—complicated by dynamic spatiotemporal changes in water availability as the global population approaches 10 billion people in a world increasingly defined and disrupted by social and economic inequality, extreme weather events and geopolitical instability.[31] Given these anticipated challenges, the world's ability to efficiently allocate water to those most in need will depend on understanding human needs in even greater resolution than current water insecurity measures provide. Knowing who is *experiencing* water disruptions will not be enough. Rather, WASH scholars and practitioners need to understand the salience and nature of water insecurity given the many forms it can take and the differential harms it accrues to individuals, households or communities. We thus propose reconceptualising both household and individual water insecurity measurement to focus on: (1) the *severity* of those experiences, (2) *adaptation* strategies (ie, what people do) that modulate the severity of those experiences and (3) the *resilience* to water insecurity gained from (ie, the effectiveness of) those adaptation strategies. Table 1 summarises each of these three characteristics and sample outcomes (perceived and objective) that water insecurity researchers might strive to measure. By understanding how communities navigate severity, adaptation and resilience, we can work together to design interventions that mitigate and build resilience to the water-related experiences that residents perceive to be the most disruptive. After describing our rationale and recommended approach to measuring severity, adaptation and resilience, we continue by explaining how water insecurity's inherent multidimensionality presents ongoing measurement challenges for constructs such as water affordability and local perceptions of water quality.

Severity of water insecurity

Frequency continues to be a generally accepted measure of resource insecurity, owing to commonly used food insecurity metrics such as the Household Food Insecurity Access Scale or the Food Insecurity Experience Scale. In such approaches, the severity of an item is assumed to be inversely related to experiential frequency within a population.[32] But

Table 1 Definitions and potential outcomes of severity, adaptation and resilience behaviours associated with water insecurity experiences

Characteristic	Definition	Perception-based outcomes	Objective outcomes
Severity	The degree of disruptiveness of a water problem as perceived by an individual or household	► Rank ordering of how disruptive someone perceives a set of water insecurity experiences ► Relative willingness to pay for the elimination of different water insecurity experiences	► Changes in physical health status (eg, illness or injury frequency or severity) associated with severity of a water insecurity experience ► Change in mental health status, measured as blood pressure, cortisol or other biomarkers, when thinking about different water insecurity experiences
Adaptation	The coping behaviours undertaken to mitigate the effects of a particular water problem	► Behaviours that someone perceives to minimise the frequency or severity of a particular experience ► Satisfaction or improved mood associated with an adaptive strategy due to perceived autonomy over the situation ► Frustration or increased anxiety from an adaptive strategy that requires other trade-offs in resources, time, etc.	► Changes in the frequency or severity of a water insecurity experience associated with an adaptive strategy ► Change in mental health status, measured as an increase or decrease in blood pressure, cortisol, or other biomarkers, when thinking about different adaptive strategies
Resilience	The effectiveness of a behaviour in mitigating exposure to, or the future severity of, a water problem	► Perceived benefit (health, economic, social, etc) accrued from an adaptive strategy ► Frustration or increased anxiety from an adaptive strategy that is not perceived to be helping ► Perceived compulsion to continue a behaviour, regardless of its effectiveness, due to group norms	► Changes in physical health status (eg, illness or injury frequency or severity) associated with an adaptive strategy ► Change in mental health status, measured as blood pressure, cortisol or other biomarkers, when thinking about the effectiveness of different adaptive strategies

Table 2 Proposed HWISE/IWISE scale module to capture severity, adaptation and resilience behaviours associated with water insecurity experiences using the original 4-week recall period

PROMPT: Next, I want to ask you about different issues related to water that you may have experienced in the past 4 weeks.				
	Quantitative items		Qualitative items (short response)	
Scale item	Experience item and scoring	Severity item and scoring	Adaptation item	Resilience item
Worry	In the past 4 weeks, how often did you worry you would not have enough water for all of your needs? Never (0 times) (0) Rarely (1–2 times) (1) Sometimes (3–10 times) (2) Often (more than 10 times) (3) Don't know (98) Missing (99)	When this happened, how disruptive was it in your daily life? Not at all (1) Somewhat disruptive (2) Very disruptive (3)	When this happened, what did you do differently, if anything, and how did it help? *Enumerator training should emphasise discerning between buffering behaviours (adaptation) vs negative externalities (maladaptation)*	Will this action reduce the likelihood of worrying about water in the future, and why? *Enumerator training should emphasise discerning between perceptions of resilience vs vulnerability*
Repeat for remaining scale items				

there is no compelling empirical evidence for this relationship. Residents facing water insecurity likely perceive water-related disruptions along a spectrum of severity related to the salience of the disruption, available adaptation strategies (and adaptive capacity, generally speaking) and their resilience to the disruption.

Very few studies have assessed the severity of specific water insecurity dimensions (eg, affordability, water quality experiences, shame, etc), which refers to how disruptive an experience is perceived to be. During development of the HWISE scale, each item's relative severity was classified using Rasch analysis,[9] but the data-driven approach to justify the assumption of severity was not fully supported by theoretical and empirical scholarship. Tesfaye and colleagues examined perceptions of water insecurity severity among women in rural Amhara, Ethiopia.[33] They found that mean subjective severity tended to be high for most items and was not correlated with experiential frequency or the household's summary water insecurity score, although some items deemed more severe tended to occur less frequently. Perceptions of severity also differed geographically across kebeles.

Following Tesfaye's approach, the perception and experience of severity may be defined for each domain of water insecurity by other critical experiences as they relate to cultural concepts of disruption. The simplest approach is to ask a follow-up question about the severity of each disruption. Table 2 presents a sample module where the HWISE or IWISE scale is implemented using a 4-week recall period (replicating the original HWISE scale protocol) with a follow-up severity rating that quickly assesses whether each of the 12 items was *not at all*, *somewhat* or *very* disruptive to the respondent.

The severity ratings can potentially be used to rescore the HWISE/IWISE scale in different ways. The severity rating can be used to reweight the corresponding experiential frequency score for each scale item using a weight of 1 for a severity level of *not at all* disruptive, 2 for *somewhat* and 3 for *very*. The additive version of this method expands the range of the HWISE/IWISE scale from 0–36 to 0–72, while the multiplicative version would yield a range of 0–108. Alternatively, other scoring methods might only incorporate scale items rated *somewhat* or *very* disruptive, or perhaps substitute the sum of the severity scores for all affirmed HWISE/IWISE experiences for the original score if it were demonstrated to be more strongly associated with health and wellness outcomes. The modest addition of a severity item thus offers considerable opportunity for refining the HWISE and IWISE scales. But as already noted, there is much more for researchers and practitioners to learn about human responses to disruption.

Adaptation to water insecurity

Contemporary household water insecurity measures also do not provide any information about how households or individuals *have* adapted, are *currently* adapting and are *planning* to adapt to their experience of water insecurity. Adaptation to water insecurity may consist of behaviours enacted to mitigate a given water insecurity shock, or to maintain the household's water supply or access, and is common in settings with frequent disruptions.[34] Adaptive capacity, and the limitations households face in enacting adaptive responses to achieve water insecurity, may differ by setting.[35]

In the same way that we conceptualise weighting water insecurity experiences by their severity, we must recognise that severity itself is mediated by household adaptation to the perceived severity of an experience and adjust our measures accordingly. Table 2 presents an example of how researchers or monitoring and evaluation specialists can operationalise adaptation by adding a short qualitative item to the HWISE or IWISE scales: *When this happened, what did you do differently, if anything and how did it help*? This kind of qualitative survey item can help researchers rapidly identify and code adaptation strategies, as well as their perceived effectiveness in mitigating each form of water disruption. The notion of perceived effectiveness is important because

it could reveal forms of maladaptation. Water-related behaviour changes could induce negative externalities regarding another physical resource, such as sacrificing food or energy,[36] or social relations, such as anxiety from borrowing water[12] or implementing a socially expected behaviour that the individual does not view as beneficial, such as growing and consuming less water-intensive—but less nutritious—foods.[37]

Adaptation behaviours, and their perceived effectiveness, could also be integrated into the HWISE/IWISE scoring for each water insecurity experience, thus extending these scales' utility to assess water insecurity changes over time due to interventions. Such use of the HWISE scale was piloted in a point-of-use filtration trial in rural North Carolina.[38] The presence of reported adaptation or maladaptation behaviours could be quantified as an additional adjustment to the item score, severity score, or sum or product of the item and severity score. There is, of course, the possibility of diminishing returns from each additional refinement to the scale. Perhaps the greatest value of soliciting individual adaptation behaviours would be providing insights about the WASH needs of residents from specific demographic, geographic or social profiles, and how WASH interventions and other anti-poverty initiatives can be adapted to address them.

Resilience to water insecurity

Adaptive management and adaptive capacity represent responses that can build resilience to the unpredictability of water insecurity. The literature is at an early stage of development in understanding the process of water insecurity resilience-building at the household level to disasters,[39 40] or how institutional actors may shape household adaptive capacity and resilience.[41 42] In practice, institutional or structural support may sometimes be needed to fully deploy or unlock adaptive capacities, and, therefore, stakeholders such as government agencies and non-profit groups must work synergistically to avoid undermining their resilience-building efforts.[43] But little is known about how these processes are related to current household water insecurity measures.

Just as we can measure how individuals adapt to water problems of varying severity, we can recognise that adaptation strategies may present an additional burden if the behaviour does not build resilience to future water disruption. Table 2 presents an example of how to operationalise resilience by adding another short qualitative item to the HWISE or IWISE scales: *Will this action reduce the likelihood of [insert IWISE item, for example, worrying about water] in the future, and why*? Again, we can adjust each HWISE or IWISE item score, but real value in resilience data is understanding how residents are improving their own water security, and how interventions can either facilitate these norms and behaviours, or remove obstacles or mitigate other limiting factors. Resilience-building is likely to be deeply localised, drawing on social, environmental and cultural contexts.[44] These practices may offer insights for participatory WASH interventions by leveraging local preferences and agency in developing new infrastructure, financing models, or governance systems.

Other considerations: multidimensionality, affordability, and perceptions of quality

In addition to severity, adaptation and resilience, the next generation of water insecurity metrics might consider additional factors that can help inform the type of water intervention or infrastructure that would yield the biggest impact. One consideration is the pursuit of unidimensional measures. Unidimensional psychometric scales that represent single constructs, such as the HWISE scale, are widely used in the social sciences due to their elegance and parsimony in implementation and explanation. A downside of reducing complex, multidimensional phenomena to a unidimensional scale is loss of fidelity/richness in the resulting construct. Unidimensional metrics such as the HWISE scale are very easy to use, but they communicate disparities in overall water problems rather than point to one subdimension of water insecurity (hygiene, quality, collection time, anxiety) that can be targeted by water programmes.[45] Well-crafted water modules can provide valuable insights along multiple dimensions, but they also increase the cost of assessment. Either way, we must be cognizant of this trade-off so that unidimensional metrics do not oversimplify practitioners' view of water insecurity and inadvertently reinforce the proliferation of generic water interventions that have historically been prone to failure.[46]

Water affordability is a growing, global problem due to water privatisation and corporatisation,[47] yet can be difficult to incorporate into water insecurity metrics. Water affordability is relative to a household's capacity to ensure any vital service. For example, households may be forced to make welfare-harming trade-offs between water services and other resources to satisfy basic needs and access critical goods and services such as food and energy.[48 49] The global pandemic and economic downturn has exacerbated an affordability crisis that left vulnerable populations facing either water debt or the threat of water service shutoffs, even in high-income countries.[50] Measures that calculate economic costs as a percentage of monthly or annual income, for example, costs exceeding 5% of the community's median household income, can be difficult to measure with precision in communities where residents engage in a mix of formal and informal income-generating activities, and use multiple water sources with different cash and opportunity costs.[51] Even in the USA, there is little consensus on how to measure water affordability.[52] Researchers and policymakers need more creative, holistic measures to address the socioeconomic inequity associated with increasing water costs and inability to pay.[53]

The lack of methods to adequately study people's understandings of water quality limits our predictions of how water quality impacts adaptability and resilience. There are established methods for directly measuring

water quality,[54] including turbidity, salinity, the presence of metals and other contaminants and microbiological contamination. But these water quality metrics can be temporally dynamic, particularly in intermittent systems and expensive to implement, especially in decentralised or multiple water source contexts. In water-insecure communities, there are indications that people intentionally allocate water of different qualities to different activities (eg, using lower quality water for toilet flushing).[55] Willingness-to-pay measures have long been known to capture some water quality perceptions, such as the value people place on higher quality water.[56 57]

However, human perceptions of water quality do not necessarily align well with actual water quality.[58] Beyond this, people can use factors such as branding and prestige as a proxy for water quality,[59] as is often the case with bottled water consumption in weak regulatory regimes.[60] Water quality perceptions may be situational and contingent, such as how people manage the trade-off between potability and taste.[61] New methods are needed to systematically capture how people actually perceive water and make allocation decisions based on perceived water qualities, including the operationalisation of social and moral meanings.[62] Such measures of perceived quality could help improve on-the-ground efficiencies in water allocation and use, especially in communities in which multiple water sources of varying quality are used to improve water resiliency. Both objective and subjective measures of water quality—and especially their relative divergence—can thus be important components of water insecurity measurement and present opportunities for community engagement and health education related to water issues.

CONCLUSION

Household and individual-scale water insecurity metrics have played an important role in highlighting and amplifying discussions around sociobehavioural and non-communicable drivers of water insecurity that hinder human development, and are increasingly being used around the world to inform water provision programmes. But these water insecurity metrics have significant limitations that cap their potential. We propose new, theoretically grounded, easy-to-use measures that can capture the relationships between water insecurity experiences, severity, adaptation and resilience. These measures can better assist water programmes in identifying a community's most urgent types of water disruptions, subsequent (mal)adaptive behaviour changes and the components of resilience (eg, human and social capital) that underpin sustainable water solutions. They will also open new pathways for significant theoretical advances in academic research on water insecurity, including better addressing water inequalities. Other aspects of water insecurity, such as multidimensionality, affordability and perceptions of quality, will be more challenging to measure cost-effectively, but also warrant ongoing efforts to find solutions.

Finally, most applications of household water insecurity scales have addressed individual communities or cities with the intent of providing rich microdata to municipal authorities. Future projects should consider deploying regional-level sampling frames with the intent of providing mesoscale evidence to assist regional stakeholders within or between nations. We hope these research strategies will advance more precise metrics of household water insecurity, help improve item weighting schemes and enable translation into interventions that build resilience to individuals' and households' most severe experiences. Such research programmes would be better-positioned to identify and address intersecting challenges such as food and other resource insecurities, WASH inequities, and roles for community-driven solutions to improve WASH interventions and policy.

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