Measuring 'no-win' waterscapes: Experience-based scales and classification approaches to assess household water security in colonias on the US–Mexico border

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Measuring 'no-win' waterscapes: Experience-based scales and classification approaches to assess household water security in *colonias* on the US–Mexico border

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ABSTRACT

This paper develops a household water security measurement for low-income peri-urban and rural communities ("colonias") on the US–Mexico border. The complexity of a "no-win" waterscape – where water service exists but is relatively expensive and water quality is still precarious – precludes a meaningful assessment and analysis because there are no existing measurement tools to capture water insecurity at the household level. Informed by critical environmental epistemology, the paper incorporates perspectives from colonias residents through qualitative research and survey development. The study advances previous work on water security by developing a cumulative scale for each characteristic of household water security then clusters households into water security classes using a non-parametric statistical procedure. The analysis identified four water security classes: (1) Water Secure; (2) Marginally Water Secure; (3) Marginally Water Insecure; (4) Water Insecure. While all households in the survey are connected to water service, only 45% are broadly "water secure" while 55% are "water insecure." Statistical analysis confirmed the robustness of the scaling and clustering procedure, thus, providing evidence to describe household water insecurity in "no-win" waterscapes.

1. Introduction

Water security increasingly carries currency with development agencies, governments, and water managers, yet problems arise in translating the concept to coherent policy initiatives (Cook and Bakker, 2011; Bakker, 2009, 2012; Norman et al., 2013). For international agencies, water security is the condition when water and sanitation are adequate, reliable, or affordable at all times for the productive capacities of society (UNESCO, 2006; GWP, 2000). Other definitions prioritize individual basic needs (Hope et al., 2012; Islam et al., 2012; Mason, 2012), and some consider water security in terms of water provision for agriculture and industry (Grey and Sadoff, 2007; Lautze and Manthrithilake, 2012) or geopolitical entitlements (Tarlock and Wouters, 2009). Ecological sustainability anchors some definitions of water security (Norman and Bakker, 2010; Scott et al., 2012) while others are anthropocentric in orientation (Wutich and Ragsdale, 2008; Wutich, 2011; Gerlak and Wilder, 2012; Stevenson et al., 2012).

Describing and measuring water security in reliable and valid ways, therefore, have proven to be difficult. Incompatibility and wide-ranging assessment tools derived from multiple definitions further confound the translation of water security goals into policy and governance. This is particularly acute for communities and households living in developed countries, where water security is narrowly defined in terms of watershed environmental sustainability and homeland security. The pervasive myth that all people in developed countries have universal and uniform indoor plumbing and water service overshadows the lived reality of the urban poor, homeless, Native Americans, and economically distressed rural communities who experience gaps in water and sanitation services or lack adequate, affordable, and safe drinking water sources (Brown and Ingram, 1987; Bernstein and Satterwhite, 2005; Mascarenhas, 2007; Wescoat et al., 2002; 2008, 802–803; Mier et al., 2008; Vanderwarker, 2009; Dolhinow, 2010; Patrick, 2011a,b). In the United States, for example, over 600,000 households, or approximately 1.5 million people, live without complete plumbing facilities (ACS, 2012). As Wescoat, Headington, and Theobold observe, the poor in developed countries "do not count among the world's 1.1 billion who lack access to safe drinking water, or 2.4 billion who lack access to improved sanitation" (2008, 802). While there are quantitative data about infrastructure availability at a regional scale, little is known about the complex experience of inadequate or unreliable water services for individual households in these marginalized communities. Moreover, the myth of universal water access in the Global North precludes data collection and assessments of human development-related water security for marginalized populations. Therefore, the purpose of this study is

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to describe, develop, and evaluate a household water security measurement to fill this critical need.

This paper examines household water insecurity in low-income communities ("colonias") along the US–Mexico border. Colonias are impoverished, unincorporated communities or subdivisions populated by Mexican Americans on urban fringes or in rural areas. They are commonly defined by their proximity to the 2000-mile US–Mexico border and are typically characterized by inadequate water and/or sanitation service, lack of electricity, and unpaved roads (Ward, 1999; Esparza and Donelson, 2008; McDonald and Grineski, 2012; Korc and Ford, 2013). Colonias along the Texas–Mexico border, for example, are home to over 400,000 residents in more than 2300 subdivisions (OAG, 2012). The focus of this study is one of the poorest regions in the United States (Lower Rio Grande Valley, LRGV) with the largest concentration of colonias (over 240,000 people) (Jepson 2005; Parcher and Humberson, 2007). In Hidalgo County, the location of this study, 37% of families with children under 18 live below the United States federal poverty level (FPL), and the median household income is almost half of the national median income (ACS, 2012).

The South Texas waterscape is defined by complex hydro-social interactions among institutions, organizations, and technologies that allocate the flow of water across the region and through infrastructure to different water users (Swyngedouw, 1999; Loftus, 2007; Budds, 2008; Kooy and Bakker, 2008; Budds and Hinojosa-Valencia, 2012). This waterscape, dominated by irrigated agricultural interests, offers colonias residents few reliable, affordable, and adequate options for drinking water. Moreover, water access between colonias and within colonias is highly variable. In Hidalgo County, rural and peri-urban water service is generally available through existing networks but not all homes are connected to the system. Disconnected households either cannot afford the hookup, or their homes do not meet the building codes required for connection. If homes are connected, colonias residents face service interruptions due to lack of payment, poor water service reliability, and concerns over tap water quality (Jepson and Lee, forthcoming). Some households fear immigration authorities and public agencies so they avoid water utilities altogether and connect illegally to neighbors' water service with garden hoses. In addition, households, whether connected or not, also depend on water vending machines because of generalized water quality concerns. The complexity of this "no-win" waterscape – where water service exists but is relatively expensive and water quality is precarious – precludes a meaningful assessment and analysis because there are no existing measurement tools to capture the lived reality of water insecurity at the household level.

The paper begins with an overview of the water security literature, critically reviewing existing definitions or frameworks and assessment tools in order to situate the present study of LRGV colonias within a broader academic and policy context. Subsequent sections summarize data collection methods and review the development of a household water security survey instrument. Survey data was used to develop three unique experiential scales (scalograms) related to household water security. Each household was assigned a cumulative score which is then used to classify households resulting in four water security classes: (1) Water Secure; (2) Marginally Water Secure; (3) Marginally Water Insecure; (4) Water Insecure. The paper then addresses the main findings: while households in the survey are connected to water service, only 10% are "water secure" and 35% are "marginally water secure," while 31% are "marginally water insecure" and almost a quarter of households (24%) are "water insecure." The paper concludes with a discussion of the study's limitations and specific contributions to research on water security and environmental justice, underscoring future research and policy directions that may be informed by this work.

2. Water security

Water security is a complex and contested goal-oriented concept. Scholars and policy makers have reviewed and commented on increased interest in water security, underscoring the problem of definition as the term is applied in multiple conceptual domains across spatial scales. Most recently, Cook and Bakker (2011) identified several framings of water security. Based on this work, one can identify four general domains: (1) human development; (2) ecological sustainability; (3) geopolitics and international relations; and (4) vulnerability and risk (Table 1).

2.1. Water security domains

Each conceptual domain is anchored by ontology of "security," a framing that informs both how water security is used and methods by which it is assessed (Table 1). Security ontology, as applied in the existing literature, refers to the emotional sense or state of wellbeing that derives from self-validating certainties that are, at least partially, anchored in the material conditions and life-worlds (Laing, 1962; Giddens, 1991; Hiscock et al., 2001; Goldstein, 2010; Hawkins and Maurer, 2011; Philo, 2011). While a sense of security or threat is intimate, tied to experiences and day-to-day praxis, one can identify other referents that are perceived to be "existentially threatened and that have a legitimate claim to survival" (Saleh, 2011, 239). For geopolitical security, the referent is the nation-state, while in sustainability science the referent is the ecosystem. Acts "to secure," then, are intended to mitigate existential threats either by marshaling collective protection in the traditional sense or increasing human capabilities (Booth, 1991; Sen, 1999; Nussbaum, 2011). Thus, the underlying notion of "security" implies an existential threat, both objective and subjective, and this influences a set of actions, responses, and positions. Therefore, different notions of security orient and inform public policies that increase human or ecosystem functioning or increase protection measures and monitoring.

Water security, as used in the domain of human development, is primarily concerned with water as it affects social reproduction, human health, wellbeing, equity, or other human capabilities. For some this definition of water security is allied with the struggle for water access and the human right to water (Gleick, 1998; Barlow, 2007; Linton, 2010; Mascarenhas, 2012). For others, water security oriented toward human development describes water affordability, adequacy, and quality for a healthy life (UNESCO, 2006; GWP, 2000) and even cultural autonomy (Gelles, 2010; Bus-

Table 1
Water security.

Conceptual domain	Referent	Orientation	Arena of interest
Human development	Self and/or family	Social reproduction; human health and well being	Household
Sustainability	Ecological processes	Ecosystem services; allocation of resources among competing uses	Biophysical
Geopolitics	Nation-state	National security; infrastructure security; production capacities; political stability	Political
Vulnerability and risk	Population	Human health and wellbeing	Regional

tamante et al., 2012). This anthropocentric view contrasts with water security in sustainability science, which defines water security in terms of ecosystem services supporting all forms of life. Water poverty, which can be interpreted as a form of water insecurity, is the lack of water resources for reproductive activities and productive activities (Sullivan, 2002). Sustainability anchors Norman and Bakker's definition of water security, understood as "sustainable access, on a watershed basis, of adequate quantities of water, of acceptable quality, to ensure human and ecosystem health" (2010, ii; Vörösmarty et al., 2010; ; Bogardi et al., 2012). The Asian Development Bank (2013) takes an expansive view of water security to incorporate five interdependent dimensions, including domains such as economic, urban, environmental, resiliency, and domestic.

The term "water security" (or security of water) also implies another domain, that of geopolitics (Zeitoun, 2011; Thapliyal, 2011). The referent for geopolitical approaches to security is the nation-state (or homeland) in relation to the international regimes of economic and political power. In this orientation, water security is understood in terms of "homeland security," inter-state relations and intra-political stability, and the lack of water security may undermine a nation's integrity, stability or competitiveness in the global context (Murray, 2009; Wouters et al., 2009; Wolf, 2011; Scozzari and El Mansouri, 2011). Concerns with water security reflect a larger engagement with vulnerability and risk of water deprivations for populations, possibly induced by climate change or pollution (Patrick, 2011b; Scott et al., 2012).

2.2. Household water security

This paper advances the study of water security for human development, where water security is broadly understood as adequate, reliable, and affordable water for a healthy life. Drawing on Amartya Sen's capabilities theory, water security is based on the notion that gaps in water reliability, quality, and access erode the functioning necessary for basic human existence (Sen, 1999). This definition conveys an understanding that water security is more than access to infrastructure (Obeng-Odoom, 2012). Synthesizing previous work within the appropriate development and human security literatures (Corbett, 1988; Radimer et al., 1990; Frongillo, 1999; Nyong and Kanaroglou, 2001; Busari, 2002; Radimer, 2002; Trevett, 2003; Ahmad, 2003; Lundqvist et al., 2003; Postel, 2003; Coates et al., 2006a,b; Wutich and Ragsdale, 2008; Stevenson et al., 2012; Nanama and Frongillo, 2012; ADB, 2013; Subbaraman et al., 2013), one can identify three dimensions of household water security (HWS):

(1) Water access: the capacity to access water for consumptive purposes, including physical access, affordability, and reliability.
(2) Water quality acceptability: the broad range of biophysical characteristics of water quality (taste, color, smell, biochemical, etc.) that influences water usage and health/well-being.
(3) Water affect: the emotional, cultural, and subjective experiences of water.

An absence or lack of any one of these three dimensions would contribute to water insecurity, although the degree to which would be variable.

Access to improved drinking water sources (piped water, public tap/standpipe, tubewell/borehole, protected well or spring, rainwater collection) is the most common way to define domestic or household water security (UNESCO, 2006; ADB, 2013). The distance to improved water sources also relates to the time and effort individuals expend to access water. Reliability determines access because it describes the extent to which otherwise available water sources and services fail or underperform. Affordability, or the capacity to buy water from improved sources without major financial burden, also contributes to water access. Water affordability is determined as a percentage of monthly income. The range differs among countries and economic or social groups, with conventional affordability ratios (CARs) ranging between 2.5% (United States Environmental Protection Agency, USEPA) and 5% (Asian Development Bank) (Fankhauser and Tepic, 2007). Other measurements exist, taking into account affordability of connection fees (Howard and Bartram, 2003; OECD, 2003; Foster and Yepes, 2006; Gawel et al., 2011; García-Valiñas et al., 2010). For the purposes of this study, water affordability refers to the share of water expenditure that exceeds a certain threshold; this study uses the US EPA standard (2.5%) as a benchmark. Affordability is calculated in terms of monthly cash income, as a large portion of these households receive public benefit yet the use of some funds may not be available for buying water or paying utility bills.

Water quality acceptability reflects the physical and biological quality of water. Determination of water quality includes, but is not limited to, direct water quality testing, taste, color, and odor. Regulatory agencies frequently disregard user perception of water as "aesthetic" because, from their point of view, it is not "actionable" in terms of any regulatory intervention. Yet these characteristics influence household practices. Water quality acceptability informs whether individuals seek alternative sources (and expense) to fill a perceived need.

The working definition of water security in this study includes a third dimension, "water affect." Rather than accept a philosophical division between "affect" or cognitive "perception" (Thien, 2005). The terms interchangeably build on the shared common ground between them to embrace affect as part of an inter-subjective process and the relationality of everyday life (Thien, 2005; Wright, 2012, n. 13; Pile, 2010).

Water affect acknowledges how water is tied to emotional or cultural subjectivities that relate to wellbeing or distress. Emotion and affect shape the human experience within the context of nature–society research and critical development studies (Wutich and Ragsdale, 2008; Dallman et al., 2011; Wright, 2012; Harris et al., 2013). For example, Sultana (2011) examines emotional geographies of water by exploring how inter-subjective "suffering for water" (access to water) and "suffering from water" (related to degraded water quality) influence the everyday negotiations for water from arsenic-contaminated tubewells in Bangladesh. In other work, emotional distress as relate to water access demonstrates the important but frequently overlooked dimension of water security (Wutich and Ragsdale, 2008). Furthermore, there is an ethical justification to include water affect, even perceptions of water quality, into a framework for water security: "to do justice to the experience of poverty, to the struggle, the meaning of experience, the subjectivities of those involved, require attention to what is valued, what is felt and sensed, to the messiness, pain, joy, and hope of experience" (Wright, 2012, 1115).

The unit of analysis for this study is the household. While recognizing debates around the household as a unit of analysis (Folbre, 1986), this study takes into account the household as the key unit of water delivery and the place where most water services are accessed. Households, conceptualized as a water management institution (Harriden, 2012), shape behaviors and decisions relating to water use. Furthermore, household interactions related to water access and use frame relational and behavioral dimensions of socio-environmental problems (O'Reilly, 2011).

Framing household water security in this way allows for the examination of potential interactions among the different dimensions and, thus, provides a fuller picture of water security or water insecurity in low-income communities where water access or quality is compromised. For example, poor drinking water quality (as perceived by householders) may generate negative emotional responses, from anxiety and fear to shame, because water deficiencies fail to conform to social and cultural expectations. But some households may not experience such negative emotional responses to similar conditions of poor water quality because coping strategies (or access to other resources) may compensate and, thus, not transgress social expectations. In other cases, households may avoid poor quality tap water through other means (e.g., regularly buying bottled water, installing illegal hookup to neighbor's tap), yet the time, labor and cost of this response may be a burden and increase stress, fear, or anxiety. In summary, the household water security approach presented in this paper builds on previous studies by acknowledging how subjective perspectives on water relate to objective and subjective wellbeing. The challenge is how to operationalize and measure this multi-dimensional concept.

3. Measuring water security

While only a few measurements explicitly address "water security," each conceptual domain of water security is associated with some type of freshwater measurement or assessment (Table 2). Indicators or measurements provide information to policy makers, communities, and governments so they may define priorities, evaluate the quality of life, improve environmental conditions, and assess process or impacts of existing policies and programs. Indicators allow for the identification of thresholds that can encourage priority setting, monitoring, and enforcement and be compared with other data on social, economic or political phenomena (Dunn and Bakker, 2011; ADB, 2013).

Beyond management or policy needs, quantitative methods informed by qualitative methods enhance the documentation and understanding of experiences many have in everyday life by allowing us to "directly address the mediated objectivity…[and] shed light on embeddedness, the texture of our everyday lives" (Moss, 1995, 447). The uncritical use of numbers or reliance on single measurements is not a substitute for qualitative approaches to social phenomena (Barnes, 2009). Diane Rocheleau warns, any move towards measurement runs the risk of facile quantification derived from standard or institutionalized categorization and technocratic problem definition that further entrenches interests of the powerful (Rocheleau, 1995, 461–462). But quantification can also be leveraged to offer important insights on distribution and pervasiveness of a social phenomenon. Rocheleau remarked, "social change requires evidence for the pervasiveness and distribution of a problem, not just the nature or seriousness of it" (1995, 461–462). Using numbers prevents, as Moss notes, "the individualization of experiences" where one person's account of a singular act or experience is not devalued; rather these experiences can be placed in a larger context of social relations (1995, 447).

3.1. Existing indicators

Several indicators are related to water and human development (Table 2). Previous studies have used single-variable measures, such as census data on household infrastructure (Wescoat et al., 2008) or the basic water requirement (Gleick, 1996). Others developed indices as key indicators of water resource deprivation. Experience-based biocultural measurements of emotional distress related to water security employ a scaling method address the question of individual water security (Wutich and Ragsdale, 2008; Hadley and Wutich, 2009; Wutich, 2009; Mason, 2012; Stevenson et al., 2012). The Asian Development Bank (2013) uses three indices for household water security: (1) access to piped water, (2) improved sanitation, and (3) hygiene. Integrated ecological indicators have offered a holistic view of water security at the watershed, regional or national scales. Most prominent in the literature is the Water Poverty Index (WPI). WPI is an integrated indicator for water management that tries to capture "a more comprehensive picture of the water-management challenge" (Sullivan et al., 2006, 415) by combining weighted averages of five variables (resources, access, capacity, use, and ecological integrity) to be applied at a range of scales (Sullivan, 2002; Feitelson and Chenoweth, 2002; Sullivan et al., 2003, 2006; Sullivan and Meigh, 2003; Komnenic et al., 2013). WPI is designed to assess structural water problems faced by different countries or regions and has been useful in cross-regional and cross-national assessments. Norman et al. (2013) build on this approach in the proposal for a "Water Security Status Indicators" (WSSI) while Chaves and Alipaz (2007) developed a "watershed sustainability index." Geopolitical and vulnerability studies measure and assess water security in terms of water supply either in relation to population, infrastructure, or international tension (Yoffe et al., 2004; Finlayson et al., 2012; Li et al., 2012) while vulnerability assessments of water security frequently link to climate-induced changes in water supply (Campbell and Love, 2008).

Each indicator is limited in its capacity to address "water security." Different definitions and data gaps confound integration of information and transferability of assessment models because of the incommensurability of scales (Gleick et al., 2002, 92–93; Ebert and Welsch, 2004). For example, single measures of water access, water quality, or water infrastructure, whether at the household, watershed, or national level, do not capture the multifaceted nature of water resources development as it relates to water's social functioning. Ecological approaches, which often rely on "natural" or ecological scales, such as watersheds, do not coincide with

Table 2
Water security indicators.

Conceptual domain	Water security indicator	Dimensions	Scale	Citations
Human development	Basic Water Requirement (BWR)	Single	Individual	Gleick (1996)
	Census	Single	Household	Wescoat et al. (2008)
	Water Poverty Index (WPI)	Multiple	Political territory	Korc and Ford (2013)
	Water Security Experiential Scale	Single	Individual	Wutich and Ragsdale (2008)
Sustainability	Water Poverty Index (WPI)	Multiple	Political or ecological territory	Sullivan et al. (2003)
	WSSI	Multiple	Watershed	Norman et al. (2013)
Geopolitics	Water Availability	Single		
Vulnerability and risk adaptation	Infrastructure-based (pollution, chemical, bacteriological, bioterror)	Single	Region	
	Water Availability		Region	Scott et al. (2012)

the appropriate water management scale (Dunn and Bakker, 2011) or household. Data demands of the WPI approach, for example, obscure small-scale variations of water poverty because of data availability and data aggregation (Sullivan et al., 2006, 415). One paper noted that no water index, for example, addressed domestic or household water problems (Feitelson and Chenoweth, 2002, 265).

3.2. Index or scalogram?

There are two approaches useful to review in the context of household water security in colonias on the US–Mexico border: Water Poverty Index (WPI) and cumulative (Guttman) scalogram (Table 2). Korc and Ford (2013) rightly argue that infrastructure information is simplistic and inadequate to describe the complexity of drinking water and sanitation services in border colonias. To fill that gap, they build a colonia-level WPI as a preliminary assessment tool for four colonias in El Paso and Hudspeth counties, Texas. The study offers a means to assess water and sanitation needs across the selected communities.

The use of WPI as a proxy for household water security, however, falls short as a viable measurement for two reasons. First, Korc and Ford's application of the WPI is aggregated at the subdivision, not the household. Any WPI that follows their method loses the capacity to assess variability among households in the same subdivision or geographical unit of study. As field research suggests, there is a great difference among households within the same subdivision, and therefore, the WPI as a proxy measure for water security cannot capture that lived reality at the household level. Second, WPI is limited because it prioritizes managerial application over descriptive validity. The WPI is designed as a prescriptive approach for water managers with the input of "decision-makers" not colonias residents, and it has been explicitly designed "to contribute to more effective water management" in a cost-effective manner (Korc and Ford, 2013, 83). Korc and Ford worked with panel of "stakeholders," including state officials and water managers, to select subcomponents of their index. Yet, the panel did not include colonias residents. As a result, the criteria for selecting variables reflect the managerial orientation of WPI not household-level water experiences.

Another approach to assess water security is to create a scalogram for households. An experiential scalogram allows one to draw inferences about an unobserved latent variable in the observed data (Guttman, 1944; Stouffer et al., 1950; Kronenfeld, 1972; McIver and Carmines, 1981). Guttman scalograms order items or responses such that the individual who positively responded more frequently will have a higher rank than an individual who responded negatively. Therefore, scalograms provide a rigorous means to order items or responses and rank order individuals in relation to those items. The position of the items and individuals are then given a numerical value.

Scalograms offer an advantage because they can assess the cumulative or progressive experiences of household water security. Hadley and Wutich (2009) argue that experience-based measurements capture bio-cultural dimensions (psycho-social stress) of water security that previous assessments of basic water requirements or water quality measures miss. Guttman scaling procedure also includes other experiences relevant to water security; both objective and subjective conditions dependent on fluid social relations and cultural norms can be assessed. Respondents, not water managers, for example, define the terms of water security or insecurity relevant to everyday lives. Scalograms do not seek to infer generalizations across different cultural contexts. Rather, this approach is highly sensitive to how culturally similar people experience water deprivation differently.

Creating a Guttman scalogram requires that the object of measurement to be one-dimensional. But, as just noted, water security is multi-dimensional. Therefore, this paper advances previous work on experience-based scaling of water security by developing a unique scale for each dimension of water security. Each household is assigned a Guttman value for each of the three characteristics of water security (water access, water quality acceptability, water distress) then the households are statistically clustered into water security classes.

4. Data collection

This paper adopts a critical mixed-methods approach with careful consideration of what Tim Forsyth calls "critical environmental epistemology" (CEE) (Forsyth, 2008, 2011). Forsyth argues that "we have to look for a new way of explaining environmental problems that makes social and political framings a key part of scientific inquiry" to achieve "more situated ways of explaining environmental problems that are more accurate and socially representative" (2011, 34–35). CEE is a process of inquiry that seeks to generate information to improve human development, but it is not managerial or "top down" in the sense of reinforcing existing knowledge regimes. Instead, CEE seeks to include those who experience environmental problems in framing the parameters of assessment. Therefore, from the perspective of CEE, this study approaches the problem water security by incorporating perspectives from colonias residents through qualitative research and survey development.

The research plan proceeded in two major phases: (1) semi-structured interviews and focus groups and (2) survey development and administration. While previous studies provide clear models to employ qualitative and quantitative techniques to assess food insecurity (Lindenberg, 2002), they cannot be simply grafted onto the problem of water security. A fundamental lack of understanding of water security experiences among the poor in the US precludes the creation of a survey instrument without detailed qualitative data to support the measurement. Scholars in food security emphasize how surveys must be developed from extensive field input and qualitative methods. In this way, both objective measures of resource scarcity and subjective assessments of scarcity can be incorporated into any subsequent survey (Bickel et al., 2000; Wolfe and Frongillo, 2001; Hall, 2004). This is particularly important when addressing water "affect" or water distress when both representation (textual, linguistic, visual, or otherwise) and non-representational interactions inform the emotive geographies of water.

The research was conducted in the Hidalgo County during nine visits between January 2009 and August 2012. All community-based research activities were conducted by researchers and accompanied by a female community health worker (*promotora*) associated with the local community center where the project was affiliated (Ramos et al., 2001; May et al., 2003; Ortiz et al., 2004; Kash et al., 2007). Promotoras, who are also residents of colonias, helped facilitate interviews, focus groups, and surveys, and they acted as a local contact for research participants. The research team included the principal investigator (author), promotoras, and three female graduate students.

In Phase One, we identified several colonias purposefully selected in consultation with the promotoras. The principal investigator and promotoras selected communities across the study region that had some prior contact with the local community center. We recruited 41 households through community meetings. We also conducted two group interviews in the local community center to broaden participation of other (male) household members. During this phase of the project we asked a series of semi-structured questions and open-ended questions related the three dimensions of water. Interviews were recorded, transcribed, and translated into English and entered and coded into NVivo software for analysis. After approximately 40 interviews, we reached a saturation point on descriptions of household water security and how residents expressed their experiences.

In the survey phase, the principal investigator drew on reported experiences of water insecurity from the interviews, collaborative work with the promotoras, and focus groups to develop a household water security survey. Water distress is an individual trait, so to scale up to the household, questions were asked of the informant, typically the female head of household, about other members of the household. The principal investigator drafted one pilot version of the survey (English and Spanish) and revised questions in consultation with five promotoras to ensure the word choice and translations were appropriate and clear for the local community. She also consulted with eight colonias residents on the length, language (word choice), appropriateness and structure; their input contributed to a final revision of the survey instrument. The final survey, which took between 30 and 45 min, was divided into four parts (1) household demographics, (2) water usages and practices, (3) series of yes/no questions related to the three water dimensions, and (4) income and wealth.

Surveys were conducted in different colonias communities selected through a stratified random sampling based on the state colonia classification system. The State of Texas mandates that colonias in six border counties be classified according to infrastructure-based assessments of "health risk": red (high), yellow (moderate), green (low), and unknown (grey) (Parcher and Humberson, 2007; Office of the Attorney General, 2012). We selected households, which were not previously contacted for Phase One, from each colonia category to avoid selection bias (Table 3). We selected 11 colonias in which to conduct surveys. The "Unclassified" group is disproportionately large, but fieldwork indicated that there are substantially more colonias not mapped or classified in the state's database. The final selection of communities and households depended upon the promotora and principal investigator's judgments related to personal safety, responsiveness, and availability of community members. We conducted 71 household surveys within a four-week period in 2012 (Table 4). We analyzed 68 surveys for this measurement exercise because three residents did not want to share information relevant to scale development.

5. Developing a household water security classification

The most well known scalogram is the US food security survey employs a Rasch model for scaling "insecurity" (Holben, 2002; Wunderlich and Norwood, 2006) to measure a given latent trait along a continuum ("severity of insecurity") that cannot be directly observed. While the Rasch scale provides many advantages, it is beyond the scope of this project to produce such a model-fitted measure. Rather, the survey used a cumulative scale procedure (Guttman scalogram) similar to a household energy security indicator (Cook et al., 2008) and the measure of emotional distress related to domestic water provision (Wutich and Ragsdale, 2008; Hadley and Wutich, 2009).

Survey questions addressed each dimension of water security (access, attributes, affect). Responses were entered 0 or 1 into a respondent-by-item matrix for each dimension of water security, with each row representing a household respondent and columns representing the indicators included in each water scale (Guest, 2000). Zero represented that absence or negative responses, and one was entered if the household indicated presence or positive response (Table 5). Responses were reordered in the data matrix to reflect progressively more items per respondent. Three conventional measures of reliability for each scale were calculated: coefficient of reproducibility (CR), coefficient of scalability (CS), and minimal marginal reproducibility (MMR). The CR should be greater than 0.60, CS more than 0.85, and MMR less than 0.90 (Guest, 2000; Wutich and Ragsdale, 2008; Abdi, 2010). The experience-based indicators that corresponded with survey responses used in scale development are described in the idealized Guttman scales (Table 6a–c).

Qualitative research informed the development of each scale as a way to select and eliminate indicators to reflect unidimensionality. Two iterations were run for each scale, and in the case of water access and water quality acceptability, two measurements of reliability were generated. Scales for each dimension of water security met conventional measures of reliability with one exception (Table 7). Both water access scales were reliable, but the scale with a lower CS was selected because the indicator question missing from the first iteration (problems with water pressure) was deemed critical to water reliability. The scale with the lower CS for water quality acceptability was selected because the indicator that would have improved the CS above 0.85 was also meaningful indicator. In sum, the empirically informed process of scale development and the resulting measurements of reliability are acceptable and consistent.

Using the three scalograms, an objective method was used to cluster the households into four groups of different levels of water security. S+ software was used to cluster the households into groups by creating a dendrogram applying the centroid method and squared Euclidean distance measurement. Using the dendrogram, the households were clustered into four groups: (1) Water Secure; (2) Marginally Water Secure; (3) Marginally Water Insecure; (4) Water Insecure. Differences among the four groups were also tested using multi-response permutation procedure (MRPP). MRPP is a non-parametric procedure to test the hypothesis of no difference between two or more groups (Biondini et al., 1988; Mielke and Berry, 2001). MRPP, calculated in R software, provides a measure of effect size and *p*-value of significance. In this case Euclidean distance as a measure of average within-group distance was used. The *p*-value evaluates how likely the observed difference is due to chance, but we need a measure of effect size that is independent of the sample size. The agreement statistic *A* describes within-group homogeneity compared to random expectation. This is called the "corrected within-group agreement" statistic; an *A*-

Table 3
Sample frame.

	Green	% in Hidalgo	Yellow	% in Hidalgo	Red	% in Hidalgo	Unclassified	% in Hidalgo	Total	% in Hidalgo
Six-County Area[a]	643		402		432		309		1786	
Hidalgo County	270		267		136		261		934	100
Study Area	7	2.6	40	15	28	21	19	7.3	94	10
Colonia Survey Sample	1	0.4	4	1.5	4	2.9	2	0.8	11	1.2
Households (Survey)	8		19		15		29		71	

[a] Cameron, El Paso, Hidalgo, Maverick, Starr, Webb Counties (Parcher and Humberson, 2007).

Table 4
Household demographics (*N* = 71).

Colonia type	Household Composition (Average)					Average Household Monthly Income				Average Water Cost/Month	
	N	Adults (Avg./HH)	Children (Avg./HH)	Adults over 65 (Avg./HH)	Avg. number of people/HH	Cash inc. ($)	Assistance ($)	Total ($)	FPL%	Water exp. ($)	Affordability (%)
Green	8	3	3.12	0.12	6.25	972	197	1168	40.53	77	9.1
Yellow	19	2.36	1.84	0.37	4.58	1882	117	1895	97.5[a]	59	5.8[a]
Red	15	2.06	0.8	0.6	3.46	1276	105	1381	70	55	7.0
Unknown	29	2.48	2.58	0.03	5.13	1041	276	1307	48.8	67	8.3
ALL HH	71	172	147	18	338	1291	197	1458	64.5	63	7

[a] *N* = 69 (three respondents did not indicate income).

Table 5
Sample matrix.

Survey	Indicator A	Indicator B	Indicator C	Indicator D	Total
1	0	0	0	0	0
2	0	0	0	1	1
3	1	1	1	1	4
4	0	1	1	1	3

statistic greater than 0.3 is considered fairly high. For the household water security indicator groups, the agreement statistic *A* is 0.3391 and the *p*-value is 0.001. Therefore, we can reject the null hypothesis of no difference among the groups.

6. Findings

6.1. Water access

Water access is defined by the capacity to obtain water for consumptive purposes, including physical accessibility, affordability, and reliability. Most households in the study cannot afford water (84%), and they adapted water usages to save money (71%). Over

Table 6
Idealized water scales.

6a. Idealized Guttman scale for water access								
Share water meter with other or given water	No	No	No	No	No	No	No	Yes
Water cut off or interrupted	No	No	No	No	No	No	Yes	Yes
Problems buying water or paying bill	No	No	No	No	No	Yes	Yes	Yes
Lacked money to pay for water	No	No	No	No	Yes	Yes	Yes	Yes
Problems with water pressure	No	No	No	Yes	Yes	Yes	Yes	Yes
Conserves water to reduce water bill	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Water is more than 2.5% monthly cash income	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Score	0	1	2	3	4	5	6	7
Definition	Score							
1 – Adequate water access	0							
2 – Marginal water access	1–3							
3 – Low water access	4–5							
4 – Very low water access	6–7							
6b. Idealized Guttman scale for water quality acceptability								
Believe that the tap water made someone in the household ill	No	No	No	No	No	No	Yes	
Tap water is visually unclean (dirty, cloudy, floaters)	No	No	No	No	No	Yes	Yes	
Garafones older than 6 months/inadequate	No	No	No	No	Yes	Yes	Yes	
Tap water has unpalatable (chorine; soil; metallic) taste or smell'	No	No	No	Yes	Yes	Yes	Yes	
Do not disinfect water containers after each use	No	No	Yes	Yes	Yes	Yes	Yes	
More than 50% drinnking water from bottles or vending machines	No	Yes	Yes	Yes	Yes	Yes	Yes	
Score	0	1	2	3	4	5	6	
Definition	Score							
1 – Acceptable water quality	0 and 1							
2 – Marginal water quality acceptability	2							
3 – Low water quality acceptability	3 and 4							
4 – Very low water quality acceptability	5 and 6							
6c. Idealized Guttman scale for water distress								
Argued with someone about water (discutir; hacer comentarios)	No	No	No	No	No	No	Yes	
Frightened or Scared (miedo; asustarse)	No	No	No	No	No	Yes	Yes	
Dissatisfied	No	No	No	No	Yes	Yes	Yes	
Troubled or Uneasy (inquietar)	No	No	No	Yes	Yes	Yes	Yes	
Disgust (mortificar/feo)	No	No	Yes	Yes	Yes	Yes	Yes	
Worry (preoccuparse)	No	Yes	Yes	Yes	Yes	Yes	Yes	
Score	0	1	2	3	4	5	6	
Definition	Score							
1 – Low water distress	0							
2 – Marginal water distress	1 and 2							
3 – High water distress	3 and 4							
4 – Very high water distress	5 and 6							

Based on Hadley and Wutich (2009).

Table 7
Measurements of reliability.

	Water access	Water quality acceptability	Water distress
Coefficient of reproducibility	0.92	0.93	0.91
Minimum marginal reproducibility	0.43	0.54	0.36
Coefficient of scalablity	0.86	0.83	0.86

half lack money to pay for water (51%), and many others reported problems with water pressure (41%). Almost 37% experienced difficulties buying water or paying the water bill because of physical or mobility problems. Over 25% of the respondents mentioned that they experienced difficulty paying for the gasoline necessary to drive to the water vending machine for drinking water: "no hay gas, no hay agua" (no gasoline, no water). Eighteen percent of households reported that water service had been cut or interrupted during the past twelve months while 7% share a water meter with someone or had been given vended drinking water because they lacked money or transportation (Table 6a).

Singular measures, however, do not reveal the cumulative or progressive experience of water inaccessibility. Therefore we look to the water access Guttman scale (Table 8). A majority of households in the survey (57%) experienced adequate or marginal water access during the past twelve months with the majority of those experiencing marginal water access (Table 8). One-third of the households surveyed experienced low water access while only 9% experience very low water access. Lack of financial resources to pay for either the water bill or to purchase water at the vending machine is one difference between marginal water access and low water access. Nine percent of households that experience very low water access also reported water interruption or reciprocal water exchange with neighbors.

The study found a significant difference between the adequate water access and marginal water access in terms of affordability. Water is only affordable in three households, with the average water expense of 1.7% monthly cash income. Water is not affordable for households with very low water access, averaging 8.6% monthly cash income. A closer inspection of households with adequate water access reveals that, on average, they have $807.00 more monthly cash income than those with marginal water access. The difference is double monthly cash income ($1605) between those with adequate water access and those with very low water access. Three of the four households with high water access live above the federal poverty level (FPL) while one household lives on income that is 49% below the FPL. This household represents one individual who is a pensioner receiving resources from adult children. A majority of households (8 households) that live above the FPL experience marginal, not high, water access.

But living in extreme poverty (49% and below the FPL) does not directly mean that a household will have low or very low water access. Half of the households living in extreme poverty experienced marginal water access. One explanation may be that variable household infrastructure or quality of service to an area may have resulted in unreliable water services and problems with water pressure. Or, the difference of water access among the very poor households may be related to the fact that they have highly variable levels of transportation. Reliable transportation determines whether or not the household members have the ability to drive to the water corporation office and pay the bill or buy drinking water at the vending machine. The household interviews and surveys demonstrate that those who are very poor but young and working may have a car while the elderly or retired, who live on restricted and low incomes, are less able to access water or pay the bill because of limited mobility. While uncommon, some reported that neighbors pool transportation resources to fetch vended water.

6.2. Water quality

The water quality acceptability Guttman scalogram includes experiences of physical characteristics (taste, color, and odor), sanitation practices for stored water, and perceptions that water caused some illness in the household. A majority of households (87%) reported drinking more than 50% of their water from bottles or vending machines. This alone does not make water unacceptable, but a significant reliance (and expenditure) on drinking water from bottled or vended sources indicates dissatisfaction with tap water. For example, 75% reported an unpalatable taste or smell (chorine or metallic). Twenty-six percent used a range of words to describe things they saw in their water (dirt, trash, earth, worms, trees, and "devils") or reported tap water as milky white, brown, or cloudy. Household practices related to care for drinking water containers also increase the possibility of contaminating drinking water. For example, water-vending companies assume and strongly recommend that the water containers, generally five-gallon plastic containers, are disinfected for each use to maintain water quality. However, only 22% of the households disinfect the container after each use; moreover, 65% of the containers are more than six months old (Table 6b). The disinfection and age of containers are important when considering water quality because contaminant build-up on the inner sidewalls of plastic domestic containers is a microfilm that contains microorganisms that may contribute substantially to the deterioration of water quality when not properly cleaned and disinfected after each use (Clasen and Bastable, 2003).

While water quality can be measured through expensive laboratory tests, the lived experience and perceptions of water and practices around water quality bear substantially on the sense of security from the point of view of colonia residents. Therefore, the development of a scale attempts to measure the progression of how water quality is accepted and the degree to which households in perceive, accept, or reject tap water based on several experiences (Table 6b). Only 9% of households experience acceptable water quality, while a majority of households experience low to very water quality acceptability (57%). One characteristic that makes tap water unacceptable is whether or not the household, all of which have access to tap water, use more than 50% from bottled or vended water. This, in addition to poor hygienic practices for water containers, then suggests households experience lower water quality. Households that also reported taste or smell problems and stored water in inadequate water containers (more than six months) further lowered their water quality acceptability score. Just over one-third experienced marginal water quality acceptability. One quarter of the households experienced very low water quality acceptability, with 18 households reporting some visual indicator of dirty water, and 14 households reported that someone believed that tap water made another household member ill Table 8.

Very little difference exists between the average of water affordability among households in terms of water quality acceptability. Water is almost as unaffordable (6% cash income) for households that experience acceptable water quality as for those who experience very low water quality acceptability (7.5% cash income). Similarly the ranges of income and FPL% are very narrow for all households across the scale. The average monthly household income for those in the acceptable range is between $1559 and $1353, respectively. This is comparable to the average monthly household income for those in the unacceptable range, which is between $1196 and $1249, respectively. Similarly the average per-

Table 8
(a–c) Water scales and household characteristics (N = 68).

	HH demographics					Income			Federal poverty level			
	Total HH	% of HH	Average per HH	Total	% Pop.	Average HH Cash Income per Month ($)	Avg. Water Affordability (% of monthly cash income)	Per Capita Income ($)	% of FPL	Above	100% and 50%	49% and below
Water access scale												
Adequate water access	4	6	3.75	15	5	2317	4	563	121	3	0	1
Marginal water access	35	51	4.42	155	47	1510	7	417	77	8	7	20
Low water access	23	33	5.91	136	41	878	9.4	226	39	0	7	16
Very low water access	6	9	3.66	22	7	712	8.6	377	46	1	1	4
Total	68			328						12	15	41
Water quality acceptability scale												
Acceptable water quality	6	9	5.6	34	10	1595	6.0	321	64.7	2	1	3
Marginal water quality acceptability	23	34	5.04	116	35	1353	7.7	409	71.4	4	6	13
Low water quality acceptability	22	32	4.36	96	29	1196	7.6	335	60.5	3	5	14
Very low water quality acceptability	17	25	4.82	82	25	1249	7.5	329	58.8	3	3	11
Total	68			328						12	15	41
Water distress scale												
No water distress	13	19	3.8	50	15	1924	5.6	568	108	5	1	7
Marginal water distress	27	40	5.1	140	43	1224	8.0	322	57	5	6	16
Water distress	18	26	5.22	94	29	1127	7.7	291	49	1	5	12
High water distress	10	15	4.40	44	13	989	8.5	298	51	1	3	6
Total	68			328						12	15	41

cent of the FPL for each level in this scale ranges between 58.8% and 71.1%.

6.3. Water distress

Emotional, cultural, and subjective perspectives on water relate to wellbeing, and thus it provides another important yet overlooked dimension to water security. Most of the work that analyzes water and water security using a Guttman scale approach examines emotional distress (Wutich and Ragsdale, 2008; Hadley and Wutich, 2009). As noted in the qualitative research phase, the vocabulary that colonias residents used to describe water, their use of water, and the various experiences and emotions with water were incorporated in the survey.

Two-thirds of the respondents reported worry (*preocupación*) as the most common emotion related to water quality, access, cost, and other problems associated with expenditure of time and effort. Many respondents (44%) described some level of disgust for tap water, which is available in all surveyed households while 40% of respondents experienced some unease (*inquietud*) with the water as it related to use, quality, or service. Despite these negative experiences only 29% expressed some form of dissatisfaction and 28% experienced fear (*miedo*). Very few households (18%) reported that water was a topic of an argument either within the household or at the water company offices.

Individual accounts of water distress, however, do not reveal the cumulative experiences within individual households. The Guttman scalogram provides a better measure of how emotional distress progresses and is expressed. For this study, the progression of distress can be summarized as follows: worry, disgust, unease, dissatisfaction, fear, and argument (Table 6c). Overall, the majority of households experienced only limited water distress (59%). Almost one-fifth of the households did not experience water distress (19%) and the largest percentage of households experienced marginal water distress (40%). About one quarter of the households experienced water distress, which progressed into unease and dissatisfaction with the water experience. The survey also determined that 15% of the households experienced high water distress Table 8.

6.4. Household water security classification

Guttman scales require unidimensionality, but water security is multi-dimensional. Therefore, the three scales were used as variables to statistically cluster the households into water security classes. Classification based on three experiential scales does not have to sacrifice the benefits of the experience-based measure or multi-dimensionality to assess household levels of water security. The classification resulted in four household water security classes: (1) Water Secure; (2) Marginally Water Secure; (3) Marginally Water Insecure; (4) Water Insecure. The mean score of the scalograms for each cluster are found in Table 9 and Fig. 1. The lowest total score of the three scalograms is 4 and the maximum total score of the scales is 11. Therefore, we do not have cases either of "highly water secure" and "highly water insecure," households with total Guttman score of equal or less than 1 and 12, respectively. That is, a household that experienced high water access (Guttman score of 0), acceptable water quality (Guttman score of 0 or 1) and no water distress (Guttman score of 0) could be classified as "highly water secure." Conversely, a household that experienced very low water access (Guttman score of 4), very low water quality acceptability (Guttman score of 4), and very high water distress (Guttman score of 4) could be classified as highly water insecure.

Only 10% of the households surveyed are water secure. The total of the mean Guttman scores is 4.15, indicating that households in this category may have problems in relation to drinking water security. For example, the average cost of water as a percentage of cash income for households in this group is 5%, double the EPA standard minor of affordability. This group also has the highest overall income, living on cash income that is at the federal poverty level (100%). But overall, in relation to the other households in the survey, seven households are water secure.

Over one-third (35%) of the households are classified as marginally water secure. The mean scores are similar, between water ac-

Table 9
Household water security classification.

Household water security class	HH demographics					Income			Federal poverty level			
	Total HH	% HH	Avg. #/ HH	Total pop.	% Pop.	Avg. HH cash inc./mo. ($)	Water cost (% cash inc.)	Per capita inc. ($)	% of FPL	Above	100% and 50%	49% and below
Water Secure	7	10	4.7	33	10	2153	5	461.16	100	4	1	2
Marginally Water Secure	24	35	4.25	102	31	1381	6.7	418.53	75.3	4	4	16
Water Insecure	21	31	5.95	125	38	1092	8.6	283.44	47.1	2	6	13
High Water Insecure	16	24	4.25	68	21	1054	8	317.16	53.9	2	4	10
Total	68			328						12	15	41

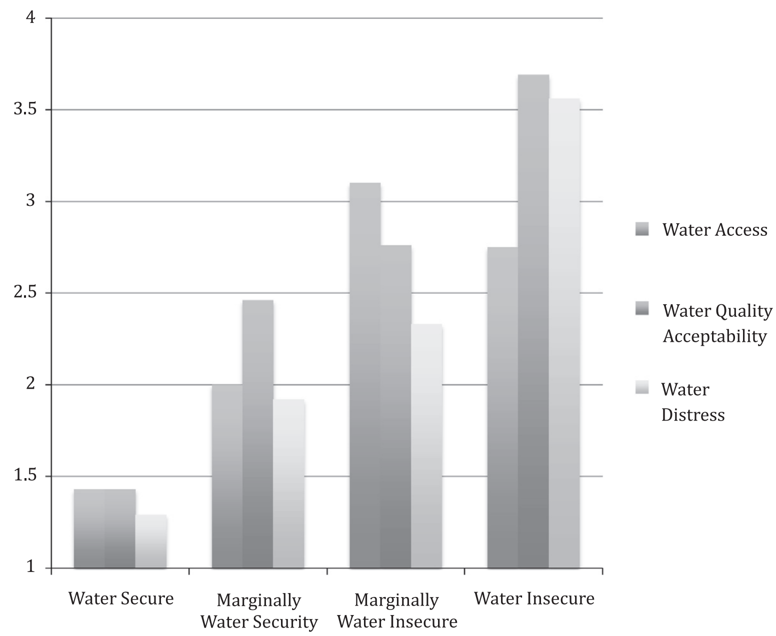

Fig. 1. Mean value of scale scores. $A = 0.3391$ and p-value = 0.0001.

Table 10
Mean value for scale scores.

	Water access	Water quality acceptability	Water distress	SD	Total
Water Secure	1.43	1.43	1.29	0.23	4.15
Marginally Water Secure	2	2.46	1.92	0.27	6.38
Marginally Water Insecure	3.1	2.76	2.33	0.36	8.19
Water Insecure	2.75	3.69	3.56	0.27	10
Total (*N*)	7	24	21		16

cess (2) and water distress (1.92) but significantly higher for water quality acceptability (2.46). The total of the mean score for this category is 6.38. The average water costs are 6.7% household cash income, and households falling within this classification live on an average monthly cash income that is 75.3% the federal poverty level.

Slightly less than one-third of the households are classified as marginally water insecure (31%). The mean scores for all scales are 3.1, 2.76, and 2.33 for water access, water quality acceptability, and water distress, respectively (Table 10; Fig. 1). The water access score is significantly higher than water distress and water quality acceptability. The total mean value for this category is 8.19. Water costs 8.6% of the average household cash income, and these households live in extreme poverty, which is an average monthly cash income equivalent to 47.1% of the federal poverty level.

Almost one quarter (24%) of the households are water insecure. The change in mean scores for each scale reflects that water insecurity among these households is distinguished by water quality and emotional distress, not by water access. The mean score for water access declines 0.26 yet the mean values for water quality acceptability and water distress increase, 0.93 and 1.23 respectively. The total mean score for this category is 10. For households in this class, water costs 8% household monthly cash income, and households live on an average monthly cash income equivalent to 53.9% of the federal poverty level.

7. Discussion

All households in the survey connect to water service, but the data reveal clear variability among households suggesting that the survey and analysis measure key issues in this "no-win" waterscape suggested in qualitative work. Water connections are available, if residents can afford them; however, connections do not guarantee water quality or adequate service. Indeed, many colonia residents may run the risk of losing service for lack of payment. Moreover, access to the water vending machine and bottled water, as an alternative, costs time, effort, emotional distress, and money, all of which are significant burdens for America's poor (Jepson and Lee, forthcoming). The problem this paper addressed was how to assess the pervasiveness and distribution of the lived experience in a no-win waterscape. By framing the question in terms of "water security" defined by three dimensions—water access, water quality acceptability, and water distress—the study opened the conceptual aperture to include the household, not just the community or colonia, as unit of analysis.

The novel approach that uses scalograms for water security classification builds on the previous research in the arena of development studies. One important advance is the ability to capture the multi-dimensionality of water security without sacrificing important insights provided by the experience-based measure. Hadley and Wutich note that there is a trade-off the investigator has to make if he or she uses a Guttman scalogram, making a decision as to what information to include or remove to retain the assumption of uni-dimensionality (2009, 458). Acknowledging the three aspects of water security, with independent scalogram for each, reduces the loss of information and provides a fuller picture of water insecurity, which in this case, is clearly determined more by quality and water distress than water access.

From a methodological perspective, the study demonstrates how scalograms can be used to classify households based on multiple dimensions of water insecurity. The statistical clustering method and MRPP test offer a valid process to measure variability among households that would have otherwise been invisible to policy makers and water managers using previous indicators, such as the WPI. The documented water security variability among households, therefore, demonstrates the need to encourage state or water managers to reframe their approach to water provision and monitoring at the household scale.

The study also advances the work by Wescoat et al. (2008), which used census data on income and household infrastructure, to speak to the relationship between water provision and poverty in the United States. The present study provides quantitative data to illustrate that there is a relationship between poverty and water access, but it is not a perfect correlation. The water access Guttman score, for example, demonstrates that for households experiencing "low water access" the average per capita monthly income is $226. This is less than households with "very low water access" ($377 per capita monthly income) (Table 8a). The data illustrates that other factors, such as service reliability or physical capacity to access drinking water, also reduce overall water access among the economically disadvantaged. In addition, declining average monthly income per capita does not directly correlate with declining household water security. Table 10 and Fig. 1 illustrate the importance of water quality acceptability as a key factor that distinguishes "water secure" households from "marginally water secure" households. Similarly, water quality acceptability helps explain the difference between households classified as "marginally water insecure" and those classified as "water insecure." Moreover, the scale scores for water distress further contributes to "water insecure" classification. Taken together, one can conclude that there is not a direct correlation relationship between income and level of household water security. Indeed, the study demonstrated how research can move away from simple measures of infrastructure access and apply a more comprehensive approach, that of household water security, to reflect the lived reality of domestic water provision among the economically disadvantaged and marginalized groups.

Several limitations should be considered when reviewing the method and results of this study. First, the coefficient of scalability, one measure of validity for the water quality acceptability scale, was slightly below the acceptable range. This demonstrates that there are tradeoffs that the investigator has to make in any scale analysis. The trade-off was between a slightly lower validity measurement and the exclusion of an ethnographically important indicator. The ethnographically important indicator was chosen over a small difference in the validity score. Second, the study included households that were all connected to a community water service, yet there is qualitative evidence that some households not included in this study were not connected to a community water supply. In addition, we under sampled households in "green" colonias ("no health risk") while potentially oversampling households in the "unknown" category. Both of these issues speak to potential selection bias in the study. Third, the time frame of twelve months was based on the US food security model, but questions that address more frequent experiences of water access, quality issues, and distress may have revealed further intensity of experiences not captured in this study. Finally, previous studies have underscored how the scalogram is not comparable across cultures. While some consider this a limitation, for the case of colonias on the US–Mexico border, comparability is not a major barrier to integrate this approach to household water security into public policy monitoring considering there are over 400,000 people living in 2300 colonias in Texas alone.

8. Conclusion

Poor households in South Texas colonias, living on an average income of 64.5% the federal poverty level, experience a wide range of water security or insecurity. Domestic water provision in the colonias can be traced to an historical geography of decentralized water governance and legal, institutional, and economic exclusion (Jepson 2005; Jepson, 2012; Jepson and Brannstrom, forthcoming; Jepson and Lee, forthcoming). This exclusion has produced a "no-win" waterscape in which residents of South Texas colonias may have precarious water service from a water supply company but tap water quality and reliability remain low. This situation drives residents to expensive private drinking water sources, the water vending machine, which greatly and disproportionately increases the costs of drinking water in terms of time, money, and effort relative to the residents' capacity.

The pervasiveness and distribution of household water insecurity were previously unknown for two major reasons. First, colonias residents fall outside traditional views of water security assessments because of the myth of universal service, where it is assumed that water access is universal and sufficiently acceptable within the United States. Second, existing freshwater indicators do not address the specific and multi-dimensional characteristics of water security at the household level. Some indicators address one of the three dimensions of water security, but none was integrated into one assessment at a scale that could elucidate the diversity and variability of experience at the household. Reliance on water infrastructure as a measure, for example, cannot describe the complex socio-cultural and economic experience of domestic water provision.

This paper addressed the empirical and conceptual gap by developing a meaningful assessment of household water security for marginalized populations in the United States. A novel method for assessing water security was tested among poor households in the colonias of south Texas, a procedure that may be replicated to measure water security in many other contexts. Statistical analysis confirmed the robustness of the scaling and clustering procedure, which provides quantitative evidence for the ways in which households experience the "no-win" waterscape. Therefore, this study offers a method to address these information gaps through the systematization of a household water security measure. Using a dual Guttman scalogram and classification method, this paper demonstrates how policy makers may collect the necessary qualitative and quantitative data to support and implement policy changes in water governance to address wide-ranging water security problems that still exist in poor communities in the United States.

The paper also contributes to broader concerns in human-environment geography and environmental justice research. The study draws on insights from critical environmental epistemology (CEE) to inform how and what qualitative information was to be included in the HWS measure. For a valid household water security measure, then, the study centers on the everyday environmental experiences of colonias residents when answering the questions of "who counts" and "what counts" when it comes to valid water measurements (Norman, 2013). The present study includes the perspective of colonias residents in both phases of the research plan. Colonia residents' participation in the qualitative research anchored the survey development, thus offering a model of how research participants can contribute to overall research objectives. More specifically, the choice of an experience-based Guttman scalogram provides a means to include the community members in defining and quantifying their experience of water security.

The study also spoke to larger questions of "the everyday" in environmental politics (Loftus, 2012). Ultimately the research design allowed for the revaluation of the subjective: following Rocheleau, the study drew on the everyday experience of household water security to "stretch and combine it into something that can be validated and verified through a variety of methods (including quantitative measures) within an ever-widening circle of shared experience" (Rocheleau, 1995, 459). Subjectivity that derives from self-validating certainties, at least partially, anchored in the material conditions demand that emotional, cultural, and subjective perspectives related to water requirements were taken into account. In this way, the experience-based scale and non-parametric classification method incorporated both subjective and objective indicators to determining household water security. The scale and classification approach resulted in a socially relevant measurement of water security rather than a top-down universalizing assessment of water infrastructure. If everyday environmentalism offers new sources for critique and insights for political ecology, as Loftus argues, then this study demonstrates the importance of theoretically informed quantitative methods to document the existence, magnitude, and distribution of the everyday experiences of socio-nature.

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