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Exploring household water insecurity in rural Tunisia: A pilot study toward scale development

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Abstract

This study aimed to explore household-level water insecurity experiences among rural households individually connected to a piped water system in rural areas in Tunisia. Conducted in three phases, the study comprised: (1) the development of a 15-item scale, based on a review of previous studies and adapted to the Tunisian context through qualitative interviews; (2) a survey of 51 households experiencing intermittent water supply during the summer of 2022; and (3) a series of analyses of the scale, including item reduction, exploratory factor analysis, and assessments of reliability and validity. Given the limited sample size, we frame this work as a pilot study designed to identify context-specific dimensions of water insecurity and to inform the development of a robust, validated tool in future research.

1. INTRODUCTION

The 2030 Sustainable Development Goals incorporate the imperative of guaranteeing universal access to water. In Tunisia, in the context of universal access to piped water systems in urban areas and nearly universal access in rural areas, maintaining sustainable universal access to water is becoming more challenging as persistent water infrastructure degradation and the omnipresence of water scarcity, worsened by climate change, exacerbate water insecurity. To capture seasonal variation, psychosocial issues, and changes in water use that occur at the household level in response to water-related issues – factors that are not captured by existing indicators – and to monitor progress towards achieving sustainable universal access, developing a household-level water insecurity scale is emerging as a crucial task. The consideration of water insecurity can facilitate the monitoring and evaluation of the effectiveness of water development investments, programs, and provisioning systems beyond water infrastructure-based assessment. This emphasis on water insecurity is important for the research and practitioner community to comprehensively evaluate water-related interventions, thereby aiding the identification of potential shortcomings and opportunities for improvement.

While existing experience-based instruments enable standardized measurement across diverse contexts, they were primarily developed for comparability in settings characterized by limited physical access to water. In rural Tunisia, where universal network connections exist but water service is intermittent, particularly in summer, water insecurity is more closely linked to reliability, predictability, and household coping practices than to access per se. This study presents a pilot application of a household-level water insecurity scale that adapts existing instruments to the rural Tunisian context, integrating qualitative insights to better capture context-specific experiences of insecurity within formally universal service systems.

In this context, because water service intermittency is shaped by how water services are planned, allocated, and managed, experiences of water insecurity are closely shaped by governance arrangements. Conceptualizing water insecurity as an experiential phenomenon therefore requires attention to the governance context in which water services are planned and regulated, underscoring the importance of approaches that link household-level experiences to broader institutional and governance dynamics.

Such experiences have been shown to occur regardless of whether they take place in high-income or low-income countries, and even in contexts where there is universal access to water (Radonic & Jacob, 2021). Rather than presenting a fully validated scale, this research offers a methodological pilot study that provides insights into household-level water insecurity in Tunisia. The findings serve as a valuable foundation for the future refinement and testing of the scale in broader, more representative samples.

2. LITERATURE REVIEW

2.1. Water (In)Security

According to the United Nations Water (2013), water security refers to "the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development; for ensuring protection against waterborne pollution and water-related disasters; and for preserving ecosystems in a climate of peace and political stability" (Bigas et al., 2013). Water security has also been defined as the ability to access and benefit from affordable, adequate, reliable, and safe water necessary for well-being and a healthy life (Jepson et al., 2017). It is increasingly conceptualized as a dynamic interaction between social and ecological systems in response to hydroclimatic and human drivers (Scott et al., 2013).

In contrast, water insecurity denotes reduced or unattainable access to affordable, reliable, adequate, and safe water, posing risks to physical and mental health as well as livelihoods (Jepson et al., 2017). It encompasses both the objective lack of access and the subjective experience of uncertainty regarding one's ability to secure water for well-being (Jepson et al., 2017). Water insecurity represents a barrier to human development that warrants scholarly and policy attention—not only to evaluate the effectiveness of water development investments, programs, and provisioning systems, but also to go beyond assessing infrastructure or mere access (Jepson et al., 2017). Although water availability is a necessary component of understanding water security, it is not sufficient for determining who has adequate access for all household uses (Young et al., 2019b).

The health, social, and economic consequences of water insecurity extend far beyond the traditional focus of water, sanitation, and hygiene (WASH), encompassing broader concerns related to psychosocial and physical health, nutrition, and economic well-being (Collins et al., 2019).

2.2. Household Water Insecurity

Household water insecurity is closely linked to health and well-being through physical, psychosocial, nutritional, and economic pathways (Wutich et al., 2017; Miller et al., 2020), and it has serious implications for livelihoods (Wutich et al., 2017).

Investigating household experiences of water insecurity—which are not captured in existing national surveys (Pierce & Jimenez, 2015) and are inadequately addressed by national or global policies that rely solely on aggregated progress indicators—has become increasingly important for advancing universal access to drinking water (Young et al., 2019b). While these indicators have been useful in measuring progress toward equitable and sufficient water access using national or regional assessments of water availability (Liu et al., 2017), they often mask population-level heterogeneity, thereby obscuring the individual health, economic, and psychosocial burdens associated with water insecurity (Young et al., 2019b).

2.3. Measuring Water Insecurity

Rather than relying solely on proxy measures, such as health indicators or measures of physical access to water, locally based research can generate experience-based measures of water insecurity, reflecting local experiences of stress and suffering. The advantages of this approach are that it directly measures the water insecurity experience and considers the social context of water use (Stevenson et al., 2012).

Developing water insecurity metrics and assessment tools will provide the necessary information to recognize the direct causes and consequences of water insecurity. They will help monitor changes in water insecurity over time, evaluate the impacts and cost-effectiveness of development interventions, target scarce resources where they are most needed, and understand how to distribute resources more effectively (Jepson et al., 2017 ; Young et al., 2019b).

3. METHODS

The research proceeded in three phases. Phase I entailed scale development through a review of existing instruments and consultation. In Phase II, a small-scale survey was administered to test the scale. Informed consent was obtained from all participants prior to data collection. Phase III involved testing of item performance and internal consistency.

3.1. Phase I: Scale development

The scale development phase focused on developing a water insecurity scale and included an in-depth literature review and a series of semi-structured interviews.

3.1.1. Literature review

The first step involved reviewing literature on water insecurity and existing scales. A comparison-based selection of both validated items and non-validated items (i.e., those tested but not included in the validated versions of the scales) from three household water insecurity scales—developed in Kenya, Cameroon (Central Africa), and twenty-three low- and middle-income countries by Bisung & Elliott (2018), Nounkeu et al. (2021), and Young et al. (2019b), respectively—was used to identify the items to be discussed and formulated in collaboration with water experts and committee members of the water user associations.

3.1.2. Semi-Structured Interviews

The previous step was supported by a series of semi-structured interviews conducted to 1) evaluate the usefulness of developing an instrument to measure household water insecurity in the context of universal access; 2) understand the complexity of providing water services in rural areas and the diversity of actors involved; 3) discuss, evaluate (including combining and deleting), and formulate the selected set of items from the existing scales to maximize content validity.

The interviews were conducted with experts from the regional representation of the Ministry of Agriculture, Water Resources and Fisheries, the Regional Commissariat for Agricultural Development (CRDA) of the Governorate of Ben Arous, as well as with committee members of the water user associations within this governorate, specifically in the Municipality of Mornag. These stakeholders guided the selection of six hamlets within the municipality—four served by water user associations known as Agricultural Development Groups (GDAs), and two by the national operator, SONEDE. Households within these hamlets reported continuous water supply for less than 12 hours per day, or even less continuous supply (e.g., a few hours to one full day of continuous supply each 2 to 3 days) during the summer of 2022, regardless of whether interruptions were linked to poor tap water quality.

3.2. Phase II: Data collection

Phase II involved a survey conducted in March 2023 among 51 households experiencing intermittent water supply during the summer of 2022. The survey was designed to collect data needed to test the scale. The questionnaire included questions about perceptions of tap water quality, the frequency and duration of water supply interruptions, satisfaction with water services, and whether households stored tap water. Additionally, it included items from the individual water insecurity scale developed by Bethancourt et al. (2022).

3.3. Phase III: Scale testing

In Phase III, the data collected during Phase II were analyzed to test the scale using item reduction analysis, factor analysis, and reliability and validity tests.

3.3.1. Item reduction analysis

The Classical Test Theory (CTT) was applied for the item reduction analysis. The primary goal of using CTT is to obtain functional items, referring to items that are correlated with each other, discriminate between individual cases, underscore a single or multidimensional domain, and contribute significantly to the underlying construct (Boateng et al., 2018b). The major techniques used to reduce the item pool include item difficulty and item discrimination indices, and inter-item and item-total correlations (Boateng et al., 2018b).

Both techniques were employed, and their outcomes were juxtaposed. Only items that met the thresholds of both techniques were retained. Ordinal variables were converted into binary variables for this analysis. The dichotomous variables were defined in a way that responses ranging from 1 to 5 were assigned a value of 1, while response 0 was assigned a value of 0 (Table 2).

Missing Cases

Items with missing values greater than 10%, including responses such as "don’t know", "not applicable", or true missing responses, were removed from the analysis. This approach is used to remove items that are not understood or widely applicable and therefore do not accurately reflect experiences related to water insecurity (Young et al., 2019a). This approach has been used in previous studies, where items with missing cases greater than 30% (Young et al., 2019a) and greater than 10% (Boateng et al., 2018a; Nounkeu et al., 2021) were eliminated.

Multicollinearity

The purpose of this step was to detect pairs of items with a collinearity coefficient greater than 0.90, and to eliminate one of the correlated items from the analysis to mitigate the problem of multicollinearity.

Inter-item and Item-Total Correlations

Inter-item correlations (also known as polychoric correlations for categorical variables and tetrachoric correlations for binary items) examine the extent to which scores on one item are related to those on all other items of a scale (Raykov & Marcoulides, 2011). Item-total correlations (also known as polyserial correlations for categorical variables and biserial correlations for binary items) examine the relationship between each item and the total score of all scale items (Boateng et al., 2018b).

Items with inter-item correlation coefficients and item-total correlation coefficients below 0.30 may not be very useful (Boateng et al., 2018a) and are therefore considered for potential removal from the tentative scale (Boateng et al., 2018a; Young et al., 2019a).

Item Difficulty Index

Under the CTT framework, the difficulty of an item, its p-value (Ebel & Frisbie, 1991), refers to the probability that an item will be answered affirmatively (Raykov & Marcoulides, 2011). The higher this index value, the lower the difficulty; and the greater the difficulty of an item, the lower its index (Backhoff Escudero et al., 2000 ; Sim & Rasiah, 2006).

The item difficulty index was calculated using two methods. The first refers to the number of affirmative answers divided by the number of affirmative answers plus the number of negative answers (Backhoff Escudero et al., 2000). The second refers to the number of affirmative responses divided by the total number of responses, taking into account blank responses to equal the sample size (Sim & Rasiah, 2006). Because there were only a few blank responses, we expected slight, negligible differences between the two methods that would not affect the analysis.

To determine whether the statements were reasonable for the participants to correctly associate them with their experiences of water insecurity, the thresholds of the Item Difficulty Index set by Nounkeu et al., (2021) (<0.3 and >0.8) were adopted.

Item Discrimination Index

The item discrimination index refers to the degree to which an item differentiates between high- and low-scoring test-takers on a particular construct. The higher the discrimination index, the better the item distinguishes between those who score high and those who score low on the test (Backhoff Escudero et al., 2000). To determine item discrimination, the point-biserial correlation coefficient, also called the discrimination coefficient, was employed. This coefficient describes the relationship between the test item score and the total test score for each participant. High positive correlations are obtained for items that high-scoring participants on the test tend to get right and low-scoring participants on the test tend to get wrong (Ebel & Frisbie, 1991).

Experience with a wide variety of tests indicates that items showing discrimination indices higher than 0.4 are considered "very good items" (Ebel & Frisbie, 1991).

3.3.2. Factor analysis

Factor analysis is an essential tool in scale development. One of its primary functions is to help researchers determine the number of latent factors underlying a set of observed measures or variables (Devellis & Thorpe, 2021; Raykov & Marcoulides, 2011), generally unknown before performing the analysis (Raykov & Marcoulides, 2011). Factor analysis can also provide a means of explaining variation among many original variables using fewer newly created variables (latent factors), and it aids in identifying items that perform better or worse. Thus, individual items that do not fit any of the categories or fit multiple categories can be identified and considered for removal (Devellis & Thorpe, 2021).

Through exploratory factor analysis, commonly used by researchers who are not testing a hypothesis or theory but rather trying to determine what type of latent structure (factors and their relationships to observed measures) would be consistent with the analyzed data (Raykov & Marcoulides, 2011), our purpose was to explore the latent structure of the scale resulting from the item reduction analysis and to examine whether there could be evidence for a single latent factor, indicating that the scale is unidimensional and measures one single factor.

By using the ordinal variables, the process begins by analyzing the correlation matrix of the items that were not removed after the item reduction analysis.

Bartlett's test of sphericity was applied to determine whether factor analysis is appropriate for the correlation matrix. The test assumes that variables follow a multivariate normal distribution. The null hypothesis is that the correlation matrix is an identity matrix, indicating that there are no linear relationships between the variables—meaning that each variable can be considered its own factor. If the test is not significant at the level of 0.05, then the factor analysis would not be meaningful. Rejecting the null hypothesis suggests that factor analysis could be useful to explore the latent structure underlying the correlation matrix, as it is likely that there are correlations among the variables that could be explained by a smaller number of underlying factors (Tobias & Carlson, 1969).

The number of factors is obtained using the eigenvalue rule, which suggests that the number of factors equals those with an eigenvalue higher than 1 (Raykov & Marcoulides, 2011). We expected to find one latent factor underlying the observed measures. If more than one latent factor was found at this stage, oblique rotation was performed. All items that did not meet the threshold (a factor loading of 0.50) or cross-loaded (loaded more than the threshold on two or more factors) were dropped from the scale.

3.3.3. Scale reliability

Scale reliability is a measure of whether items would generate similar or identical responses if they are re-administered to the same survey respondents (Cronbach, 1951; Santos & Reynaldo, 1999). It is a test of consistency, repeatability, and reproducibility (Jepson et al., 2017). The most common method for measuring scale reliability is Cronbach's α, which assesses the internal consistency of the scale items. In other words, this coefficient examines the degree to which the set of items in the scale co-vary with the total scale score (Cronbach, 1951; Devellis & Thorpe, 2021; Santos & Reynaldo, 1999). Cronbach's alpha values range from 0 to 1, with higher values indicating greater reliability (Santos & Reynaldo, 1999).

In accordance with previous studies, an alpha coefficient of 0.7 or greater, using the ordinal variables, will be deemed acceptable for the purposes of the present research.

3.3.4. Scale validity

Scale validity refers to the extent to which the instrument measures the construct it was developed to evaluate (Raykov & Marcoulides, 2011).

Predictive validity

Predictive validity, as a form of criterion validity, tests the ability of a scale to predict future water insecurity-related outcomes (Boateng et al., 2018b; Nounkeu et al., 2021). The predictive construct validity was assessed by determining whether the final scale scores predicted individual water insecurity (Bethancourt et al., 2022) and satisfaction with the household water situation.

Convergent validity

Evidence of convergent validity of a construct can be provided by how strongly the developed scale correlates with other variables designed to measure the same construct (Raykov & Marcoulides, 2011). The convergent validity, as a form of construct validity, was assessed by examining the correlation between the final scale scores and two dichotomous variables: (1) perceptions of tap water quality (=1 Good or rather good; =0 Otherwise), known, based on previous research, to be related to water insecurity; and (2) the household water supply situation during summer (=0 More than a few hours to one full day of continuous supply each 3 to 4 days, e.g., a few hours to one full day of continuous supply each 2 to 3 days; =1 a few hours to one full day of continuous supply each period longer than 3 to 4 days).

Discriminant validity

Discriminant validity, as a form of construct validity, refers to the degree to which scores on an instrument under study are differentiated from the behavioral manifestations of other constructs that theoretically can be expected to be unrelated to the construct being studied (Raykov & Marcoulides, 2011). This type of validity is indicated by the absence of correlation between the measure of interest and other measures that supposedly do not measure the same variable or concept. The discriminant validity was assessed by examining the correlation between the final scale scores and a dichotomous variable representing respondents' tap water storage practices (=1 Storing tap water; =0 Otherwise).

Discriminant construct validity can also be tested using differentiation between 'known groups' to examine whether the measured concept behaves as expected in relation to groups known to have different water situations (Boateng et al., 2018b; Young et al., 2019a).

The student's t-test was conducted to compare the household water insecurity scores for two groups of households: those connected to the national operator's network and those connected to user associations' networks. We aimed to determine that the final scale performed identically for both subgroups.

4. RESULTS

4.1. Semi-structured interviews: Key findings

The semi-structured interviews offered context-specific insights into water insecurity that are not fully captured by the examined existing scales. The qualitative findings highlight locally salient dimensions of water insecurity and led to combining, deleting, and formulating the selected set of items from the existing scales and make the version of the scale to be tested.

This phase resulted in a fifteen-element scale (Table 1), with each element—except for items 8 and 13, which are binary—scored on a six-point Likert-type scale measuring the severity or

Table 1. Household Water Insecurity Scale for validation

How frequently, on average per month, over the past 12 months has your main water source been interrupted or limited?

1. did you lack water with no alternative way of getting water immediately to meet the basic needs of your household (direct consumption, food preparation and hand washing)?
2. were you obliged to fetch water due to the irregular water supply?
3. have you had to adapt your schedule (wake up earlier or sleep later than usual time/cancel an income-generating activity) to get prepared for an expected or unexpected interruption by storing tap water or to fetch water?
4. were you not able to drink tap water because it tasted and/or smelled bad?
5. have you had to drink water from an uncontrolled source (natural e.g.: springs or untreated e.g.: vendors) due to frequent interruptions or poor tap water quality?
6. were you not able to practice basic personal hygiene because of long interruptions or poor tap water quality?
7. were you not able to finish the household chores due to sudden or long water interruption?
8. did you stop raising livestock due to the irregular water supply?
9. did you feel worried about not having enough water to meet the needs of your household?
10. has your water access situation caused you to feel ashamed/stigmatized?
11. did you get into an argument or fight with neighbors or local managers due to water access-related issue (e.g.: with local managers due to lack of maintenance of existing infrastructure or while queueing for water at a water point that you regularly use because of long interruptions and/or poor quality of tap water?)
12. did you observe differences in the frequency and duration of interruptions in your neighborhood?
13. has the situation worsened compared to the previous year (more frequent interruptions and/or increasingly degraded quality of tap water)?
14. did you feel sick after drinking tap water?
15. did you feel sick after drinking water from an uncontrolled source that you regularly use due to long interruptions and/or poor quality of tap water?

Table 2. The six-point Likert-type scale

0	1	2	3	4	5
Never / Sometimes in winter and summer	Never/Sometimes in winter and often in summer	Never/Sometimes in winter and always in summer	Often in summer and winter	Often in winter and always in summer	Always in summer and winter
	Never/Sometimes in summer and often in winter	Never/Sometimes in summer and always in winter		Often in summer and always in winter	

Never/Sometimes = 0 to 5 times / month; Often = Fewer than 15 times / month ; Always = More than 15 times / month frequency of experiences (Table 2). This six-point Likert-type scale, along with the time reference, was designed to capture the effects of seasonal variability.

The responses are ordered based on our expectation of increasing severity of water insecurity, assuming that certain situations reflect greater severity than others. The description "Often in summer and winter" is considered to be more severe than "Never/Sometimes in winter and always in summer". This assumption was made because the former description might reflect issues related to infrastructure, necessitating immediate intervention. The following pairs of descriptions, respectively: 1) "Never/Sometimes in winter and often in summer" and "Never/Sometimes in summer and often in winter", 2) "Never/Sometimes in winter and always in summer" and "Never/Sometimes in summer and always in winter", and 3) "Often in winter and always in summer" and "Often in summer and always in winter" carry the same level of severity.

The 15-item scale included an introductory question to determine the respondent's eligibility to continue with the rest of the questionnaire (Table 1).

4.2. Item reduction analysis

A series of analyses was conducted on the results of a small-scale survey (51 households), beginning with item reduction. The ratio of responses per item, 3.4 (51 responses / 15 items), was below the recommended minimum of 10 responses per item (Boateng et al., 2018b).

Three items – stop raising livestock (8.), feeling sick after drinking tap water (14.), and feeling sick after drinking water from an uncontrolled source (15.) – had percentages of missing cases higher than 10%, 53%, 22%, and 24%, respectively (Table 3). Consequently, these statements were deleted from the scale.

Checking for multicollinearity among the items was an important initial step in performing the item reduction analysis. A collinearity coefficient greater than 0.9 indicates that a pair of items measures the same aspect of the underlying construct. Examining multicollinearity to identify and remove the most redundant items early in the process did not reveal any pairs of items with high collinearities.

Item difficulty indices were computed to represent the proportion of affirmative answers to each element. Acceptable values range from 0.3 to 0.8, as suggested by Nounkeu et al. (2021). Item discrimination indexes were computed using the point-biserial correlation coefficient of affirmative answers to the total score, with acceptable values ≥ 0.4 (Ebel & Frisbie, 1991).

Table 3. Rationale for dropping items

Analysis informing decision	Numbered dropped element	Rationale
Descriptive statistics	8. Stop raising livestock	Missing values
	14. Feeling sick after drinking tap water	Missing values
	15. Feeling after drinking water from an uncontrolled source	Missing values
Inter-item and item-total correlations	12. Spatial heterogeneity	Poor item-total correlation
Item difficulty index and/or Item discrimination index	1. Running out of water	Low item difficulty index
	5. Drinking water from an uncontrolled source	Low item difficulty and discrimination indices
	9. Feeling worried	High item difficulty index
	11. Conflicts	Low item difficulty and discrimination indices
	12. Spatial heterogeneity	Low item discrimination index
	13. Temporal heterogeneity	High item difficulty index
Cronbach's alpha	4. Not able to drink tap water	Its deletion increased Cronbach's alpha

This represented the extent to which respondents who answered affirmatively to a particular element had a high total water insecurity score.

Three items – running out of water (1.), feeling worried (9.), and temporal heterogeneity (13.) – did not meet the thresholds of the item difficulty index. Therefore, they were excluded from the scale. Two items referring to drinking water from an uncontrolled source (5.) and conflicts (11.) did not meet the thresholds of the item difficulty index. Additionally, their discrimination indices were below 0.4. They were also removed from the scale. The element referring to spatial heterogeneity (12.) was eliminated based on a poor item-total correlation coefficient and a low item discrimination index (Table 3).

4.3. Factor analysis

The p-value of the Bartlett's test of sphericity (<0.05) provided evidence against the null hypothesis that the items were not intercorrelated. The remaining items were intercorrelated, allowing to proceed with factor analysis.

Exploratory factor analysis revealed one factor with an eigenvalue greater than 1 (an eigenvalue of 2.82). The remaining items loaded positively on this factor, with factor loadings ranging from 0.44 to 0.82.

4.4. Scale Reliability

The resulting six-element scale was internally consistent, as suggested by its Cronbach's alpha of 0.74. This coefficient indicated an acceptable level of internal consistency, demonstrating a good reliability of the resulting scale. We sequentially tested removing each element one at a time from the scale and recalculated the Cronbach's alpha after each deletion. The goal was to determine whether removing any item would cause the Cronbach's alpha to increase, and thus improve the internal consistency and reliability of the scale. The results showed that removing the element referring to the inability to drink tap water because it tasted and/or smelled bad (4.) and holding the smallest factor loading (0.44) appreciably increased the Cronbach's alpha from 0.74 to 0.8 (Table 3). Conceptually, this item captures perceived acceptability (taste/smell) of available water rather than the broader experiential construct of household water insecurity measured by the remaining items. In this context, taste/smell concerns may reflect preferences and therefore do not necessarily co-vary with experiences of scarcity or access disruption.

4.5. Scale Validity

The household water insecurity score ranged from 0 to 25, with higher scores indicating greater household water insecurity (Table 4). The predictive construct validity was evaluated by examining whether the five-element scale scores were associated with individual water insecurity status (Bethancourt et al., 2022) and dissatisfaction with the household water situation. There was a significant positive relationship between household water insecurity scores and individual water insecurity scores ($r = 0.8463$, $p < 0.001$). Higher water insecurity scores were also significantly

Table 4. Five-element household water insecurity scale

How frequently, on average per month, over the past 12 months; *has your main water source been interrupted or limited?*
1. were you obliged to fetch water due to the irregular water supply?
2. have you had to adapt your schedule (wake up earlier or sleep later than usual time/cancel an income-generating activity) to get prepared for an expected or unexpected interruption by storing tap water or to fetch water?
3. were you not able to practice basic personal hygiene because of long interruptions or poor tap water quality?
4. were you not able to finish the household chores due to sudden or long water interruption?
5. has your water access situation caused you to feel ashamed/stigmatized?

<table>
<tr><th>0</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th></tr>
<tr><td rowspan="2">Never/Sometimes in winter and summer</td><td>Never/Sometimes in winter and often in summer</td><td>Never/Sometimes in winter and always in summer</td><td rowspan="2">Often in summer and winter</td><td>Often in winter and always in summer</td><td rowspan="2">Always in summer and winter</td></tr>
<tr><td>Never/Sometimes in summer and often in winter</td><td>Never/Sometimes in summer and always in winter</td><td>Often in summer and always in winter</td></tr>
</table>

Never/Sometimes = 0 to 5 times / month; Often = Fewer than 15 times / month; Always = More than 15 times / month associated with higher levels of dissatisfaction with the household water situation ($r = 0.5265$, $p < 0.001$). The latter relationship is in accordance with the findings of Young et al. (2019b).

The convergent validity was assessed by examining the correlation between the five-element scale scores and two variables: (1) perceptions of tap water quality and (2) the household water supply situation. The study found a significant correlation between both variables and the final score, although the correlation coefficients did not reach statistical significance at the 0.01 level (Table 5).

Table 5. Summary of convergent and discriminant validity tests

Type of construct validity	Variables the final score is associated with / Test	Expectations	Results
Convergent validity	Perceptions of tap water quality	Negative correlation	*r = -0.3444, p= 0.0205*
	Household water supply situation	Positive correlation	*r = 0.2788, p= 0.0637*
Discriminant validity	Storing tap water or not	No correlation	*r = 0.2244, p= 0.1384*
	Differentiation between two groups of households according to their water access situations	No difference between groups	*t = 0.9195, p= 0.3630*

The discriminant validity was assessed by examining the correlation between the final scale scores and a variable representing tap water storage practices that was expected to be unrelated to household water insecurity. The results showed that this expectation was met, as there were no statistically significant results at the 0.01 level (Table 5). This result was in alignment with the findings of Nounkeu et al. (2021). This similarity could validate the study's outcomes, as it demonstrated that the result replicated a prior finding, lending support to the fact that storing tap water could be unrelated to household water insecurity.

The discriminant validity was also tested using differentiation between two groups known to have different water access situations–those connected to the SONEDE network and those connected to a GDA network–to determine whether the five-element scale performed identically for both subgroups. The assumption was that there would be no significant difference between the two groups, and the results confirmed this assumption (Table 5).

While the results are statistically significant and align with the a priori hypotheses, the small sample size limits the precision of the estimates and increases sampling variability. A larger sample would reduce uncertainty, strengthening the robustness of the findings.

5. DISCUSSION

In this study, we developed a scale to capture household water insecurity in rural Tunisia. While the research has certain limitations—particularly the small sample size—it also has notable strengths, including a structured approach and careful integration of the local context. The findings provide a useful starting point for future refinement and testing of the scale in broader settings.

One limitation is the absence of cognitive interviews to verify whether the proposed items were fully understandable and answerable. Another is the small sample size, influenced by time and funding constraints, as well as the focus on a single region in northern Tunisia. A larger, more regionally diverse sample would enable more robust testing of the scale's reliability and validity, and allow for broader generalization to different rural settings. Given the ratio of responses per item, this work should be considered a pilot study, requiring further investigation.

The scale items were adapted from previous studies (Bisung & Elliott, 2018; Young et al., 2019b; Nounkeu et al., 2021) and tailored to the specific setting of the study area through interviews with GDA committee members and water experts. We believe this process helped capture the full range of relevant experiences of water insecurity. Our findings also align with previous research indicating that water insecurity can occur even in contexts where universal water access exists (Radonic & Jacob, 2021).

To reduce recall bias from seasonal variation in water interruptions, items referred to experiences over the past 12 months. Similar to Tsai et al. (2016), our study recognized the importance of water for both drinking and non-drinking uses, such as personal hygiene, household chores, and livestock care.

Factor analysis revealed a unidimensional structure despite including items that addressed diverse aspects—availability, quality, coping strategies, health risks, and emotional impacts.

By quantifying lived experiences of water insecurity, refined and validated future versions of the 15-item scale could support needs assessments and evaluate interventions (e.g., pre- and post-intervention comparisons), as suggested by Bisung and Elliott (2018). For SONEDE and GDAs, these experience-based measures could complement technical indicators by pinpointing where and when unmet demand, intermittent supply, and reliability concerns are most acute. Integrated into monitoring systems, the scale could inform prioritization of maintenance, rehabilitation, and short-term mitigation measures, while enabling transparent tracking of service improvements over time. At the policy level, embedding such indicators within rural water monitoring frameworks could strengthen early-warning capacity for seasonal stress, support equity-oriented planning, and provide a consistent basis for comparing intervention performance across communities and governance arrangements. However, further testing and refinement are necessary before the scale can be widely applied. It would also be valuable to compare our 51-household sample results with those from a larger sample meeting the recommended standard of more than 10 responses per item, to determine whether the sample size meaningfully influenced the findings.

6. CONCLUSION

While efforts have been made to improve individual water access, little attention has been paid to understanding the lived experiences of water insecurity in rural areas in Tunisia. The study used a structured, phased approach to explore how rural households in Tunisia experience water insecurity in the context of piped but intermittent water supply. This approach, grounded in local input and household responses, helped identify specific aspects that may not be adequately captured by existing scales. These findings provide a starting point for refining measurement tools that reflect the realities of water insecurity in this setting.

The 15-item scale captures both tangible and emotional dimensions of water insecurity through clearly worded, concise items. While promising in its design, the tool requires further validation with larger and more diverse samples to ensure its reliability and broader applicability.

This study offers an initial step toward identifying the dimensions of household water insecurity in piped rural settings in Tunisia. Further research is needed to assess whether the items are consistently relevant across other rural areas, and whether they allow for valid comparisons between groups. Future testing in more diverse samples will be essential for establishing the reliability and utility of this tool in supporting targeted interventions.

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