frontiers | Frontiers in Water

TYPE Original Research
PUBLISHED 21 August 2024
DOI 10.3389/frwa.2024.1423237

Who is more water insecure? Gendered evidence from urban Pakistan

Sidra Khalid[1]*, Mohsin Hafeez[2] and Sohaib Aqib[3]

[1]International Water Management Institute, Islamabad, Pakistan, [2]International Water Management Institute, Lahore, Pakistan, [3]Faculty of Economics and Administrative Science, Department of Economics, Near East University, Nicosia, Cyprus

Check for updates

OPEN ACCESS

EDITED BY
Gemma Carr,
Vienna University of Technology, Austria

REVIEWED BY
Sara Nowreen,
Bangladesh University of Engineering and Technology, Bangladesh
Priyam Das,
University of Hawaii at Manoa, United States

*CORRESPONDENCE
Sidra Khalid
s.khalid@cgiar.org

RECEIVED 25 April 2024
ACCEPTED 31 July 2024
PUBLISHED 21 August 2024

CITATION
Khalid S, Hafeez M and Aqib S (2024) Who is more water insecure? Gendered evidence from urban Pakistan. *Front. Water* 6:1423237. doi: 10.3389/frwa.2024.1423237

Gender and social dimensions of access to and use of water resources are often overlooked in policy and programming despite their importance in shaping water security. This study examines factors affecting water security in urban Pakistan through a gender lens. We surveyed 560 men and women in two towns in Islamabad and Rawalpindi facing water and sanitation challenges. Through a binary logit model and marginal effects analysis, we analyzed the relationship between water security and multiple variables, including gender, education, age, employment status, payment for water, urban wealth quintile, drinking water source, individual water concern level, water satisfaction, and water quality perception. While more than 50 percent of both genders experience water insecurity, the prevalence of water insecurity is notably higher among women. Men in the surveyed population had higher levels of employment, wealth, and education levels compared to women. The regression analysis across both genders reveals that paying for drinking water negatively and significantly impacts water security, while concern about future water issues, satisfaction with drinking water, and water quality significantly and positively impact water security levels. For women specifically, access to improved drinking water sources, higher education levels, and employment significantly improve their water security level, underscoring the importance of promoting women's education and economic empowerment. For men, age and wealth levels emerged as significant factors impacting their water security, with older men more vulnerable to water insecurity than younger men and women. These findings underscore the complex interplay of individual, social, and structural dynamics shaping water security experiences, emphasizing the need for gender-responsive and intersectional approaches to water interventions in urban Pakistan and beyond. Equitable water policies and programs necessitate the collection of more disaggregated data. This study marks the first application of the Individual Water Insecurity Experiences (IWISE) Scale used in Pakistan's urban context, with recommendations for its broader implementation to improve decision-making that can lead to sustainable water solutions across diverse gender and social groups.

KEYWORDS
gender, water security, urban, Pakistan, water insecure, IWISE Scale

1 Introduction

Water is essential for life and fundamental for the health and wellbeing of individuals, societies, and nations. However, access to clean and reliable water sources is not always equitable or uniform, and this disparity disproportionately impacts historically marginalized groups, particularly in low-income countries (IPCC, 2023). Climate-induced water scarcity has contributed to around half of the world's population

10.3389/frwa.2024.1423237

experiencing water insecurity, with Asia and African urban areas being high-risk locations for water insecurity and related climate impacts (IPCC, 2023). Further, water is intricately linked with the economy, politics, culture, gender, and power relations; the way water is acquired, used, and controlled often mirrors social inequalities (Das, 2017). Thus, water insecurity acts as a driver of social polarization, civil unrest, and political instability (World Economic Forum, 2023).

1.1 Understanding water security

Water security has been defined, conceptualized, and measured in multiple ways (Cook and Bakker, 2012; Jepson W. E. et al., 2017; Gerlak et al., 2018; Octavianti and Staddon, 2021). The four major domains of water security include aspects of availability, accessibility, use, and stability or reliability (Young et al., 2021b). Quantity, quality, affordability, and safety are also highlighted as critical components which fall under these domains (Venkataramanan et al., 2020; Young et al., 2021b; Tallman et al., 2023). Widely recognized definitions of water security are drawn from UN Water, The World Bank, and the Global Water Partnership (GWP). These definitions emphasize the availability of acceptable quantity and quality of water, access to safe water at an affordable cost, protection of the natural environment, and the capacity to safeguard access to water for sustaining livelihoods, human wellbeing, and socio-economic development, all within a climate of peace and political stability (Global Water Partnership, 2000; Grey and Sadoff, 2007; UN Water, 2013). An additional framing expands the notion of water security as a relational "hydro-social process" that accounts for the role of broader social and political relations in how water is organized, used, and controlled by different social groups (Jepson W. et al., 2017). Water security is also evaluated differently across sectors (i.e., agriculture, public health, energy, etc.), across scales (e.g., from individual, household, community, national, to regional level), across geographies, and even by the type of water source being examined (surface water, groundwater, rainwater, etc.) (Cook and Bakker, 2012; Gerlak et al., 2018; Octavianti and Staddon, 2021).

Water insecurity, then, occurs when one or more of the above-mentioned components is missing or disrupted, hindering productive and social activities and threatening wellbeing (Jepson W. E. et al., 2017). Water insecurity can be captured by metrics such as supply levels, presence of water-related conflicts, inadequate infrastructure, unequal distribution of water resources/poor management, socio-economic disparities, psychosocial variables, and environmental degradation (Gerlak et al., 2018; Young et al., 2021b). Water insecurity can manifest in different forms and degrees, ranging from occasional shortages or water quality issues to chronic and severe water crises affecting entire regions or populations (Young et al., 2021b). If left unchecked, water insecurity can threaten human health and economic development, exacerbate social inequalities, and weaken ecosystems and biodiversity.

1.2 Water insecurity in Pakistan

Pakistan's most pressing issue is its water crisis, impacting public health and the economy, with implications for national security at large (Mustafa et al., 2013; Klare, 2020). The country faces severe water scarcity, compounded by climate change and a growing population of around 241.5 million (Pakistan Bureau of Statistics, 2023). Inadequate water storage systems, rising groundwater depletion, poorly implemented conservation strategies, inefficient water management, and weak governance mechanisms further drive the country toward water insecurity (Ashraf, 2018; Shah et al., 2022). For example, Pakistan has only 30 days of carry over capacity of water in comparison to India with 170 days, Egypt with 700 days, and the USA with 900 days (Malik et al., 2019). Water quality continues to deteriorate over time in both urban and rural areas and poses a huge public health risk (Ishaque et al., 2024). Additionally, despite improvements in water, sanitation, and hygiene (WASH) infrastructure, access to improved water and sanitation varies widely between urban and rural areas, in part due to poor sewerage and drainage systems, with implications on poverty levels (Mansuri et al., 2018). Of further concern, Pakistan ranks "critically insecure," the lowest category, in the United Nations University Global Water Security 2023 Assessment, evaluated across 10 components of water security, including drinking water, sanitation, water quality, water availability, and water governance (MacAlister et al., 2023). In particular, the report highlights Pakistan's limited access to clean water and sanitation services, high WASH-related mortality rates, water shortages and contamination, high vulnerability to droughts and floods, and weak implementation of integrated water resources management (MacAlister et al., 2023). Water insecurity in Pakistan is a ticking time bomb, with vulnerable groups on the front lines.

1.3 Gender components of water insecurity

Water insecurity is experienced by people in different ways, with women and girls disproportionately impacted (Fleifel et al., 2019; Tandon et al., 2022). This includes heightened vulnerability to psychosocial stress and mental health impacts (Wutich and Ragsdale, 2008; Stevenson et al., 2012; Mushavi et al., 2020; Brewis et al., 2021). Globally, women and girls are the primary water collectors and responsible for water distribution and management within the household and for water-related domestic tasks (Sorenson et al., 2011; Graham et al., 2016; Geere and Cortobius, 2017), though this varies across contexts. This increases their time burden, reduces income-earning opportunities and leisurely time, and adds to their mental load (Tomberge et al., 2021). Water insecurity is also tied to poor education and economic outcomes for women (Robson et al., 2013; Kher et al., 2015; Demie et al., 2016; Dhital et al., 2022; UNICEF and WHO, 2023), with adverse effects on their physical wellbeing (Truelove, 2011; Bisung and Elliott, 2017; Geere et al., 2018; Kayser et al., 2019; Pouramin et al., 2020; De Guzman et al., 2022) and mental health (Bisung and Elliott, 2017), including higher risk for depression (Cooper-Vince et al., 2018). Poor WASH, including menstrual hygiene management (MHM), is also directly correlated with increased disease burden for women and girls (Pouramin et al., 2020). Water insecurity also impacts infant feeding practices (Geere and Cortobius, 2017; Fleifel et al., 2019; Schuster et al., 2020) and is positively associated with food insecurity and poor nutritional outcomes (Brewis et al., 2019; Young et al., 2021b, 2023; Bethancourt et al., 2022).

Additionally, gender-based violence is linked to water insecurity, in the form of emotional, physical, and sexual abuse, intimate partner violence, and verbal attacks/disputes, disproportionately faced by women and girls (Truelove, 2011; Sommer et al., 2014; Tallman et al., 2023). This includes animal attacks and physical injuries while navigating unsafe terrains to access water (Pommells et al., 2018). Because women have lower political and decision-making power related to water management as compared to men, their voices and concerns are often disregarded (De Guzman et al., 2022), leading to a loss of bargaining power. In contexts where women do participate in community-based water governance setups, such as Water User Associations (WUA), their roles are often tokenistic and devoid of any real power, illustrating that even community-based organizations can become "spaces of exclusion" if equitable participation and decision-making are not practiced in true letter and spirit (Adams et al., 2018).

1.4 The need for disaggregated water data

Despite calls to collect more sex- and gender-disaggregated data in the WASH sectors (Caruso and Sinharoy, 2019), there is still a large gap in gender water data in research, particularly when designing and assessing impact of water programs (UNESCO, 2021). In a comprehensive report published by the World Bank on Pakistan's water security situation, the twelve high-level recommendations outlined to improve water security made no mention of gender and social inclusion considerations, including the collection of disaggregated water data or conducting differential impact analyses (Young W. et al., 2019). As there is no one-size-fits-all approach to addressing water insecurity, policies and interventions must be tailored to the specific socio-demographic and cultural characteristics of different geographies (Quandt et al., 2022). Without collecting disaggregated water data, designing said policies and interventions is difficult if decision-makers have no evidence on which groups of people experience water insecurity, and to what extent.

Moreover, only collecting household level water data may overestimate equitable water use and access among household members, as cultural norms or physical limitations may prevent women from accessing different sources of water (Patrick et al., 2023). In a review of monitoring tools for gender and WASH targets of the Sustainable Development Goals (SDGs), Caruso et al. (2021) found that majority of indicators and monitoring are targeted at households, schools, healthcare facilities, and communities, with very few capturing individual-level experiences. Assessments at the individual level, however, may provide better insight and allow for a more precise measurement of water insecurity, overcoming some of the gaps in household level data. The Water Insecurity Experiences (WISE) Scales are a set of survey tools that can effectively capture disaggregated water insecurity experiences, including at the individual level.

The WISE Scales capture water insecurity experiences across the domains of adequacy, reliability, accessibility, and safety (Young S. L. et al., 2019). It is a reliable and validated tool used across low- and middle-income countries (LMICs) and aims to capture universal human experiences of water insecurity—to "bring the voice of the people to the water sector" (Young et al., 2024a). There are two versions: the Household Water Insecurity Experiences (HWISE) Scale and Individual Water Insecurity Experiences (IWISE) Scale. Both are comprised of the same 12 questions worded at either household or individual level. Currently, nationally representative IWISE data of 40 LMICs has been collected and assessed, highlighting differences in water insecurity levels across gender, age, rural and urban areas, and household wealth quintiles (Young et al., 2024b). The WISE Scales have not been widely used in Pakistan; during tool validation, only the HWISE Scale was tested in Pakistan (approximately 250 households) in rural areas of Punjab province (Stoler et al., 2021).

1.5 Study rationale and objectives

Despite the critical importance of water security in Pakistan, there is a significant gap in understanding how water insecurity is experienced differently by men and women, particularly in urban contexts. Existing studies on urban water security in Pakistan are limited and have not employed the WISE Scales in their assessments (Fatima and Leghari, 2020; Khan and Arshad, 2022; Shah et al., 2022). Gender-specific studies are even more rare (Anwar et al., 2019) or focus on rural contexts (Ahmed F. et al., 2020; Lanjwani et al., 2023). Only one study has highlighted the importance of collecting disaggregated data as a priority action for improving water security, though the study itself did not involve any primary data collection (Syvrud et al., 2020).

An overlooked aspect of water insecurity research, which this study aims to address, is understanding how gender interacts with other socio-economic and WASH variables to impact experiences of water insecurity. Even within the same household, women often experience water insecurity more severely and more frequently than men (Tsai et al., 2016), highlighting the limitations of relying solely on household level data and the importance of considering intra-household experiences. Current literature suggests that water is a gendered resource, with calls for integrating a feminist political ecology framework which analyzes embodied water experiences to better understand the complex dynamics involved in water access, use, and control across socio-cultural and political contexts (Sultana, 2011; Truelove, 2011, 2019; Nunbogu and Elliott, 2021; Adams et al., 2022). This framework allows for a feminist and intersectional analysis of water security that goes beyond technocratic measurements of water quantity, quality, source, and affordability—common indicators in water programming (Wutich et al., 2017)—to allow for more nuanced understanding of water inequalities across gender and social groups. In some cases, men are more water insecure than women (Young et al., 2022), and this can only be discovered through more thoughtful context-specific gender analyses.

Given the severity of water insecurity in Pakistan and its disproportionate impact on women and marginalized groups, there is a need to collect and analyze sex-disaggregated data. This data is crucial for designing effective policies and interventions that address the specific needs of different social groups and ensure equitable access to water resources. The present study aims to fill the gender water data gap in Pakistan and is, to the authors' best knowledge, the first which employs the Individual Water Insecurity Experiences (IWISE) Scale in Pakistan specifically within an urban context. The main objective of this study is to evaluate the level of water insecurity experienced by men and women and how socio-economic and WASH-related variables influence water security status. We use a binary logistic model, including marginal effects calculation, to assess this relationship.

2 Methods

2.1 Study area

We employed quantitative research methods to administer a survey to men and women in two urban towns in the capital city of Islamabad and neighboring Rawalpindi, Pakistan (referred to as the "twin cities") using multi-stage cluster random sampling (Figure 1). The twin cities face immense water security challenges. Climate change, urbanization, rising water demands, groundwater depletion, water-related health risks, and weak regulatory systems create the perfect storm for the ongoing water crisis (Ahmed T. et al., 2020). Islamabad's current water supply of around 45 MGD (million gallons per day) is insufficient to meet the approximately 246 MGD water demand (Hafeez, 2022), while groundwater across both cities is depleting at a rate of 1.7 meters per year (Hafeez, 2023). The two towns—Farash Town in Islamabad and James Town in Rawalpindi—were selected due to their ongoing problems with water, including poor quality and supply, issues with affordability, and inadequate sanitation and drainage facilities. Farash Town falls under Islamabad's Capital Development Authority's jurisdiction, meaning it is administratively planned and built with distinct streets, while James Town is located within Rawalpindi with no formal planning or infrastructure, including water supply and proper roads.

2.2 Sampling

We employed a multi-stage cluster random sampling method to select households for the survey. Sample size was determined using UNICEF (2024) Multiple Indicator Cluster Survey (MICS) sample size calculator with a design effect of 1.5 and a 95% confidence interval. First, using Google Earth Maps, the boundaries of both towns were marked to accurately delineate their perimeters. Next, within each town's boundaries, clusters were marked at the beginning of each major street or lane within the towns, and location pins were dropped at regular intervals of 40 meters to systematically cover the entire geographic area of each town. Using the MICS calculator, a total of 40 clusters were distributed proportionally between both towns based on population distribution, resulting in 28 clusters for Farash Town and 12 clusters for James Town. A total of 14 interviews were conducted per cluster.

Households were selected through systematic randomization. Starting from the designated cluster point location pin assigned to each enumerator, households were selected by systematically approaching every third household on the right-hand side of the street or lane for participation in the survey. If a selected household declined to participate, the subsequent household in the sequence was approached until 14 households per cluster were surveyed. Male and female enumerators surveyed respondents of the same sex to ensure cultural comfort. This systematic approach ensured uniform distribution within each cluster, minimized selection bias, and ensured a representative sample for the study. Households served as the entry point for individual-level data collection with either a male or female respondent who were preferably head of the household (HH), primary breadwinner, spouse of either, or household elder (i.e., someone aware of the details concerning the HH's water and sanitation situation). Respondents had to be living in the area for at least 1 year to ensure they could adequately speak to community water and sanitation issues. The inclusion criteria for the sample were women and men aged 18 to 60 years living in the selected towns.

Based on the population sizes of the two towns and the MICS calculator, the total sample size calculated was 560 respondents, outlined in Table 1. Only self-identified men and women were surveyed. However, it is acknowledged that other gender identities exist within the population of Pakistan. Future research may further explore nuances of water insecurity across diverse gender groups.

2.3 Data collection and analysis

Data collection was conducted with electronic tablets using SurveyCTO data collection software to administer the survey. A group of 8 trained male and female enumerators were assigned clusters within each town and conducted four interviews per day over the course of 2 weeks in September 2022. The data were analyzed through statistical software packages (SPSS and STATA) and were sex-disaggregated across each question. Pre-testing was done before the finalization of the tool. Around 5% of the total sample size (around 25) were surveyed during pre-testing in adjacent towns. The pre-testing allowed corrections in the tool (e.g., question skips, rephrasing questions for clarity) and improvement in the local language (Urdu) translation.

SPSS was used for descriptive analysis and STATA was used for the logit model and calculating marginal effects. Means were calculated for continuous variables and proportions/frequencies calculated for binary and categorical variables. Descriptive data were compiled and further analyzed using Chi-square analysis. Chi-square analysis was used to identify any statistically significant relationships between two categorical variables through cross-tabulation.

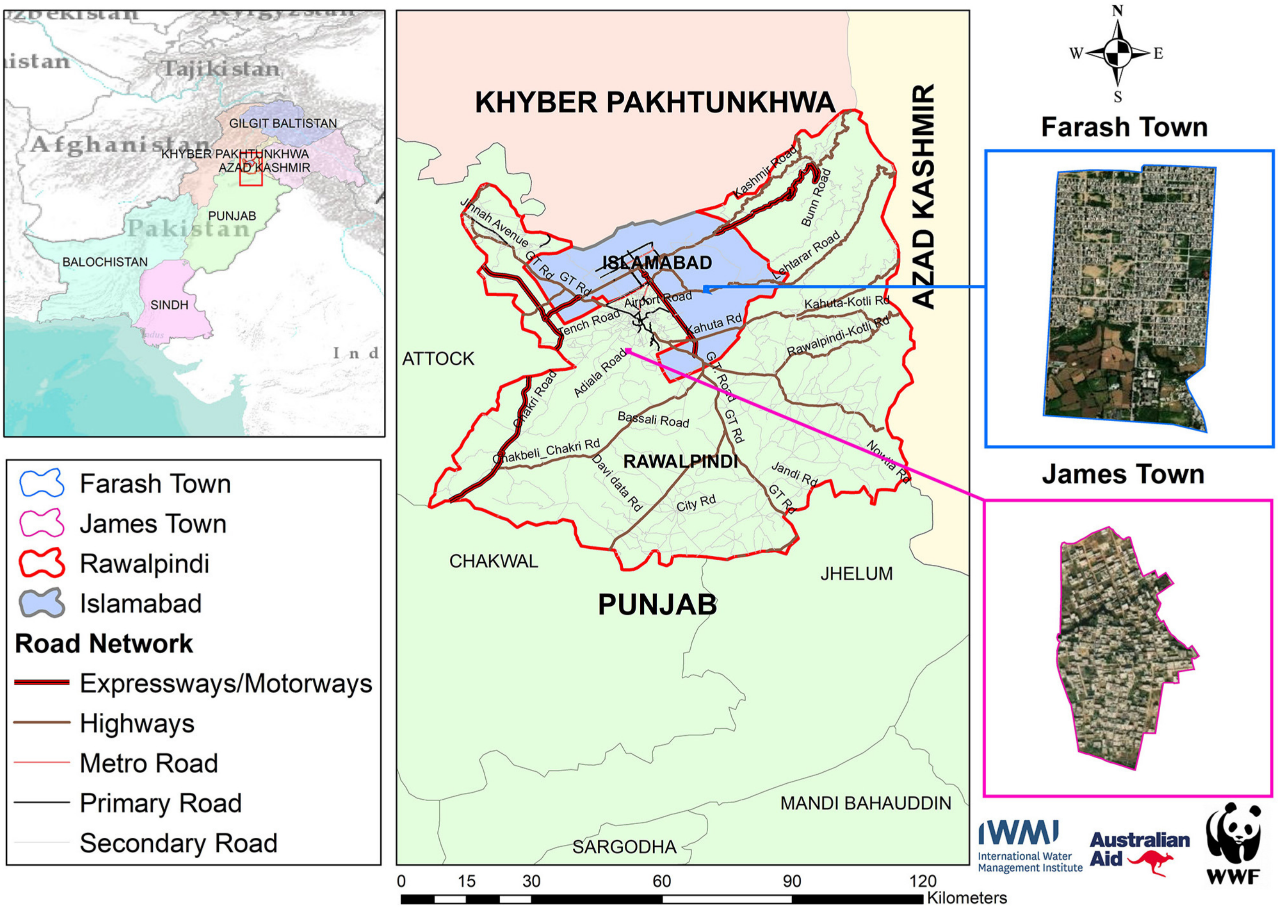

FIGURE 1
Study area map.

TABLE 1 Distribution of sample size.

	Population (Est.)	Number of clusters	Interviews per cluster	Total interviews	No. of men	No. of women
Farash Town	21,000	28	14	392	196	196
James Town	3,500	12	14	168	84	84
Total	24,500	40		560	280	280

2.4 The Individual Water Insecurity Experiences (IWISE) Scale

To measure individual water security, the IWISE Scale was included in the survey, comprising of 12 items to assess the frequency of individual experiences associated with water insecurity across access, use, and reliability (Young et al., 2021a). Each item is assigned a score from 0 to 3, and scores are summed to obtain a total score between 0 and 36. A score of 12 or more is indicative of water insecurity. The IWISE Scale was employed instead of the HWISE Scale because the latter would not be able to offer comparisons between men and women.

2.5 Index for assessing individual concern levels regarding water issues

An index was developed from survey questions to assess individual concern levels (ICL) related to water issues. Key indicators included concern about water availability, water contamination, water storage, flooding, sanitation, water cost, and climate change. The survey included a total of 7 questions related to concern level. Responses were coded either 0 (not concerned) or 1 (concerned) for each indicator. The index was calculated as a simple sum of the items using SPSS. Scores 4–7 were classified as "concerned." Scores below 4 were categorized as "unconcerned." Table 2 summarizes the ICL index and its variables.

TABLE 2 Index for assessing level of concern for water issues.

Domains	Variables	Possible score
Individual concern level on water issues (ICL)	Concern about: • Water availability in the future • Water contamination/pollution • Water storage • Flooding during storms/heavy rains • Poor sanitation • Cost of water • Climate change (i.e., change in temperature or weather patterns)	7

Source: Author's creation based on survey questions and literature.

2.6 Binary logistic models and equations for analysis of water insecurity factors

To identify key factors influencing water insecurity (IWISE score), three distinct binary logistic models were used. Model A analyzed the aggregate survey data, and Model B and C analyzed women's and men's responses, respectively. Throughout all three models, the dependent variable (water security) remained the same.

The independent variables (x_i) include gender, payment for water, age, age*gender (iteration term), urban wealth quintile, employment status, drinking water source, ICL scale score, water satisfaction, education level, and water quality. These variables were chosen based on literature, available indicators included in the survey, and the study objective of understanding factors influencing water insecurity.

The following binary logistic model equation for Model A (Equation 1) was used, including all independent variables:

$$\log\left(\frac{P(Y=1)}{1-P(Y=1)}\right) = \beta_0 + i.\beta_1 x_1 + i.\ \beta_2 x_2 + i.\beta_3 x_3 + i.\beta_4 x_4 + c.\beta_5 x_5 + i.\beta_6 x_6 + i.\beta_7 x_7 + i.\beta_8 x_8 + i.\beta_9 x_9 + i.\beta_{10} x_{10} + i.\beta_{11} x_{11} + \varepsilon_i \tag{1}$$

- P(Y = 1): Probability of the dependent variable Y taking the value 1
- *Log(.)*: Natural log
- $\frac{P(Y=1)}{1-P(Y=1)}$: Odds of the event Y = 1

$$y = log\left(\frac{P(Y=1)}{1-P(Y=1)}\right)$$

Here, $P(Y = 1)$ denotes the probability of experiencing water insecurity (Y = 1), while $1 - P(Y = 1)$ represents the probability of not experiencing water insecurity (Y = 0). ε_i represents the error term. y_i^* signifies the binary outcome of IWISE, where 0 indicates water security and 1 indicates water insecurity. The vector β signifies the binary regression coefficients. Each coefficient represents the change in the log-odds of the dependent variable associated with a one-unit change in the corresponding independent variable.

In Model B (women), the binary logistic model (Equation 2) is:

$$y_i^* = \beta_0 + i.\beta_1 x_1 + i.\ \beta_2 x_2 + c.\beta_3 x_3 + i.\beta_4 x_4 + i.\beta_5 x_5 + i.\beta_6 x_6 + i.\beta_7 x_7 + i.\beta_8 x_8 + i.\beta_9 x_9 + \varepsilon_i \tag{2}$$

- Where, $y_i^* = log\left(\frac{P(Y=1)}{1-P(Y=1)}\right)$

Similarly, in Model C (men), the binary logistic model (Equation 3) is:

$$y_i^* = \beta_0 + i.\beta_1 x_1 + i.\ \beta_2 x_2 + c.\beta_3 x_3 + i.\beta_4 x_4 + i.\beta_5 x_5 + i.\beta_6 x_6 + i.\beta_7 x_7 + i.\beta_8 x_8 + i.\beta_9 x_9 + \varepsilon_i \tag{3}$$

With the exception of the gender and age*gender (iteration term) variables, the dependent variable (y_i^*) and independent variables remain the same in both Models B and C, allowing for a gender-specific statistical analysis of the factors influencing water insecurity.

2.6.1 Marginal effects of binary logistics model

In binary logistics models, odds ratios show the direction and significance of relationships between independent variables and the probability of the dependent variable (e.g., water security). These ratios measure how likely an event (e.g., water security) will occur between different groups (e.g., men and women). In contrast, marginal effects quantify the change in the probability of the event happening with a one-unit change in the independent variable (e.g., age, education, gender) (Norton et al., 2019). In this study, the odds ratios indicate whether men or women are more likely to achieve water security, while marginal effects quantify how much an independent variable influences the probability of men and women achieving water security.

Marginal effects were calculated to identify potential gender-specific differences in water security.

The calculation of marginal effects:

Assuming the binary logistic regression (Equation 4):

$$\log\left(\frac{P(Y=1)}{1-P(Y=1)}\right) = \beta_0 + i.\beta_1 x_1 + i.\ \beta_2 x_2 + i.\beta_3 x_3 + i.\beta_4 x_4 + c.\beta_5 x_5 + i.\beta_6 x_6 + i.\beta_7 x_7 + i.\beta_8 x_8 + i.\beta_9 x_9 + i.\beta_{10} x_{10} + i.\beta_{111} x_{11} + \varepsilon_i \tag{4}$$

Predicted Probability Calculation (Equation 5):

$$P(Y=1) = \frac{1}{1 + e^{-(\beta_0 + i.\beta_1 x_1 + i.\ \beta_2 x_2 + i.\beta_3 x_3 + i.\beta_4 x_4 + c.\beta_5 x_5 + i.\beta_6 x_6 + i.\beta_7 x_7 + i.\beta_8 x_8 + i.\beta_9 x_9 + i.\beta_{10} x_{10} + i.\beta_{11} x_{11} + \varepsilon_i)}} \tag{5}$$

Summarized equation of probability calculation (Equation 6):

$$P(Y=1) = \frac{1}{1 + e^{-(\beta_0 + \sum_{i=1}^{11} \beta_i x_i + \varepsilon_i)}} \tag{6}$$

2.6.2 Marginal effects calculation (overall model)

$$Marginal\ effect_{X_i} = P(Y = 1) \times (1 - P(Y = 1)) \times \beta_i$$

This represents the change in the probability of the dependent variable (Y = 1) for a one-unit change in the independent variable (X).

2.6.2.1 Comparison of marginal effects for different categories

When comparing genders, with X as the dummy variable representing gender (0 for male, 1 for female), the equation is:

$$Marginal\ Effect_{female} = P\left(Y = 1 \middle| female\right) - P\left(Y = 1 \middle| Male\right)$$

This represents the change in the probability of the dependent variable (Y = 1) between men and women, holding all other variables constant.

3 Results

3.1 Socio-demographics

The sociodemographic profile of the study population is summarized in Table 3. More women are married than men (86% vs. 68%) and most live in joint family systems. The average household size is 8 members, and the average number of children is 4. In terms of education, more women are uneducated (35% vs. 20% for men), while more men have intermediate or higher education levels (67% vs. 51% for women). The majority of women are unemployed (84% vs. 24% for men), implying they are homemakers. Men reported higher household incomes, with an average monthly income of PKR 41,098 (USD 148), compared to PKR 33,526 (USD 120) reported by women.

TABLE 3 Disaggregated socio-demographics.

Gender	Female $N = 280$	Male $N = 280$	Pearson X^2 test
	50%	50%	
Marital status			
Married	86%	68%	$X^2 = 35.2541$ $P = 0.000^{***}$ Cramer's V = 0.2509
Single	11%	32%	
Family system			
Nuclear	51%	37%	$X^2 = 9.9163$ $P = 0.002^{***}$ Cramer's V = −0.1331
Joint/extended	49%	63%	
Age bracket			
17–30 years	34%	43%	$X^2 = 4.1786$ $P = 0.030^{*}$ Cramer's V = 0.0918
31 and above	66%	57%	
Education			
No education	35%	20%	$X^2 = 16.8408$ $P = 0.000^{***}$ Cramer's V = 0.1734
Primary	14%	13%	
Intermediate and higher	51%	67%	
Employment status			
Unemployed	84%	24%	$X^2 = 202.6338$ $P = 0.000^{***}$ Cramer's V = −0.6015
Employed	16%	76%	
Household income			
Average monthly income	PKR 33,526 (USD 120)†	PKR 41,098 (USD 148)	

$^{***}p < 0.01$, $^{*}p < 0.1$. †1 USD = PKR 278.

3.1.1 Urban wealth quintile

Urban wealth quintiles were calculated using Pakistan's Equity Tool survey, which includes a total of 12 questions related to asset ownership, cooking fuel, and household building materials (Metrics for Management, 2020). More women fall in the poor and poorest wealth quintiles as compared to men, while a higher percentage of men fall in the rich and richest wealth quintiles, indicating disparities in wealth distribution between genders (Table 4).

TABLE 4 Disaggregated urban quintile results.

Urban quintile	Women	Men	Significance test p-value
Poorer	15%	10%	
Poor	26%	15%	$X^2 = 28.006$ $P = 0.000^{***}$ Cramer's V = 0.224
Middle	30%	26%	
Rich	18%	29%	
Richest	11%	21%	

$^{***}p < 0.01$.

3.2 Drinking water source, satisfaction, and quality

Respondents were asked of their drinking water source, if they pay for drinking water, level of satisfaction with the drinking water, and water quality perception (Table 5). An equal percentage of men and women reported paying for drinking water. Based on the World Health Organization's (WHO) definitions, majority of men and women use an improved drinking water source (e.g., household connection, public taps, boreholes, and filtration plant) and around a quarter report using unimproved sources (e.g., surface water, vendor-provided water, and tanker-truck provided water). Majority are satisfied with the quality of their drinking water, while more

TABLE 5 Source of drinking water, satisfaction and water quality perception.

Status of drinking water	Women	Men	Pearson X^2 test
Improved source	71%	75%	$X^2 = 1.3112$ $P = 0.252$ Cramer's V = 0.0484
Unimproved source	29%	25%	
Pay for water	46%	46%	$X^2 = 0.000$ $P = 0.000^{***}$ Cramer's V = 0.0000
Drinking water satisfaction			
Dissatisfied	30%	22%	$X^2 = 4.1040$ $P = 0.043^{**}$ Cramer's V = 0.1147
Satisfied	70%	78%	
Water quality perception			
Good	51%	40%	$X^2 = 6.9109$ $P = 0.009^{**}$ Cramer's V = 0.1147
Poor	49%	60%	

$^{***}p < 0.01$, $^{**}p < 0.05$.

men (60%) reported poor drinking water quality despite a higher proportion being satisfied with their drinking water (78%).

3.3 IWISE scores

IWISE Score results show a higher percentage of women are more water insecure than men (Figure 2). Both genders are overall more water insecure than water secure <50% of men and women are water secure but more than 50% are water insecure. Chi-square test indicates a significant difference between the genders ($X^2 = 0.7964$, $P = 0.005^{**}$), suggesting that women are significantly more likely to be water insecure than men.

3.4 Concern about water and sanitation issues (ICL index)

The ICL index scores indicate that majority (more than 80 percent) of men and women are concerned for future water and sanitation issues, with slightly more women not concerned (17%) compared to men (13%) (Table 6).

3.5 Determinants of factors affecting IWISE (binary logit model)

The independent variables in the model include gender, payment for water, age, urban quintile, employment status, drinking water source, ICL scale, water satisfaction, education level, and water quality. The binary logistic regression analysis results are outlined in Table 7 and marginal effects calculations in Table 8 at the end of the section.

Figure 3 below summarizes the variables in the model that have a statistically significant impact on water security for men and women, with detailed results outlined below on all variables.

3.5.1 Gender

The odds ratio results for women suggest they are more likely to be water secure compared to men in the study area (OR: 1.058, SE: 0.403). Since the odds ratio is only slightly above 1, the difference may not be substantial. However, the negative marginal value for women indicates that, all else being equal, being a woman is associated with a 7.37% decrease in the predicted probability of being water secure compared to men (Coef: −0.0737, SE: 0.045). Essentially, women are less likely to be water secure than men. Although this effect was not statistically significant, it underscores gender differences in water security outcomes. While gender does not have statistically significant effects on water security on its own, its interaction with other variables does. Age showed a statistically significant relationship for men only, with older men more likely to be water insecure compared with younger men (OR: 0.531, SE: 0.185). The marginal effects indicate a 9.28% decrease in water security (Coef: −0.0928, SE: 0.052) for each 1-year increase in age for men. Age did not have any significant impact on water security for women, suggesting that other factors play a stronger role for women's water security.

3.5.2 Paying for drinking water

The odds values in all three models are <1, suggesting that men and women who pay for drinking water are less likely to be water secure compared to those who do not pay for their drinking water. This variable is significant at the 1% level for women (OR: 0.377, SE: 0.110), and at the 5% level for men (OR: 0.447, SE: 0.155). The marginal effects show that for women, paying for water is associated with a larger decrease of 18% (Coef: −0.181, SE: 0.054) in water security compared with men experiencing a 12% decrease (Coef: −0.118, SE: 0.051), implying that women who pay for water are more likely to be water insecure than men.

3.5.3 Urban quintile (weath)

Odd ratios indicate that respondents who have higher urban quintile scores (i.e., are wealthier) are more likely to be water secure at 1% level (OR: 1.279, SE: 0.121), and this is statistically significant for men at 5% level (OR: 1.440, SE: 0.207). Specifically, among men this association is statistically significant at the 1% level (OR: 1.440, SE: 0.207). Marginal effects analysis shows that a 1% increase in the urban quintile score corresponds to a 3.1% increase in water security probability for women and a 5.2% increase for men, with statistical significance observed only for men ($p < 0.01$). This suggests that higher wealth among men is strongly associated with improved water security, whereas the relationship is weaker for women.

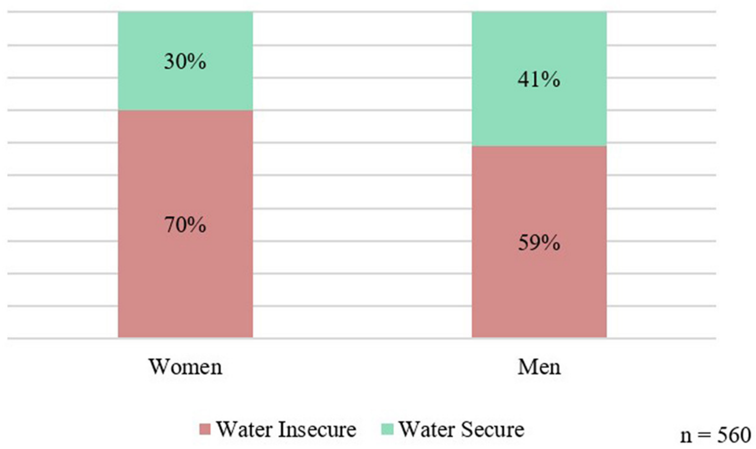

FIGURE 2
Percent distribution of water security status for men and women in study area.

TABLE 6 Individual level of concern (ICL) toward water and sanitation issues.

ICL	Women	Men	Significance test *p* value
Concerned	83%	87%	$X^2 = 19.492$ $P = 0.000^{***}$ Cramer's V = 0.183
Not concerned	17%	13%	

$^{***}p < 0.01$.

3.5.4 Employment status

Employed women are more likely to be water secure compared to those who are unemployed, with results significant at the 5% level (OR: 1.233, SE: 0.433). However, employment status does not significantly impact water security of men. The marginal effects for women indicate that being employed corresponds with a 3.7% increase in probability of water security (Coef: 0.037, SE: 0.061).

3.5.5 Drinking water source

Women who use improved drinking water sources are more likely to be water secure than those who use unimproved drinking water sources, with significant results at the 5% level (OR: 1.327, SE: 0.438). However, water source does not impact water security of men. The marginal effects indicate that women who use an improved drinking water source have a 5% (Coef: 0.05, SE: 0.059) increased probability of water security compared to women who use an unimproved drinking water source, significant at 5% level.

3.5.6 Individual concerned level of water availability in future

Individuals who express greater concern about future water issues are more likely to be water secure, with high significance levels across all models. The marginal effects also reveal a positive and significant relationship, with a 1% increase in level of concern corresponding with a 31.7% (Coef: 0.317, SE: 0.078) and 47.3% (Coef: 0.473, SE: 0.077) increase in water security for women and men, respectively.

3.5.7 Drinking water satisfaction

Individuals who are satisfied with their drinking water are more likely to be water secure compared to those dissatisfied with their drinking water, with high significance levels across all models. The marginal effects also show statistically significant results for men ($p < 0.05$) and women ($p < 0/01$). An increase in drinking water satisfaction levels is associated with a 28.7% increase in water security among women (Coef: 0.287, SE: 0.058) and a 12.7% increase among men (Coef: 0.127, SE: 0.052).

3.5.8 Education

Gender and education level showed a significant relationship for women ($p < 0.05$). Women with higher education levels are more likely to be water secure compared to those with no education (OR: 1.454, SE: 0.599). However, having only primary education did not show any significant impact on water security than those with no education The marginal effects also indicate that increase in education levels lead to greater water security for women. Women with higher education levels have a 6.7% increased probability for water security compared to those with no education (Coef: 0.067, SE: 0.073). However, men's education levels did not indicate any significant influence on their water security.

3.5.9 Drinking water quality

Individuals who report good drinking water quality are more likely to be water secure compared to those who report poor drinking water quality, with significance observed at 1% level for women (OR: 3.228, SE: 0.951) and 5% level for men (OR: 2.123, SE: 0.74). The marginal values indicate that good drinking water quality is associated with an increase of water security by 22.8% (Coef: 0.228, SE: 0.058) and 10.9% (Coef: 0.109, SE: 0.05) for women and men, respectively.

TABLE 7 Binary logistic regression analysis results.

Variables	(A) Combined	(B) Women	(C) Men
Gender (men)			
Women	1.058 (0.403)		
Pay for water (no)			
Yes	0.395*** (0.0865)	0.377*** (0.110)	0.447** (0.155)
Age (17–30 years)			
31 and above Years	1.335 (0.390)	1.345 (0.404)	0.531* (0.185)
Age bracket* gender			
Women 31 and above years	0.429* (0.186)	-	-
Urban quintile	1.279*** (0.121)	1.192 (0.154)	1.440** (0.207)
Work status (unemployed)			
Employed	1.212 (0.331)	1.233** (0.433)	0.346 (0.471)
Drinking water source (unimproved)			
Improved	1.137* (0.277)	1.327** (0.438)	0.875 (0.327)
ICL scale (not concerned)			
Concerned	8.051*** (2.550)	5.562*** (2.584)	12.46*** (5.579)
Water satisfaction (not satisfied)			
Satisfied	4.022*** (1.164)	5.467*** (2.314)	2.569** (1.062)
Education (no education)			
Primary	0.934 (0.357)	0.750 (0.410)	1.248 (0.690)
Higher	1.665* (0.471)	1.454** (0.599)	1.883 (0.763)
Water quality (poor)			
Good	2.681*** (0.593)	3.228*** (0.951)	2.123** (0.740)
Constant	0.0385*** (0.0216)	0.0396*** (0.0303)	0.0425*** (0.0297)
LR chi2 (13)	176.99	82.57	94.05
Prob > chi2	0.0000	0.0000	0.000
Pseudo R2	0.2425	0.2174	0.2749
Observations	560	280	280

Standard errors in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

TABLE 8 Marginal effects of binary logit model.

Variables	(A) Combined	(B) Women	(C) Men
Gender (men)			
Women	−0.0737 (0.0454)		
Pay for water (no)			
Yes	−0.157*** (0.0367)	−0.181*** (0.0537)	−0.118** (0.0510)
Age (17-30 Years)			
31 and above years	−0.0160 (0.0370)	0.0522 (0.0522)	−0.0928* (0.0521)
Urban quintile	0.0400*** (0.0150)	0.0311 (0.0227)	0.0516*** (0.0197)
Work status (unemployed)			
Employed	0.0313 (0.0445)	0.0369** (0.0610)	−0.00634 (0.0642)
Drinking water source (unimproved)			
Improved	0.0210* (0.0399)	0.0505** (0.0592)	−0.0188 (0.0522)
ICL scale (not concerned)			
Concerned	0.389*** (0.0535)	0.317*** (0.0775)	0.473*** (0.0774)
Water satisfaction (not satisfied)			
Satisfied	0.214*** (0.0387)	0.287*** (0.0584)	0.127** (0.0518)
Education (no education)			
Primary	−0.0104 (0.0578)	−0.0489 (0.0922)	0.0286 (0.0722)
Higher	0.0830* (0.0449)	0.0670** (0.0731)	0.0878 (0.0538)
Water quality (poor)			
Good	0.169*** (0.0377)	0.228*** (0.0575)	0.109** (0.0503)
Observations	560	280	280

Standard errors in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

4 Discussion

In this study we evaluated different determinants of water security in two urban towns of Pakistan with a specific gender focus, contributing to the gender water data evidence base that is currently lacking and that does not meaningfully contribute to policy and decision-making in Pakistan (Fatima et al., 2022). Results highlight the multifaceted nature of water security and how the interplay of various factors like socioeconomics, gender dynamics, wealth, water source, and water quality perceptions all play a role in how individuals experience water insecurity.

We found that across the study area, a higher percentage of women are classified as water insecure than men. Across genders, men and women are overall more water insecure than water secure, which speaks to the growing water crisis in the twin cities. Interestingly, the logistic regression results for gender on its own showed that women have slightly higher odds of water security as compared to men, but the negative marginal values suggest that other variables may have a weaker impact on women's actual probability of being water secure compared to men. For example,

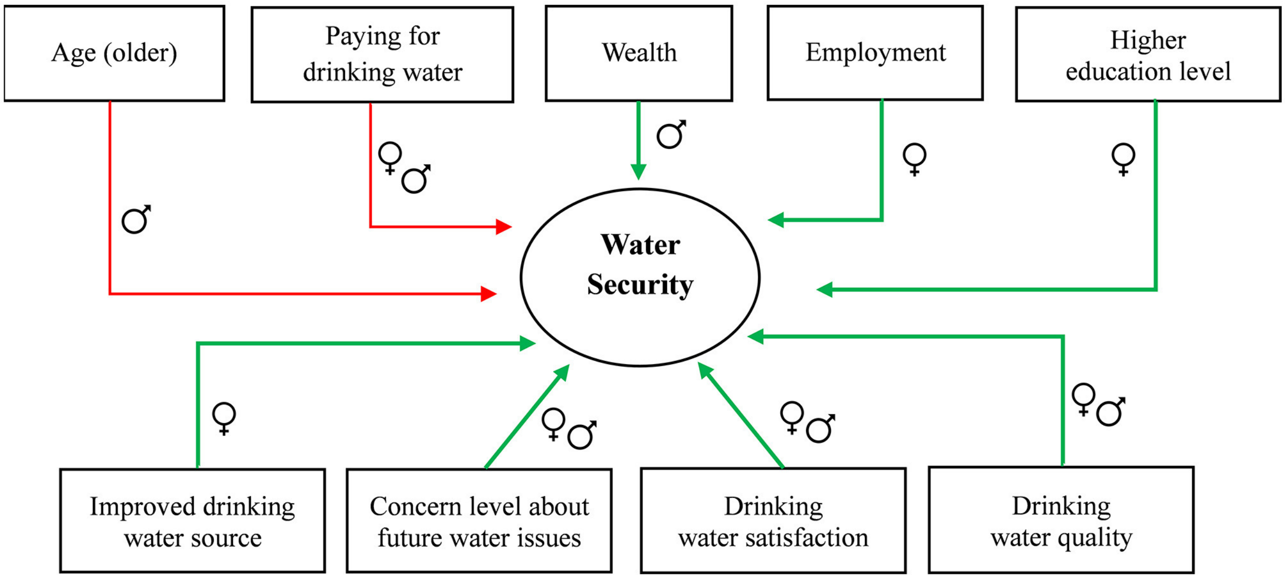

FIGURE 3
Summary of binary logit model variables with statistically significant impact on water security for men and women. Source: Authors' creation based on model results. A green line indicates the variable has a positive significant impact on water security while a red line indicates the variable has a negative significant impact on water security. The symbol (♀) represents women and (♂) denotes men.

if water security is influenced by socio-economic status, this will have a larger impact on improving men's water security levels in Pakistan than women's because men tend to be wealthier. What this implies is that, despite women in the study area potentially having better overall odds of being water secure, the actual conditions and constraints they face in Pakistan can "dilute" the effectiveness of other variables that are meant to improve their water security. This could be due to various reasons such as cultural norms and differences in resource allocation, decision-making power, or mobility, and explains why more men are found to be water secure.

While our analysis revealed that gender and age did not have statistically significant effects on water security independently, their interaction did impact water security probability levels differently for men and women. For example, age had a negative impact on water security, with older age groups more water insecure than younger age groups. This relationship was statistically significant for men but not for women. Older men may be most vulnerable to water insecurity due to traditional social and gender norms where men are typically viewed as household heads and primary breadwinners. As men age, these roles may place greater burden on them, particularly if they lack familial support systems. In contrast, age-related impacts on women's water security may be less severe due to cultural expectations that prioritize their care and wellbeing, regardless of age. For instance, husbands, sons, or brothers are traditionally responsible for ensuring women's welfare, including access to essential resources like water.

The model results illustrate that different variables may play a stronger role in affecting water security than gender alone, underscoring the importance of examining how intersecting identities may affect men and women differently and applying an intersectional lens when thinking about water security (Harrington et al., 2023). While women are often disproportionately impacted by water issues (Pouramin et al., 2020), which warrants attention and gender-responsive and gender-transformative interventions, we cannot assume that women will always be more water insecure than men (Young et al., 2022). The relationship between gender and water insecurity is complex and can vary depending on contextual factors and other determinants (Young et al., 2024a). Implementing tools like the IWISE, however, can help pinpoint these differences and better guide where intervention is needed, and for whom.

For example, the indicator of using an improved water source or being satisfied with water quality may indicate water security in the traditional sense. Digging deeper, despite majority of respondents in the study area using an improved drinking water source and being generally satisfied with water quality, this did not translate into high levels of overall water secure men and women across the towns. Evidence does suggest that perceptions of water quality do not always align with actual water quality, and perceptions can be influenced by multiple factors (Rowles et al., 2018; Delpla et al., 2020). The binary logit model indicates that women who use improved drinking water sources are significantly more likely to be water secure than those who use unimproved sources, while results were insignificant for men. This could be attributed to several reasons. Improved water sources reduce the risk of waterborne diseases and since women have unique health and hygiene needs that require clean and safe water as compared to men (e.g., menstrual hygiene), they would benefit more directly from access to an improved water source (Pouramin et al., 2020). In addition, access to an improved water source (e.g., piped household connection, handpump/standpipe, borehole) may imply a reduction in the time and effort required for water collection, particularly if the water source is near the home. In the study's urban setting, it can be assumed that, unlike their rural counterparts, women are not traveling extremely far distances to obtain their drinking water. Improved water sources are often closer to homes or provide more reliable access, reducing safety risks associated with traveling long distances or waiting in long queues at public sources, which disproportionately affects women (Tallman et al., 2023). For men, the type of water source does not significantly affect their water security. This indicates that other factors may play a more prominent role in determining their water security status. Men may be less directly involved in drinking water collection and management, making the quality and accessibility of the water source less significant toward their overall water security.

Results also confirmed that individuals who pay for drinking water are less likely to be water secure, with significant results for both men and women. While the ability to afford water might suggest improved water security, the source and quality of water should also be examined. If households do not have free access to clean water, they will be forced to pay for water. Water that is paid for, either from public or private tankers, or bottled water from vendors, is at risk of being contaminated or may not be available year-round, which can ultimately lead to greater water insecurity compared to those who have a reliable and consistent water supply. Tanker-provided water is also considered an unimproved water source based on the WHO's definitions. In Islamabad, the Capital Development Authority (CDA) provides public tankers to neighborhoods, but this coverage does not extend to Rawalpindi, where many households rely on private tankers. This "private tanker mafia" has exploited the market due to water shortages and often sells contaminated water at high prices (Yasin, 2023).

Additionally, education level had a statistically significant impact on water security levels only for women with higher education levels. Higher education significantly impacts women's water security more than men's, potentially due to its empowerment effect. One reason could be that higher education for women might empower them to engage more actively in decision-making processes within their households and communities, leading to better access to water resources and improved water management practices. Education also opens doors to better income-generation opportunities. This economic empowerment allows women to contribute financially to their households, potentially influencing decisions about investing in better water infrastructure or services that enhance water security. Educated women may have greater access to information, local regulations, and their own rights, enhancing their ability to make informed decisions about water use and management and leverage resources more effectively compared to those who are uneducated.

Conversely, the patriarchal context of Pakistan generally gives men greater access to resources and decision-making power in the household, regardless of their education level, thus the impact of higher education on their water security is less significant as compared to women. External factors may also play a more prominent role in impacting water security despite education levels. While those with higher education may have better knowledge of safe water and hygiene practices, there still may be external forces at play such as issues with infrastructure and access to clean water sources which have a greater influence on water security outcomes than individual characteristics.

Lastly, the disparity in urban wealth quintile scores between men and women in the study area hints at broader socio-economic inequalities that affect water security. Men had higher urban wealth quintile scores compared to women, correlating with a greater likelihood of being water secure. This discrepancy reflects underlying socio-cultural dynamics where men traditionally have more access to financial resources, assets like land and home ownership, and economic opportunities (Abbas et al., 2021), explaining the significant relationship for men but insignificant relationship between wealth and water security for women. In the socio-cultural context of Pakistan, gender norms often dictate that men are primary earners and decision-makers within households. This economic and social positioning can afford men greater influence over household resource allocation, including decisions related to water management and infrastructure investment. In contrast, women's access to resources and decision-making power may be constrained, limiting their ability to address water security challenges directly through wealth accumulation alone.

While our study has shown how multiple variables intersect to affect water security, it is important to note that gender dynamics still remain significant in shaping individuals' experiences of water insecurity. Thus, our results should not be interpreted as diminishing the importance of gender-responsive or gender-transformative approaches to water security interventions. Addressing gender inequalities is key to achieving the SDGs, especially SDG 6 (Clean Water and Sanitation). When gender inequalities are addressed, access to safe drinking water may improve (Wijesiri and Hettiarachchi, 2021). Our results emphasize the need for a more holistic perspective that encompasses a wide range of factors, including socio-cultural influences and the broader political, economic, and governance context that impacts access to and control over water resources.

4.1 Intersectional gender analyses are key in understanding water inequalities

Water security challenges cannot be adequately addressed without addressing underlying inequalities, power dynamics, and structural barriers that disproportionately affect marginalized communities, including women. Interventions that prioritize technocratic solutions or capacity building of marginalized groups without addressing gender and social relations and larger structural forces are bound to fail. We must shift our policy and programming paradigms and approach water security as a social justice issue rather than only a technical or development issue.

In our study, gender was not the strongest determinant of water security, but in other contexts it may be. More disaggregated data across the country is needed to provide a clearer picture. Moving forward, efforts to enhance water security in urban Pakistan should prioritize intersectional approaches that consider the complex interplay of gender, socio-economic status, access to water resources and governance structures to develop more effective and inclusive strategies. We echo Schilling et al. (2018) who posit the need to move beyond thinking of gender as only women and applying a gender-relational approach to analyses, which means thinking about diverse gender groups and differences between and among gender groups, along with how gender identities intersect with other social identities. Collecting disaggregated data across gender, age, socioeconomic status, and other relevant variables can offer a nuanced understanding of water insecurity and help bridge gender data gaps in the water sector across Pakistan. Leveraging this evidence base can lead to more effective advocacy efforts by highlighting disparities and thereby pushing for more equitable and inclusive water management practices. This not only enhances decision-making but also creates accountability with decision-makers; ignoring such evidence and perpetuating water inequalities becomes a deliberate policy choice rather than an oversight.

Without collecting disaggregated data, particularly sex-disaggregated data, policies and programs often miss important gender and water linkages that are needed for sustainable water solutions and may inadvertently implement gender-unaware solutions that bring unintended harm. For example, in a water supply intervention in India, public taps installed closer to households were assumed to bring positive outcomes for a community by saving women time traveling far distances to collect water. Conversely, researchers found that women still spent hours collecting water from the public taps because water demand increased with the introduction of a closer supply source. While men increased their water usage, the burden of fulfilling household water needs still inevitably fell on women (Narain, 2014). Thus, the delivery of a closer water source did not in and of itself result in changes in gender norms or a reduction in women's workload, though it may have brought positive changes in other aspects. This speaks to the importance of looking beyond the technical outputs of water interventions and assessing social and gender impacts. This necessitates better data and better analysis, understanding and application of that data.

4.2 Policy and programming implications

This study presents a case study of water insecurity in two urban towns, offering insights with broader implications for water policies and programming in Pakistan. As a first step, relevant stakeholders at the national, provincial and local levels need to be sensitized on the importance of gender and social inclusion in the water sector. This includes capacity-building on the gendered impacts of water inequalities and a recognition that water solutions should not only focus on new technologies and infrastructure. It also includes building capacity on institutionalizing gender into relevant departments, such as how to conduct gender analyses and properly analyze sex- and gender-disaggregated data, and inclusive community engagement. For example, Pakistan Bureau of Statistics regularly publishes national level reports on economic and social indicators; these could be improved with more thorough gender analyses. At the policy level, gender considerations should be systematically integrated into all water-related policies and plans, such as the National Water Policy and National Adaptation Plan. This should involve the use of gender-sensitive and gender-responsive indicators and the collection of sex-disaggregated data to monitor progress and outcomes, including updating existing monitoring and evaluation systems to assess the impact of water policies and programs on different gender groups. As a longer-term goal to tackle structural inequities, federal ministries should review and update legal and regulatory frameworks to ensure they support gender equity in water access and management. This may include laws that protect women's and other marginalized groups' rights to water resources and promote equal opportunities in the water sector workforce.

From an implementation standpoint, entities such as the Capital Development Authority (CDA) in Islamabad and the Water and Sanitation Association (WASA) in Rawalpindi could consider adopting the IWISE Scale across select towns in twin cities when designing and developing new water infrastructure projects. Beyond the twin cities, provincial and district authorities could also make use of this data. Implementing the Scales would generate a comprehensive water security map, identifying the most affected towns and neighborhoods, and more importantly, which segments of the population are most affected. Because the tool is quick and easy to administer, it could be easily integrated into data collection activities. This information could guide authorities in tailoring responses to specific needs, such as constructing water filtration plants at strategic and accessible locations in water-scarce areas, regulating public tanker prices to prevent exploitation in poor communities, or addressing health and pollution concerns. Collecting disaggregated water data can also help shift the current culture of technocratic solutions to deeper social problems. For instance, while installing a water filtration plant may solve a community's immediate water needs, sex-disaggregated data might show that women face more water-borne illnesses and have challenges with menstrual hygiene management, which calls for broader solutions to tackle root issues of public health inequities. Collecting specific data on transgender persons would also provide more insight into their unique water security challenges, enabling more inclusive and equitable interventions. Moreover, international and civil society organizations may find value in incorporating the WISE Scales into their water programs to support monitoring of water security levels on a quarterly or yearly basis. Organizations like UNICEF and other research institutions can partner with local authorities and provide the technical support needed to implement large-scale data collection activities.

The WISE Scales can also be used in conjunction with other indicators related to food security, economic development, health, WASH, and climate change, among others (Young et al., 2024b). This would help strengthen understanding on cross-sectoral linkages with water insecurity and make for improved advocacy efforts. This data can be complementary to existing data sources that federal and provincial departments should be collecting. For example, the Ministry of Planning, Development and Special Initiatives houses the federal SDGs Support Unit which collects data on SDG indicator progress in Pakistan. Most of the indicators tracked are reported at the household or population level (Cheema et al., 2021), though disaggregated data (by gender, age, disability, income level, etc.) would give a much clearer picture of Pakistan's actual progress on the SDGs.

As pointed out by Stoler et al. (2021), however, there are some limitations in the WISE Scales that should be addressed, including the addition of metrics to capture severity of water insecurity experiences, adaptation or coping strategies employed, and resilience to water security based on effectiveness of adaptation strategies employed. This reconceptualization can more adequately capture water insecurity experiences and provide insight on effective adaptation strategies. As water insecurity is complex and varies even within the same community, this stresses the importance of deeper community and civil society engagement to understand grassroots issues.

5 Conclusion

While gender dynamics are important in shaping water security outcomes, they do not operate in isolation. Our findings underscore the need for a multifaceted approach that considers broader context surrounding water access and distribution. In urban areas of Pakistan, issues such as unequal distribution of resources, inadequate infrastructure, and social dynamics may exacerbate water insecurity and disproportionately impact certain gender and social groups over others. By adopting a holistic approach that considers the intersectionality of gender, socio-economic status, infrastructure accessibility, and governance frameworks, among other variables, policymakers can develop targeted interventions to address the root causes of water insecurity and promote sustainable water management practices. It is not enough to think about gender in isolation without considering the broader context. Moreover, fostering community engagement and participatory decision-making processes can empower local residents, especially women and marginalized groups, to actively contribute to the design and implementation of gender-responsive water initiatives.

Future research should continue to explore the complex interplay of gender with other social determinants, as well as the effectiveness of specific interventions and policies in mitigating water insecurity in urban settings. More research is needed to understand differences in water security across income levels, education levels, age, disability status, and male or female-headed households (e.g., widows), as well as comparing urban and rural water insecurity experiences. Tools like the WISE Scales can be incorporated into national surveys or used as monitoring tools for organizations to capture changes in water security across time. Additionally, future research should consider the role of climate change and its impact on urban water security, as well as the potential for community-based and participatory approaches in addressing water challenges. Understanding the resilience and adaptive capacities of different communities, especially marginalized groups, can provide valuable insights into sustainable water management practices. Through such efforts, we can advance our understanding of the underlying drivers of water insecurity and inform evidence-based solutions to tackle water insecurity in urban areas of Pakistan and beyond.

5.1 Limitations of study

There are several limitations to this study. First, the relies on cross-sectional data, providing a snapshot of water insecurity at a single point in time in the two towns. However, water insecurity can fluctuate across different periods and seasons. Longitudinal studies would better capture these temporal variations and provide deeper insights into the dynamics of a community's water insecurity. Second, focusing on only two urban towns may not be representative of other urban or rural areas in Pakistan. Third, while the study incorporated gender and social determinants, it did not fully explore environmental variables and governance structures. Lastly, the analysis is based on self-reported data which may have introduced response bias, and future studies should aim to triangulate data from multiple sources to enhance reliability.

Data availability statement

The datasets presented in this article are not readily available because of ongoing research activities being conducted under the project. Requests to access the datasets should be directed to s.khalid@cgiar.org.

Ethics statement

The studies involving humans were approved by the International Water Management Institute's Institutional Review Board. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin because informed consent was obtained verbally before participation.

Author contributions

SK: Conceptualization, Investigation, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing. MH: Funding acquisition, Project administration, Resources, Supervision, Writing – review & editing. SA: Formal analysis, Methodology, Writing – review & editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. Funding for the study was provided by the Australian Government (Australian Aid) through the Department of Foreign Affairs and Trade (Grant no. 7661) under the Australia Pakistan Water Security Initiative (APWASI), implemented by WWF Pakistan in collaboration with IWMI and Hydrology and Risk Consulting (HARC). Australian Aid had no direct role in the research design or interpretation of results. All analysis and interpretations presented in this study are the authors' own.

Acknowledgments

The authors acknowledge the support of WWF Pakistan in facilitating the study survey with our field team. We also thank our colleagues Dr. Muhammad Zohaib for GIS support and Dr. Bunyod Holmatov for feedback on earlier drafts.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Abbas, S., Isaac, N., Zia, M., Zakar, R., and Fischer, F. (2021). Determinants of women's empowerment in Pakistan: evidence from Demographic and Health Surveys, 2012–13 and 2017–18. *BMC Public Health* 21, 1–14. doi: 10.1186/s12889-021-11376-6

Adams, E. A., Byrns, S., Kumwenda, S., Quilliam, R., Mkandawire, T., and Price, H. (2022). Water journeys: Household water insecurity, health risks, and embodiment in slums and informal settlements. *Soc. Sci. Med.* 313:115394. doi: 10.1016/j.socscimed.2022.115394

Adams, E. A., Juran, L., and Ajibade, I. (2018). 'Spaces of Exclusion' in community water governance: a feminist political ecology of gender and participation in malawi's urban water user associations. *Geoforum* 95, 133–142. doi: 10.1016/j.geoforum.2018.06.016

Ahmed, F., Shahid, M., Cao, Y., Qureshi, M. G., Zia, S., Fatima, S., et al. (2020). A qualitative exploration in causes of water insecurity experiences, and gender and nutritional consequences in South-Punjab, Pakistan. *Int. J. Environ. Res. Public Health* 18:12534. doi: 10.3390/ijerph182312534

Ahmed, T., Zounemat-Kermani, M., and Scholz, M. (2020). Climate change, water quality and water-related challenges: a review with focus on Pakistan. *Int. J. Environ. Res. Public Health* 17:8518. doi: 10.3390/ijerph17228518

Anwar, N. H., Sawas, A., and Mustafa, D. (2019). 'Without water, there is no life': negotiating everyday risks and gendered insecurities in Karachi's informal settlements. *Urban Stud.* 57, 1320–1337. doi: 10.1177/0042098019834160

Ashraf, M. (2018). *Water Scarcity in Pakistan: Issues and Options.* Hilal Publications. Available at: https://www.hilal.gov.pk/view-article.php?i=42 (accessed February 7, 2024).

Bethancourt, H., Frongillo, E., Viviani, S., Cafiero, C., and Young, S. (2022). Household water insecurity is positively associated with household food insecurity in low- and middle-income countries. *Curr. Dev. Nutr.* 6:549. doi: 10.1093/cdn/nzac060.007

Bisung, E., and Elliott, S. J. (2017). Psychosocial impacts of the lack of access to water and sanitation in low-and middle-income countries: a scoping review. *J. Water Health* 15, 17–30. doi: 10.2166/wh.2016.158

Brewis, A., Roba, K. T., Wutich, A., Manning, M., and Yousuf, J. (2021). Household water insecurity and psychological distress in Eastern Ethiopia: Unfairness and water sharing as undertheorized factors. *SSM - Mental Health* 1:100008. doi: 10.1016/j.ssmmh.2021.100008

Brewis, A., Workman, C., Wutich, A., Jepson, W., and Young, S. (2019). Household water insecurity is strongly associated with food insecurity: Evidence from 27 sites in low- and middle-income countries. *Am. J. Hum. Biol.* 32:e23309. doi: 10.1002/ajhb.23309

Caruso, B. A., Salinger, A., Patrick, M., Conrad, A., and Sinharoy, S. (2021). *A Review of Measures and Indicators for Gender in WASH. WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation, and Hygiene.* Available at: https://washdata.org/sites/default/files/2021-10/jmp-2021-gender-review-final-report.pdf (accessed February 12, 2024).

Caruso, B. A., and Sinharoy, S. S. (2019). Gender data gaps represent missed opportunities in WASH. *Lancet Global Health* 7:e1617. doi: 10.1016/S2214-109X(19)30449-8

Cheema, A. R., Kemal, M., Ahmed, N., and Hassan, H. (2021). *Pakistan SDGs Status Report. Federal SDGs Support Unit.* Ministry of Planning, Development and Special Initiatives, Government of Pakistan. Islamabad, Pakistan. Available at: https://pndajk.gov.pk/uploadfiles/downloads/Pak_SDGs_Status_Report_2021.pdf (accessed July 2, 2024).

Cook, C., and Bakker, K. (2012). Water security: debating an emerging paradigm. *Global Environ. Change* 22, 94–102. doi: 10.1016/j.gloenvcha.2011.10.011

Cooper-Vince, C. E., Arachy, H., Kakuhikire, B., Vorechovská, D., Mushavi, R. C., Baguma, C., et al. (2018). Water insecurity and gendered risk for depression in rural Uganda: a hotspot analysis. *BMC Public Health* 18, 1–9. doi: 10.1186/s12889-018-6043-z

Das, M. B. (2017). *The rising tide: a new look at water and gender*. World Bank. doi: 10.1596/27949

De Guzman, K., Stone, G., Yang, A. R., Schaffer, K. E., Lo, S., Kojok, R., et al. (2022). Drinking water and the implications for gender equity and empowerment: a systematic review of qualitative and quantitative evidence. *Int. J. Hyg. Environ. Health* 247:114044. doi: 10.1016/j.ijheh.2022.114044

Delpla, I., Legay, C., Proulx, F., and Rodriguez, M. J. (2020). Perception of tap water quality: assessment of the factors modifying the links between satisfaction and water consumption behavior. *Sci. Total Environ.* 722:137786. doi: 10.1016/j.scitotenv.2020.137786

Demie, G., Bekele, M., and Seyoum, B. (2016). Water accessibility impact on girl and women's participation in education and other development activities: the case of Wuchale and Jidda Woreda, Ethiopia. *Environ. Syst. Res.* 5, 1–12. doi: 10.1186/s40068-016-0061-6

Dhital, R. P., Ito, T., Kaneko, S., Komatsu, S., and Yoshida, Y. (2022). Household access to water and education for girls: the case of villages in hilly and mountainous areas of Nepal. *Oxford Dev. Stud.* 50, 142–157. doi: 10.1080/13600818.2021.1965978

Fatima, B., Hasan, F., and Ashraf, M. (2022). *Sustainable Development Goal 6.0 Policy Support System (PSS). Pakistan Council of Research in Water Resources (PCRWR).* Available at: https://unosd.un.org/sites/unosd.un.org/files/sdg-pss_explanatory_handbook_pakistan.pdf (accessed July 3, 2024).

Fatima, B., and Leghari, I. U. (2020). Exploring socio-economic experiences of water insecurity in District Rawalpindi, Punjab. *PalArch's J. Archaeol. Egypt/Egyptol.* 17, 301–310. Available at: https://archives.palarch.nl/index.php/jae/article/view/5227 (accessed February 12, 2024).

Fleifel, E., Martin, J., and Khalid, A. (2019). *Gender specific vulnerabilities to water insecurity*. Waterloo: University of Waterloo. Available at: https://ic-sd.org/wp-content/uploads/2019/11/eliana-fleifel.pdf (accessed February 7, 2024).

Geere, J. A., and Cortobius, M. (2017). Who carries the weight of water? Fetching water in rural and urban areas and the implications for water security. *Water Altern.* 10, 513–540. Available at: https://www.water-alternatives.org/index.php/alldoc/articles/vol10/v10issue2/368-a10-2-18 (accessed March 3, 2024).

Geere, J. A. L., Cortobius, M., Geere, J. H., Hammer, C. C., and Hunter, P. R. (2018). Is water carriage associated with the water carrier's health? A systematic review of quantitative and qualitative evidence. *BMJ Global Health* 3:e000764. doi: 10.1136/bmjgh-2018-000764

Gerlak, A. K., House-Peters, L., Varady, R. G., Albrecht, T., Zúñiga-Terán, A., De Grenade, R. R., et al. (2018). Water security: a review of place-based research. *Environ. Sci. Policy* 82, 79–89. doi: 10.1016/j.envsci.2018.01.009

Global Water Partnership (2000). *Towards Water Security: A Framework for Action*. GWP. Stockholm, Sweden. Available at: https://www.gwp.org/globalassets/global/toolbox/references/towards-water-security.-a-framework-for-action.-mobilising-political-will-to-act-gwp-2000.pdf (accessed March 5, 2024).

Graham, J. P., Hirai, M., and Kim, S. (2016). An analysis of water collection labor among women and children in 24 sub-saharan African countries. *PLoS ONE* 11:e0155981. doi: 10.1371/journal.pone.0155981

Grey, D., and Sadoff, C. W. (2007). Sink or swim? Water security for growth and development. *Water POLICY* 9, 545–571. doi: 10.2166/wp.2007.021

Hafeez (2022). *Dealing with Pakistan's growing water insecurity*. The Nation. Available at: https://www.nation.com.pk/13-Jan-2022/dealing-with-pakistan-s-growing-water-insecurity

Hafeez, M. (2023). *Dealing with looming water crisis*. Geo News. Available at: https://www.geo.tv/latest/463237-climate-resilience

Harrington, C., Montana, P., Schmidt, J. J., and Swain, A. (2023). Race, ethnicity, and the case for intersectional water security. *Global Environ. Polit.* 23, 1–10. doi: 10.1162/glep_a_00702

IPCC (2023) "Summary for Policymakers," in *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change,* eds. Core Writing Team, H. Lee and J. Romero (Geneva, Switzerland: IPCC), 1–34.

Ishaque, W., Sultan, K., and Zia ur Rehman. (2024). Water management and sustainable development in Pakistan: environmental and health impacts of water quality on achieving the UNSDGs by 2030. *Front. Water* 6:1267164. doi: 10.3389/frwa.2024.1267164

Jepson, W., Budds, J., Eichelberger, L., Harris, L., Norman, E., O'Reilly, K., et al. (2017). Advancing human capabilities for water security: a relational approach. *Water Secur.* 1, 46–52. doi: 10.1016/j.wasec.2017.07.001

Jepson, W. E., Wutich, A., Colllins, S. M., Boateng, G. O., and Young, S. L. (2017). Progress in household water insecurity metrics: a cross-disciplinary approach. *Wiley Interdisc. Rev.* 4:e1214. doi: 10.1002/wat2.1214

Kayser, G. L., Rao, N., Jose, R., and Raj, A. (2019). Water, sanitation and hygiene: Measuring gender equality and empowerment. *Bull. World Health Organ.* 97, 438–440. doi: 10.2471/BLT.18.223305

Khan, H. F., and Arshad, S. A. (2022). Beyond water scarcity: Water (in)security and social justice in Karachi. *J. Hydrol.* 42:101140. doi: 10.1016/j.ejrh.2022.101140

Kher, J., Aggarwal, S., and Punhani, G. (2015). Vulnerability of poor urban women to climate-linked water insecurities at the household level: a case study of slums in Delhi. *Indian J. Gend. Stud.* 22, 15–40. doi: 10.1177/0971521514556943

Klare, M. T. (2020). Climate change, water scarcity, and the potential for interstate conflict in South Asia. *J. Strat. Secur.* 13, 109–122. doi: 10.5038/1944-0472.13.4.1826

Lanjwani, A. H., Shah, Q., Shaikh, G. S., Shaikh, A., Ali, A., Atif, A., et al. (2023). Assessment of poverty vulnerability and water insecurity in the Tharparkar, Sindh, Pakistan-A Kap Survey. *J. Pharmac. Negat. Results* 14, 311–323.

MacAlister, C., Baggio, G., Perera, D., Qadir, M., Taing, L., and Smakhtin, V. (2023). *Global Water Security 2023 Assessment.* United Nations, University Institute for Water, Environment and Health, Hamilton, Canada. doi: 10.53328/FCLG9188

Malik, T., Lee, S., Lee, H. E., and Sharma, S. (2019). Pak-Afghan water issue: a case for benefit-sharing. *Policy Persp.* 16, 77–98. doi: 10.13169/polipers.16.1.0077

Mansuri, G., Sami, M. F., Ali, M., Doan, H. T. T., Javed, B., Pandey, P., et al. (2018). *When water becomes a hazard: a diagnostic report on the state of water supply, sanitation and poverty in Pakistan and its impact on child stunting.* WASH Poverty Diagnostic Series. Washington, DC: World Bank Group.

Metrics for Management (2020). *EquityTool – Pakistan [Survey Tool].* Available at: https://www.equitytool.org/pakistan (accessed January 12, 2024).

Mushavi, R. C., Burns, B. F. O., Kakuhikire, B., Owembabazi, M., Vorechovská, D., McDonough, A. Q., et al. (2020). "When you have no water, it means you have no peace": a mixed-methods, whole-population study of water insecurity and depression in rural Uganda. *Soc. Sci. Med.* 245:112561. doi: 10.1016/j.socscimed.2019.112561

Mustafa, D., Akhter, M., and Nasrallah, N. (2013). *Understanding Pakistan's Water-Security Nexus.* Washington, DC: United States Institute of Peace.

Narain, V. (2014). Shifting the focus from women to gender relations: assessing the impacts of water supply interventions in the Morni-Shiwalik hills of northwest India. *Mt. Res. Dev.* 34, 208–213. doi: 10.1659/MRD-JOURNAL-D-13-00104.1

Norton, E. C., Dowd, B. E., and Maciejewski, M. L. (2019). Marginal effects-quantifying the effect of changes in risk factors in logistic regression models. *JAMA* 321, 1304–1305. doi: 10.1001/jama.2019.1954

Nunbogu, A. M., and Elliott, S. J. (2021). Towards an integrated theoretical framework for understanding water insecurity and gender-based violence in Low-and middle-income countries (LMICs). *Health Place* 71:102651. doi: 10.1016/j.healthplace.2021.102651

Octavianti, T., and Staddon, C. (2021). A review of 80 assessment tools measuring water security. *Wiley Interdisc. Rev.* 8:e1516. doi: 10.1002/wat2.1516

Pakistan Bureau of Statistics (2023). *7th Population and Housing Census 2023.* Ministry of Government of Pakistan. Available at: https://www.pbs.gov.pk/sites/default/files/population/2023/Pakistan.pdf (accessed January 23, 2024).

Patrick, M., Hennink, M., Dasmohapatra, M., Rout, M., Clasen, T., and Caruso, B. A. (2023). Influences on water source selection and use among women in rural Odisha, India. *Front. Water* 5:1040981. doi: 10.3389/frwa.2023.1040981

Pommells, M., Schuster-Wallace, C., Watt, S., and Mulawa, Z. (2018). Gender violence as a water, sanitation, and hygiene risk: Uncovering violence against women and girls as it pertains to poor WaSH access. *Viol. Against Women* 24, 1851–1862. doi: 10.1177/1077801218754410

Pouramin, P., Nagabhatla, N., and Miletto, M. (2020). A systematic review of water and gender interlinkages: assessing the intersection with health. *Front. Water* 2:6. doi: 10.3389/frwa.2020.00006

Quandt, A., O'Shea, B., Oke, S., and Ololade, O. O. (2022). Policy interventions to address water security impacted by climate change: adaptation strategies of three case studies across different geographic regions. *Front. Water* 4:935422. doi: 10.3389/frwa.2022.935422

Robson, E., Porter, G., Hampshire, K., and Munthali, A. (2013). Heavy loads: children's burdens of water carrying in Malawi. *Waterlines* 32, 23–35. doi: 10.3362/1756-3488.2013.003

Rowles, L. S., Alcalde, R., Bogolasky, F., Kum, S., Diaz-Arriaga, F. A., Ayres, C., et al. (2018). Perceived versus actual water quality: community studies in rural Oaxaca, Mexico. *Sci. Total Environ.* 622, 626–634. doi: 10.1016/j.scitotenv.2017.11.309

Schilling, J., Froese, R., and Naujoks, J. (2018). ""Just Women" is not enough: towards a gender-relational approach to water and peacebuilding," in *Water Security Across the Gender Divide. Water Security in a New World,* eds. C. Fröhlich, G. Gioli, R. Cremades, H. Myrttinen (Cham: Springer). doi: 10.1007/978-3-319-64046-4_9

Schuster, R. C., Butler, M. S., Wutich, A., Miller, J. D., Young, S. L., Household Water Insecurity Experiences-Research Coordination Network (HWISE-RCN), et al. (2020). "If there is no water, we cannot feed our children": the far-reaching consequences of water insecurity on infant feeding practices and infant health across 16 low- and middle-income countries. *Am. J. Hum. Biol.* 32:e23357. doi: 10.1002/ajhb.23357

Shah, A., Karim, R., and Ali, K. (2022). Review of impacts of climate changes on the urban water security of Islamabad, Pakistan. *J. Water Landv.* 54, 109–115. doi: 10.24425/jwld.2022.141561

Sommer, M., Ferron, S., Cavill, S., and House, S. (2014). Violence, gender and WASH: spurring action on a complex, under-documented and sensitive topic. *Environ. Urban.* 27, 105–116. doi: 10.1177/0956247814564528

Sorenson, S. B., Morssink, C., and Campos, P. A. (2011). Safe access to safe water in low income countries: water fetching in current times. *Soc. Sci. Med.* 72, 1522–1526. doi: 10.1016/j.socscimed.2011.03.010

Stevenson, E. G., Greene, L. E., Maes, K. C., Ambelu, A., Tesfaye, Y. A., Rheingans, R., et al. (2012). Water insecurity in 3 dimensions: an anthropological perspective on water and women's psychosocial distress in Ethiopia. *Soc. Sci. Med.* 75, 392–400. doi: 10.1016/j.socscimed.2012.03.022

Stoler, J., Miller, J. D., Adams, E. A., Ahmed, F., Alexander, M., Asiki, G., et al. (2021). The household water insecurity experiences (HWISE) Scale: comparison scores from 27 sites in 22 countries. *J. Water Sanit. Hygiene Dev.* 11, 1102–1110. doi: 10.2166/washdev.2021.108

Sultana, F. (2011). Suffering for water, suffering from water: Emotional geographies of resource access, control and conflict. *Geoforum* 42, 163–172. doi: 10.1016/j.geoforum.2010.12.002

Syvrud, A., Pohlner, H., Punthakey, J. F., Grant, M., and Green, T. (2020). Advancing Urban water security in the indus basin, Pakistan—priority actions for Karachi and Lahore. *Water* 13:3399. doi: 10.3390/w13233399

Tallman, P. S., Collins, S., Salmon-Mulanovich, G., Rusyidi, B., Kothadia, A., and Cole, S. (2023). Water insecurity and gender-based violence: a global review of the evidence. *Wiley Interdisc. Rev.* 10:e1619. doi: 10.1002/wat2.1619

Tandon, I., Wallace, C., Caretta, M. A., Vij, S., and Irvine, A. (2022). Urban water insecurity and its gendered impacts: on the gaps in climate change adaptation and sustainable development goals. *Clim. Dev.* 16, 187–198. doi: 10.1080/17565529.2022.2051418

Tomberge, V. M. J., Bischof, J. S., Meierhofer, R., Shrestha, A., and Inauen, J. (2021). The physical burden of water carrying and women's psychosocial wellbeing: evidence from rural Nepal. *Int. J. Environ. Res. Public Health* 18:7908. doi: 10.3390/ijerph18157908

Truelove, Y. (2011). (Re-) Conceptualizing water inequality in Delhi, India through a feminist political ecology framework. *Geoforum* 42, 143–152. doi: 10.1016/j.geoforum.2011.01.004

Truelove, Y. (2019). Rethinking water insecurity, inequality and infrastructure through an embodied urban political ecology. *Wiley Interdisc. Rev.* 6:e1342. doi: 10.1002/wat2.1342

Tsai, A. C., Kakuhikire, B., Mushavi, R., Vorechovská, D., Perkins, J. M., McDonough, A. Q., et al. (2016). Population-based study of intra-household gender differences in water insecurity: reliability and validity of a survey instrument for use in rural Uganda. *J. Water Health* 14, 280–292. doi: 10.2166/wh.2015.165

UN Water (2013). *Water Security and Global Water Agenda: A UN-Water Analytical Brief.* United Nations University, Institute for Water, Environment and Health. Hamilton, ON, Canada. Available at: https://www.unwater.org/sites/default/files/app/uploads/2017/05/analytical_brief_oct2013_web.pdf (accessed March 5, 2024).

UNESCO (2021). *Taking Stock of Progress Towards Gender Equality in the Water Domain: Where do we stand 25 years after the Beijing Declaration? World Water Assessment Programme.* Paris: UNESCO. Available at: https://unesdoc.unesco.org/ark:/48223/pf0000377601 (accessed January 12, 2024).

UNICEF (2024). MICS 7 *Sampling Tools.* "Sample Size Calculation Template." Available at: https://mics.unicef.org/tools (accessed September 12, 2022).

UNICEF and WHO (2023). *Progress on household drinking water, sanitation and hygiene 2000–2022: special focus on gender*. United Nations. New York. Available at: https://www.who.int/publications/m/item/progress-on-household-drinking-water--sanitation-and-hygiene-2000-2022---special-focus-on-gender

Venkataramanan, V., Collins, S. M., Clark, K. A., Yeam, J., Nowakowski, V. G., and Young, S. L. (2020). Coping strategies for individual and household-level water insecurity: a systematic review. *Wiley Interdisc. Rev.* 7:e1477. doi: 10.1002/wat2.1477

Wijesiri, B., and Hettiarachchi, A. (2021). How gender disparities in urban and rural areas influence access to safe drinking water. *Utilities Policy* 68:101141. doi: 10.1016/j.jup.2020.101141

World Economic Forum (2023). *Global Risks Report 2023.* World Economic Forum, Geneva, Switzerland. Available at: https://www.weforum.org/reports/global-risks-report-2023/ (accessed February 7, 2024).

Wutich, A., Budds, J., Eichelberger, L., Geere, J., M. Harris, L., A. Horney, J., et al. (2017). Advancing methods for research on household water insecurity: Studying entitlements and capabilities, socio-cultural dynamics, and political processes, institutions and governance. *Water Secur.* 2, 1–10. doi: 10.1016/j.wasec.2017.09.001

Wutich, A., and Ragsdale, K. (2008). Water insecurity and emotional distress: coping with supply, access, and seasonal variability of water in a Bolivian squatter settlement. *Soc. Sci. Med.* 67, 2116–2125. doi: 10.1016/j.socscimed.2008.09.042

Yasin, A. (2023). *'Contaminated water for sale' as private tankers exploit 'lucrative' market in Rawalpindi*. Dawn News. Available at: https://www.dawn.com/news/1760503

Young, S. L., Bethancourt, H., Frongillo, E., and Bose, I. (2024b). *Water Insecurity Experiences (WISE) Country Profiles.* Evanston, IL: Institute for Policy Research; Northwestern University. doi: 10.21985/n2-avk4-9932

Young, S. L., Bethancourt, H. J., Frongillo, E. A., Viviani, S., and Cafiero, C. (2023). *Adults experiencing water insecurity are more likely to experience food insecurity in nationally representative samples of 25 low-and middle-income countries.* Bulletin WHO. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9874369/pdf/BLT.22.288771.pdf

Young, S. L., Bethancourt, H. J., Ritter, Z. R., and Frongillo, E. A. (2021a). The Individual Water Insecurity Experiences (IWISE) Scale: reliability, equivalence and validity of an individual-level measure of water security. *BMJ Global Health* 6:e006460. doi: 10.1136/bmjgh-2021-006460

Young, S. L., Bethancourt, H. J., Ritter, Z. R., and Frongillo, E. A. (2022). Estimating national, demographic, and socioeconomic disparities in water insecurity experiences in low-income and middle-income countries in 2020–21: a cross-sectional, observational study using nationally representative survey data. *Lancet Planet. Health* 6, e880–e891. doi: 10.1016/S2542-5196(22)00241-8

Young, S. L., Boateng, G. O., Jamaluddine, Z., Miller, J. D., Frongillo, E. A., Neilands, T. B., et al. (2019). The Household Water InSecurity Experiences (HWISE) Scale: development and validation of a household water insecurity measure for low-income and middle-income countries. *BMJ Global Health* 4:e001750. doi: 10.1136/bmjgh-2019-001750

Young, S. L., Frongillo, E. A., Jamaluddine, Z., Melgar-Quiñonez, H., Pérez-Escamilla, R., Ringler, C., et al. (2021b). Perspective: the importance of water security for ensuring food security, good nutrition, and wellbeing. *Adv. Nutr.* 12, 1058–1073. doi: 10.1093/advances/nmab003

Young, S. L., Miller, J. D., and Bose, I. (2024a). *Measuring Human Experiences to Advance Safe Water for All.* Evanston, IL: Institute for Policy Research; Northwestern University. doi: 10.21985/n2-xvrr-7693

Young, W., Anwar, A., Bhatti, T., Borgomeo, E., Davies, S., William Garthwaite, W. R., et al. (2019). *Pakistan: Getting More from Water (English).* Water Security Diagnostics Washington, DC: World Bank Group. doi: 10.1596/31160