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HOUSEHOLD WATER CONSERVATION IN PAKISTAN: AN EXAMINATION OF STRATEGIES, BEHAVIORS AND DETERMINANTS

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ABSTRACT

Water scarcity poses a major sustainability challenge for Pakistan's social, economic and environmental conditions. Implementing effective domestic water conservation techniques can significantly reduce consumption and wastage amidst supply constraints. This study evaluates household water conservation behaviors and drivers in Faisalabad city using primary survey data from 140 urban and rural households. Descriptive analysis is conducted to assess water usage patterns, infrastructure access, and conservation habits. An ordered logit model is estimated to determine the socioeconomic factors influencing adoption of daily water saving practices. The results indicate that basic no-cost actions like controlled tap use and leak monitoring are widely practiced across both urban and rural residences. However, the uptake of advanced solutions like rainwater harvesting remains limited. Age, family size and location are significant predictors of conservation orientation. Older residents, smaller families and rural households display greater propensity for prudent water use. The findings suggest that tailored educational programs, inclusive technologies, and pricing mechanisms can further propagate sustainable utilization behaviors, especially among young urban cohorts. Building an enduring culture of conservation is imperative to overcoming Pakistan's escalating water scarcity crisis.

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INTRODUCTION

Water is an invaluable resource that is essential for human survival and dignity, food production, economic growth and environmental sustainability. However, the availability of usable freshwater is declining across the world due to factors like climate change, pollution, environmental degradation, demographic shifts, lifestyle changes and poor management practices (WWAP, 2019). The global population has tripled over the last 70 years, but water demand has increased six-fold, creating unprecedented scarcity and stress in many regions (WWDR, 2021).

Pakistan is one of the most water-stressed countries in the world (Razzaq et al., 2019, 2022a). Ranked third on the WRI Baseline Water Stress Index, the per capita availability of water in Pakistan has declined from 5,000 cubic meters in 1947 to below 1,000 cubic meters in 2016 (PCRWR, 2016). This scarcity is driven by aspects like rapid population growth, unplanned urbanization, agricultural expansion, climate change impacts, high leakage losses, and inefficient usage (ADB, 2015; Javed et al., 2019; Sarker et al., 2021). Agriculture accounts for around 95% of current water utilization in the country (PCRWR, 2016). However, the industrial and domestic sectors are also significant and expanding users, accounting for 5% and 12% of demand, respectively, in urban areas (PCRWR, 2016).

Simultaneously, researchers have evaluated household water conservation, employing economic and psychological models. Age, for instance, shows a correlation with water-saving behaviors. Older individuals are more inclined towards water conservation, primarily because of environmental concerns and greater time spent at home for managing consumption (Clark and Finley, 2007; Gilg and Barr, 2006; Lam, 2006; Randolph and Troy, 2008). Education levels show a mixed relationship with conservation behavior. While some studies affirm that higher education enhances water-saving practices (Aprile and Fiorillo, 2017; Arbués et al., 2010; Zhang and Brown, 2005), others find no such correlation after adjusting for income (Domene and Saurí, 2006; Renwick and Green, 2000).

The household structure also comes into play. Larger families demonstrate economies of scale with lower per capita usage but face challenges in coordinating water-saving measures (Arbués et al., 2003; Höglund, 1999; Troy and Randolph, 2006). Ownership status further segregates behavior; homeowners invest more in water-efficient technologies than renters (Makki et al., 2015). Psychological elements such as environmental concern also influence water-saving activities (Aprile and Fiorillo, 2017; Clark and Finley, 2007; Corral-Verdugo et al., 2002). Moreover, pricing mechanisms and non-price interventions like technological upgrades and social norms act as policy levers (Arbués et al., 2003; Dalhuisen et al., 2003; Grafton et al., 2011; Nataraj and Hanemann, 2011; Fielding et al., 2013; Lowe et al., 2015; Seyranian et al., 2015).

Given the paucity of research in the Pakistani context, this study aims to fill the existing knowledge gap, particularly concerning household-level adoption of water-saving technologies and behaviors. Effective demand management and conservation practices, such as low-flow fixtures and greywater recycling, have demonstrated a 25-60% reduction potential in global studies (Zhu et al., 2022). Their implementation in Pakistani cities could substantially mitigate the prevailing water stress (Razzaq et al., 2022b, 2023).

The pressing need to manage water scarcity in Pakistan underscores the significance of this research, which is centered on the city of Faisalabad in Punjab province. The study aims to achieve four specific objectives: first, to scrutinize the socioeconomic features of the households in the sample; second, to identify prevalent water conservation strategies at the domestic level; third, to model the array of factors influencing the adoption of water-saving practices; and fourth, to offer empirically grounded policy recommendations.

MATERIALS AND METHODS

Study Area

The study was conducted in Faisalabad City, the third-largest metropolitan area in Pakistan's Punjab province. Water shortages are a major challenge in the city, with demand exceeding supply, especially during the summer months (Asim et al., 2012). Large variations exist between peak and off-peak supply flows. Piped water from tube wells and canal sources is only available for a few hours each day across most city neighborhoods (Ul-Allah et al., 2014). This intermittent supply necessitates in-house storage and heightens the need for judicious end-use.

Sampling Technique

A randomized sample of 140 households was selected from across Faisalabad district for primary surveys. Stratified random sampling was applied to ensure representative coverage of 70 households each from the designated rural and urban areas. The rural sample was taken from Chak Jhumra village on the outskirts of Faisalabad city, while the urban sample was selected from Madina Town locality within the main metropolitan boundary. This comparative stratification enabled analysis of variability in water conservation behaviors and drivers between urban and rural households facing differing socioeconomic constraints.

The required sample size was determined based on a 95% confidence level and confidence interval of 10 for the estimated proportion of households adopting different conservation practices. This yielded a minimum sample size of 96 households. The actual sample of 140 households covered both urban and rural sub-populations adequately.

Data Collection

Primary data was collected from sampled households through face-to-face surveys using pre-tested structured questionnaires. The questionnaires were prepared after an extensive review of similar instruments used in international studies on household water end-use. They were pre-tested through pilot interviews with 25 households and revised accordingly to maximize clarity and interpretability in the local context.

The questionnaires captured key information on household socioeconomic attributes, water supply sources, storage infrastructure, motivations for saving water, and adoption frequencies for various conservation strategies. The demographic variables included age, education, income, family size, and home ownership. The water conservation indicators were measured on a 4-point ordinal scale of adoption frequency: 1 (Never), 2 (Occasionally), 3 (Often), and 4 (Always). This enabled the quantification of household conservation habits.

To minimize interviewer bias, all questionnaires were administered through in-person interaction at the home or workplace of the selected respondents. Each survey was completed individually to ensure uniform interpretation of the questions asked in colloquial Punjabi dialect. Answers were directly recorded by the interviewers into the printed questionnaires. The survey duration averaged around 15-20 minutes per household.

Analytical Techniques

The completed questionnaires were systematically digitized and analyzed using the Statistical Package for Social Sciences (SPSS) version 21 and STATA version 15 analytical software tools.

Univariate analysis was first conducted to calculate descriptive summary statistics like frequencies, means and percentages for the demographic variables and water conservation indicators. This provided insights into the socioeconomic attributes and water saving behaviors of the sampled households.

Bivariate analysis was then performed to assess correlations between demographic factors and reported water conservation habits. Cross-tabulations of age, education, income, family size and location against the saving strategy frequencies indicated preliminary relationships.

Finally, an ordered logistic regression model was estimated with water conservation frequency as the ordinal dependent variable and key demographics as the predictors. This multivariate modeling approach identified the determinants with statistically significant impact on the likelihood of households adopting regular water saving behaviors, after controlling for confounding factors. The ordered logit model is suitable for ordinal outcome variables and avoids restrictive assumptions of normality and homoscedasticity required for linear regression (Greene and Hensher, 2010). It is estimated using the following Equation (1):

$$yi^* = xi'\beta + \varepsilon i \quad (1)$$

where:

y_i^* is the unobserved latent variable determining the ordinal frequency category y chosen by household i.

x_i is the vector of demographic predictor variables for household *i.*

β is the vector of regression coefficients.

ε_i is the error term for household *i.*

In the case of an ordered logistic regression, the observed ordinal variable yi is defined in terms of the latent variable yi* and a set of cutpoints k as follows:

$y_i = 1 \text{ if } y_i^* \leq k_1$

$y_i = 2 \text{ if } k_1 < y_i^* \leq k_2$

$y_i = j \text{ if } k_{j-1} < y_i^* \leq k_j$

$y_i = J \text{ if } yi^* > k_{J-1}$

Here, the k_j are unknown parameters to be estimated, along with the β coefficients. The k_j parameters are usually called "thresholds" or "cutpoints". They split the real line into J contiguous intervals, each one corresponding to a category of the observed ordinal response $y_{i.}$ The model assumes that the effects of the predictor variables on the latent variable y_i* are constant across all categories of the outcome y_i (this is the "parallel lines" or "proportional odds" assumption).

The probability of observing yi = j is given by the logistic cumulative distribution function:

$$\mathrm{P(yi = j)} = \frac{\exp(xi'\beta+kj)\}}{1+\exp(xi'\beta+kj)} \quad (2)$$

for j=1,2,...,J.

In Equation (2), the odds ratios are calculated to quantify the probability of households moving to a higher frequency category when the independent variable increases by one unit. The coefficients and the cutpoints are estimated through maximum likelihood estimation.

RESULTS AND DISCUSSION

Sample Characteristics

The descriptive statistics in Table 1 highlight key characteristics of the sample from rural and urban Faisalabad. The average age of respondents was higher in rural areas at 45.02 years compared to 38.18 years in urban areas. This indicates relatively older household members were surveyed in villages. The maximum reported age was 70 years in rural and 88 years in urban areas.

Education levels were lower among rural respondents, with a mean of 7.97 years of schooling versus 13.42 years in cities. The maximum education was 16 years in villages compared to 18 years in urban areas. This disparity reflects broader rural-urban divides in educational access in developing countries (Hao et al., 2014).

Marital status also differed significantly; 74.3% of urban respondents were single, compared to just 22.9% in rural areas. The mean family size was smaller in cities at 6.46 members versus 9 in villages. The average number of children per household was also lower in urban areas. These patterns reflect changing demographic profiles with urbanization.

Home sizes demonstrated substantial variation. The average rural home was 11.45 marlas, nearly double the 6.26 marlas for urban homes. However, the maximum home size was 25 marlas in both localities.

As expected, incomes were higher in cities, but income dispersion was also greater in urban areas as seen from the higher standard deviations. The range between minimum and maximum incomes also highlighted the rural-urban disparity.

In summary, the descriptive findings reveal key socioeconomic differences between the village and city samples that can influence water behaviors.

Water Source Usage

Figure 1 presents usage patterns of various water sources by location.

Tap water usage was evenly split in rural areas with 50% household reliance. But in cities, only 24.5% of homes used tap water, likely reflecting lower municipal piped supply access.

Handpump access was exclusive to rural households, with 50% reporting use. None of the urban respondents relied on handpumps. Reliance on motorized pumps was universal across both areas.

In-house water filter plants were used by only around 20% of rural and urban households. Their high setup and maintenance costs limit adoption.

Table 1. Descriptive statistics of study variables.

Variable	Location	Mean	Standard Deviation	Maximum	Minimum
Age	Rural	45.02	15.88	70	25
	Urban	38.18	17.70	88	19
	Overall	41.70	16.25	88	19
Education (years)	Rural	7.97	4.90	16	0
	Urban	13.42	2.48	18	8
	Overall	10.74	4.76	18	0
Size of Home (marlas)	Rural	11.45	6.67	25	4
	Urban	6.26	4.59	20	1.75
	Overall	8.93	6.28	25	1.75
Family Size	Rural	9	3.98	16	3
	Urban	6.46	1.89	12	3
	Overall	7.67	3.30	16	3
Male Family Members	Rural	3.45	1.50	12	1
	Urban	2.63	1.54	12	1
	Overall	3	1.44	9	1
Female Family Members	Rural	3.07	0.91	7	2
	Urban	2.95	1.62	12	1
	Overall	2.94	1.06	7	1
Children Family Members	Rural	2.68	2.63	8	0
	Urban	1.22	1.94	12	0
	Overall	1.88	2.26	8	0
Income (Rs)	Rural	38942.86	20461.265	100000	15000
	Urban	64728.57	40277.27	200000	25000
	Overall	51835.71	34359.00	200000	15000
Primary Source of Income (%)	Rural	81.86	21.79	100	40
	Urban	84.72	21.65	100	0
	Overall	83.00	22.97	100	0
Secondary Source of Income (%)	Rural	19.57	24.69	100	0
	Urban	14.87	20.19	70	0
	Overall	17.22	22.61	100	0

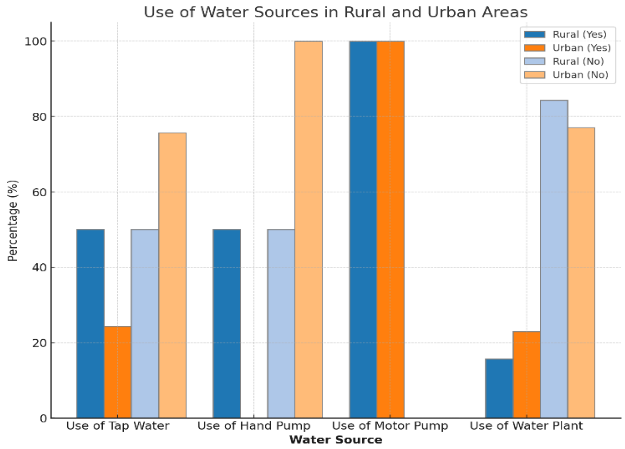

Figure 1. Use and capacity of different water sources.
Source: Authors' own calculations based on the survey data.

Nearly all households had in-house water storage tanks, with an average capacity of around 300 gallons. Storage is essential, given Faisalabad's intermittent piped supply (Khaliq et al., 2021). These results highlight continued dependence on groundwater and supply uncertainties in both rural and urban Faisalabad homes.

Water Usage Habits and Perceptions

Figure 2 summarizes parameters related to water usage habits and availability perceptions.

The frequency of in-house tank refilling varied significantly between rural and urban users. Rural households refilled less frequently, with 65.7% doing so only once daily. In cities, 42.9% were refilled multiple times each day, indicating greater water availability and consumption.

Regarding perceived changes in supply and groundwater levels over time, the majority of rural (77.1%) and urban (60%) respondents reported declines. However, 27% of urban respondents noticed no changes, higher than the rural share (5.7%). Perceptions of decreasing groundwater were more consistent across locations.

For conservation habits across activities, medium effort levels were mostly reported by rural and urban respondents. However, a high effort was more commonly cited in washing/laundry by rural users (41.4%) versus urban (30%), highlighting indigenous thrift practices in villages facing greater uncertainties.

In summary, the analysis reveals differing water availability, usage patterns, and conservation orientations between rural and urban households alongside common concerns about resource declines.

Factors Influencing Water Conservation

Figure 3 depicts respondent perceptions regarding various factors motivating conservation behaviors. The results provide insight into the daily water conservation practices of individuals in rural and urban areas. A variety of strategies were considered, including using less water for house cleaning, turning off the water while brushing teeth, using a bucket instead of a shower, plugging the sink when washing dishes, using slow tap water pressure for cleaning, watering plants during the coolest part of the day, and collecting rainwater or recycling wastewater.

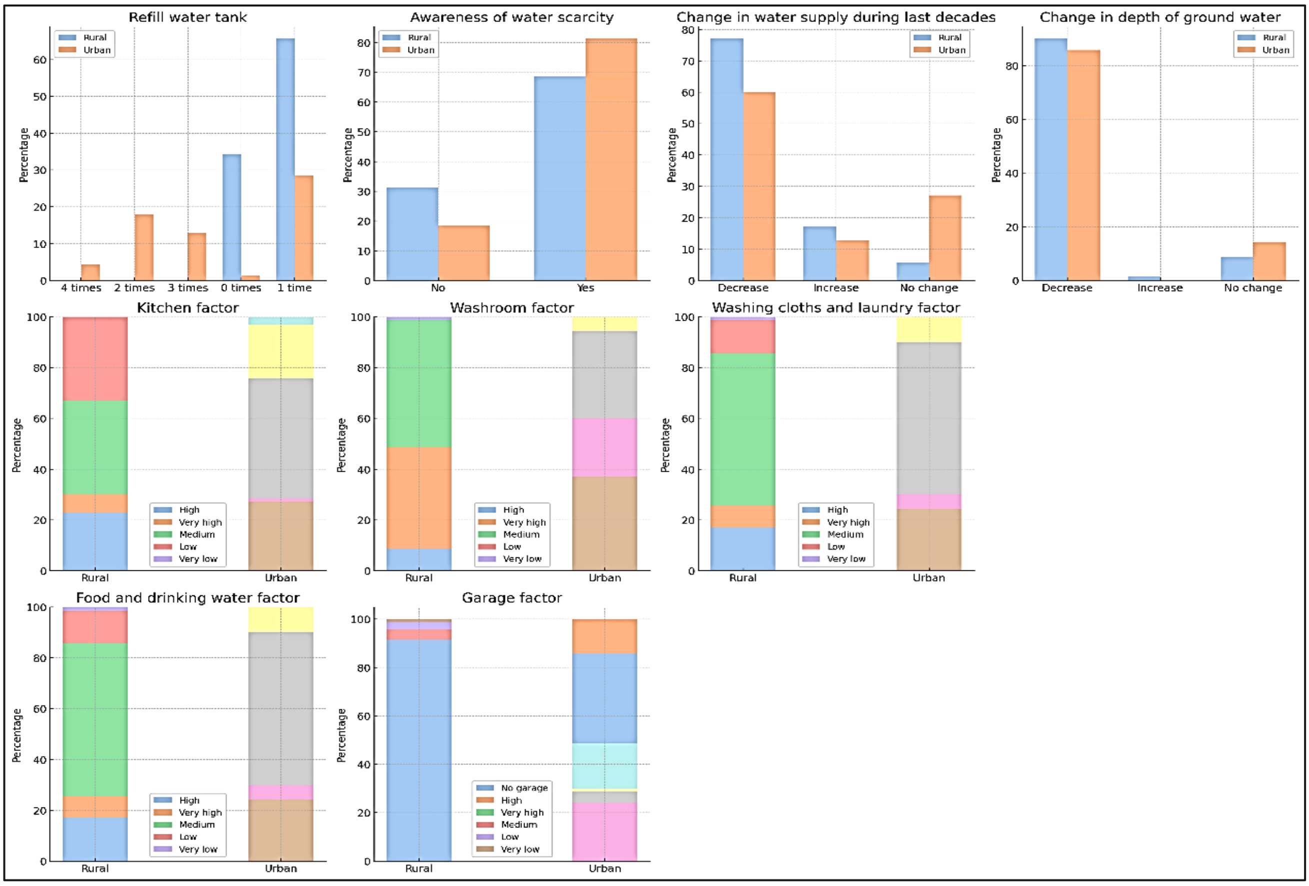

Figure 2. Water usage habits and perceptions of water availability among rural and urban populations; Source: Authors' own calculations based on the survey data.

Using less water for house cleaning

In urban areas, 51.4% of respondents reported often or always using less water for house cleaning, compared to 50% of respondents in rural areas. However, a considerable proportion of respondents in rural areas (32.9%) stated they never practiced this water conservation strategy, in contrast to only 12.9% in urban areas (Figure 3).

Turning off the water while brushing teeth

A significant difference was observed between rural and urban areas in terms of turning off the water while brushing teeth. In urban areas, 70% of respondents reported they always do this, compared to only 8.6% in rural areas. Furthermore, more than half (52.9%) of the rural respondents never practice this water-saving strategy.

Using a bucket instead of a shower

In rural areas, the use of a bucket instead of a shower to save water is more common, with 55.8% often or always doing this, compared to only 31.4% in urban areas. However, a significant proportion of urban respondents (51.4%) never use a bucket instead of a shower.

Plugging the sink when washing dishes

In urban areas, 65.7% of respondents often or always plug the sink when washing dishes, a strategy that can lead to significant water savings. In contrast, only 32.8% of rural respondents practice this strategy with the same frequency.

Using slow tap water pressure for cleaning

The use of slow tap water pressure for cleaning is a common practice in both urban and rural areas, with approximately 84.3% of urban respondents and 84.3% of rural respondents often or always doing so.

Watering plants during the coolest part of the day

A noticeable proportion of respondents do not have a garden (27.1% in urban areas and 34.3% in rural areas). However, among those who do, watering plants during the coolest part of the day to reduce evaporation is a common practice, particularly in urban areas where 51.4% of respondents often or always do so, compared to 35.7% in rural areas.

Collecting rainwater or recycling waste water

Unfortunately, the practice of collecting rainwater or recycling waste water is infrequent among respondents. In both urban and rural areas, a high proportion of respondents (88.6% in urban and 90% in rural) reported they never do this.

These findings highlight the need for enhanced awareness and education on water conservation strategies, particularly in rural areas where several practices are less common. Policies and programs that promote water-saving strategies can play a crucial role in ensuring sustainable water management.

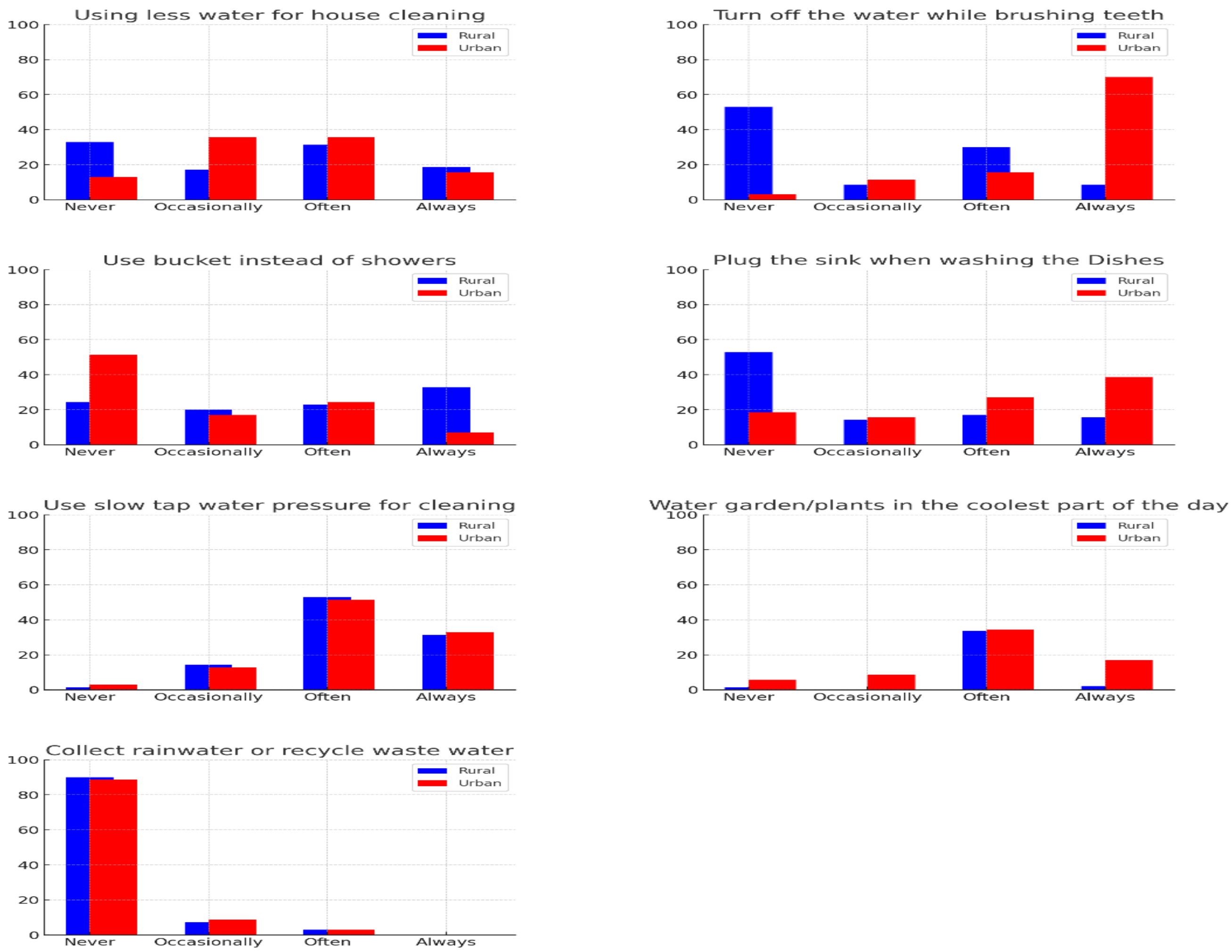

Figure 3. Water conservation practices in daily life; Source: Authors' own calculations based on the survey data.

Relative Importance of Water Conservation Strategies

Figure 4 provides a comparison between rural, urban, and overall respondents on various factors influencing water conservation. Each factor is represented by a distinct group of bars, with each bar within the group representing the percentage of respondents who cited that factor as a strong influence on their water conservation behavior. In both urban and rural areas, environmental concerns, water scarcity, and the need to preserve water for future generations were the most cited reasons for conserving water. These factors were followed by financial reasons, which had a slightly higher influence in rural areas. Government programs had the least influence in both areas.

Overall, it can be seen that environmental concerns, water scarcity, and the need to preserve water for future generations have a significant influence on water conservation behavior across both urban and rural areas. However, the effectiveness of government programs in encouraging water conservation appears to be relatively.

Finally, the relative importance of the suggested interventions for water conservation was assessed and ranked. Using slow tap water pressure for various cleaning activities was the most practiced strategy, followed by turning off the tap while brushing teeth and using a bucket instead of showers to save water (Figure 5). The least practiced strategy was collecting rainwater or recycling waste water (in water tanks etc.). This analysis offers valuable insights for developing targeted interventions for promoting water conservation at the household level.

Empirical Analysis of Factors Affecting Water Conservation Strategies

We also analyzed the various factors affecting water conservation strategies using econometric models. The results of ordered logistic regression (Table 2) indicate that age positively and significantly influenced the likelihood of using controlled tap pressure while cleaning and turning taps off during brushing at 5% level. Older residents were more frequent adopters of these basic conservation habits.

Family size had a highly significant negative effect on adopting slow tap usage and bucket bathing at 1% level. Larger households faced greater challenges in coordinating conservation despite lower per capita water consumption. Urban location strongly reduced the likelihood of routine tap turning off during brushing relative to rural areas, at 1% significance level. Tap monitoring practices are likely more ingrained in villages facing greater water insecurity.

House size significantly increased the probability of tap turning off during brushing at 1% level. Larger living spaces require greater monitoring efforts for workflows.

Other variables like education, income, and water source type did not demonstrate statistical significance. Demographic factors emerged as the key determinants of conservation habits.

In conclusion, the multivariate analysis provided empirical evidence on the demographic attributes and motivations shaping water conservation behaviors at the household level in Faisalabad.

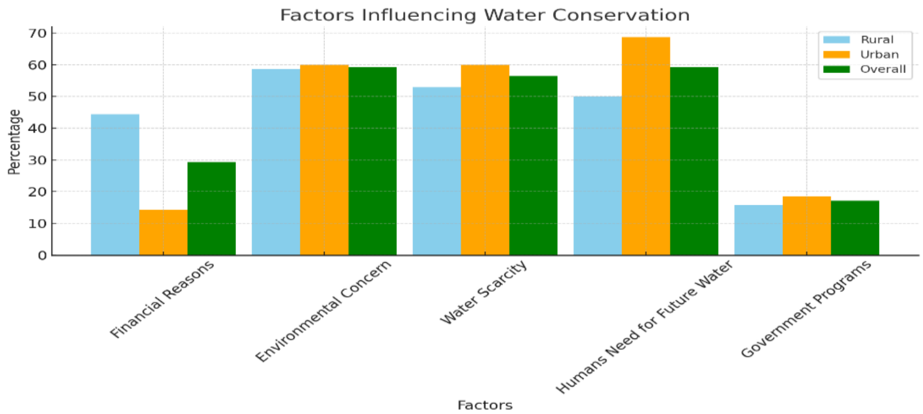

Figure 4. Factors influencing water conservation; Source: Authors' own calculations based on the survey data.

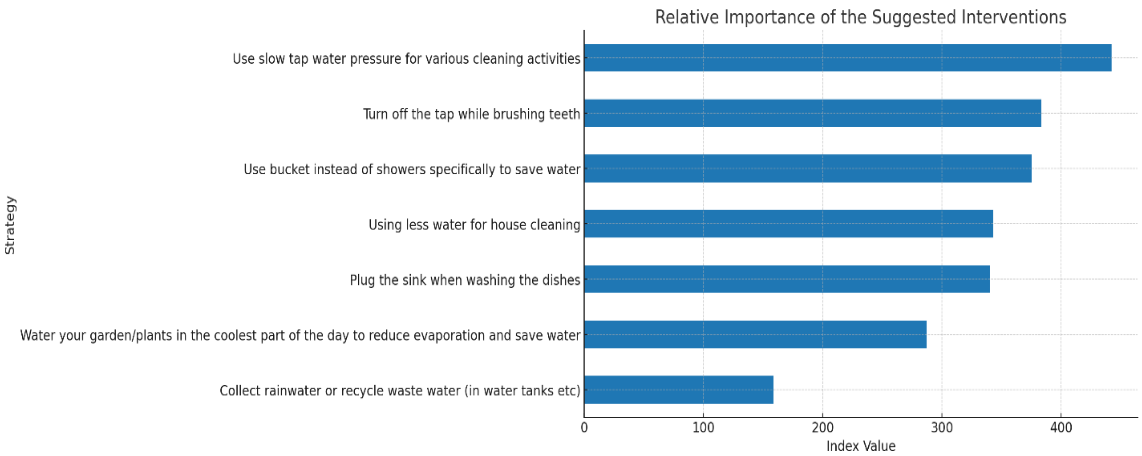

Figure 5. Relative importance of other factors that might influence water conservation; *Source:* Authors' own calculations based on the survey data.

Table 2. Summary of ordered logistic regression models.

Variables	Use Slow Tap Water Pressure	Turn Off Tap While Brushing Teeth	Use Bucket Instead of Showers
Age	0.064	0.036**	0.028**
Education	0.405	0.450	0.318
Income	0.128	0.124	0.871
Family Size	0.000***	0.013*	0.085
House Size	0.170	0.004***	0.199
Tap Water	0.296	0.414	0.621
Hand Pump	0.740	0.691	0.385
Location	0.290	0.000***	0.005***
Log Likelihood	-125.33	-134.29	-170.97
Pseudo R2	0.1445	0.2553	0.0928
LR chi2	42.33***	92.09***	34.96***
Observations	140	140	140

Note: * $p<0.1$; ** $p<0.05$; *** $p<0.01$.

Discussion

The study results provide interesting insights into household water conservation behaviors and influencing factors in Faisalabad city. The predominance of basic low-cost strategies like controlled tap use and monitoring aligns with findings from developing countries like India, Thailand, and Indonesia, where periodic tap management and leak checks are the most prevalent conservation tactics (Kumpel et al., 2018; Mungkung et al., 2013). However, the limited adoption of more advanced solutions like rainwater harvesting and wastewater reuse diverges from trends in high-income countries where uptake of such technologies is accelerating, although biased towards early adopters (Domene and Saurí, 2006; Asano and Cotruvo, 2004).

The strong positive association between age and water conservation habits corroborates extensive prior evidence that older residents often have a greater propensity to save water, stemming from heightened environmental awareness and experience of resource constraints (Aitken et al., 1994; Gilg and Barr, 2006; Lam, 2006). Younger cohorts display lower conservation orientation across multiple contexts. However, the non-significance of education as a driver contrast with some studies showing positive linkages between schooling and water efficiency (Aprile and Fiorillo, 2017; Arbués et al., 2010). It indicates that entrenched usage behaviors rooted in formative contextual experiences can override standard demographic variables in shaping conservation outcomes.

While field studies in developed countries like Australia and the USA have found home size, ownership, and income levels to be key determinants of household water demand and conservation (Domene and Saurí, 2006; Renwick and Green, 2000), these factors did not demonstrate statistical significance in the Faisalabad sample. Family size and location emerged as the prime drivers, underlining the importance of social dimensions and water availability constraints. Overall, the findings highlight the need for contextualized, evidence-based policy interventions that move beyond generic demographic assumptions on water conservation behaviors. These findings also offer valuable insights for other developing countries aiming to promote sustainable consumption and production (Ye et al., 2023).

CONCLUSIONS

This study analyzed household water conservation strategies and influencing factors in Faisalabad city using primary survey data. The findings suggest that basic behavioral measures like controlled tap use are widely adopted across both urban and rural households. However, advanced technological solutions remain limited. Age, family size, and residential location are significant drivers, with older individuals, smaller families, and rural areas displaying greater conservation orientation.

The results highlight the need for tailored educational programs, infrastructure upgrades, and inclusive pricing mechanisms to encourage further sustainable water utilization behaviors, especially among younger urban cohorts. Building an enduring culture of conservation is essential amidst Pakistan's escalating water scarcity crisis. The research provides useful insights to inform evidence-based policies for engaging households in addressing the country's water challenges. Further studies can apply more advanced econometric approaches on larger representative samples to elucidate the complex behavioral motivations and trends.

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