RESEARCH ARTICLE

Driving mechanisms of psychological perception of water scarcity on water-saving behavior: An extension of the theory of planned behavior

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ABSTRACT

Psychological perception of water scarcity, despite its strong correlation with water-saving behavior, has not been explored within major behavioral theoretical frameworks. This study develops an extended Theory of Planned Behavior (TPB) model incorporating psychological perception of water scarcity as an antecedent variable. This research paper investigates how scarcity perception impacts water-saving behavior by examining three mediating mechanisms: attitude, subjective norm, and perceived behavioral control. Additionally, it assesses the extended model's incremental explanatory power over the original model. Using data taken from China General Social Survey, this study uses structural equation model for path analysis and Bootstrap methods to test mediating effects. According to the findings, perceived scarcity is a significant predictor of all three main constructs of the Theory of Planned Behavior. The attitude path makes the biggest contribution as all three chained mediating paths are significant. The extended model demonstrates superior fit and predictive accuracy. This study establishes four specific objectives which include clarifying the theoretical positioning of perceived scarcity as a precursor variable within the behavioral model; outlining its specific psychological pathways to stimulate water-saving behavior; and providing targeted evidence for water-saving interventions. Policymakers must focus on effort on developing strategies that shape attitudes and enhance people's self-efficacy to promote an overall shift residential water-saving behaviors.

Keywords: psychological perception of water scarcity; water-saving behavior; theory of planned behavior; structural equation modeling; mediating effect

1. Introduction

Water resources are essential for socioeconomic development and ecological balance. However, water resources now face unprecedented supply-demand conflicts. Water scarcity has become an increasingly serious crisis. This crisis is characterized by climate-induced precipitation variability and population-driven demand growth. Water shortages have been a serious threat to regional sustainable development in semi-arid regions.[1]. Research in the west United States reveals strong relationships between water insecurity and social vulnerability[2]. As cities grow faster, climate change is making more people not have good enough

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water. This is making urban water users use water differently[3]. Water resources per capita in China are only a quarter of the world average. Research conducted on urban dwellers suggests that psychological variables play an important role in determining water use behavior [4]. Traditional water resource management paradigms relied primarily on engineering and technological solutions. Recognition that technical approaches alone cannot resolve the problem has prompted a transition from engineering-based to behavioral water conservation. The academia has begun systematically addressing the behavioral and psychological aspects in water security discourse [5]. Research on water savings interventions in public buildings shows that effective psychological and behavioral interventions lead to significant and permanent water savings[6]. Experiences of water scarcity have been shown to create "opportunity windows" that greatly enhance the ability of individuals to receive water-saving messages[7]. According to a research of household levels, enduring change requires a better knowledge of psychological mechanisms that generate change[8].

Psychological perception of water scarcity refers to individuals' cognitive evaluation of the severity and future trajectory of water resource inadequacy, encompassing judgments of shortage severity, supply expectations, and problem urgency[9]. This subjective construct, distinct from objective hydrological indicators, has demonstrated strong behavioral relevance yet remains theoretically underexplored. The Theory of Planned Behavior (TPB) is the most widely used theoretical model for predicting environmental behaviors due to its explanatory power and parsimony.Predicting green hotel selection has been successfully applied by it[10], recycled seafood consumption[11], and farmers' eco-friendly behaviors [12]. Researchers have generally identified limitations in the explanatory power of the original model and attempted to extend it by integrating additional constructs[13]. The Norm Activation Model (NAM) and Value-Belief-Norm Theory (VBN) explain pro-environmental behavior from ethical and value perspectives. A systematic review of NAM demonstrates its robust predictive power in explaining pro-environmental behavior [14]. Extending NAM to desert tourism contexts reveals that environmental concern significantly enhances the model's explanatory power[15]. Corporate social responsibility information research reveals how external information activates personal norms[16]. A two-decade review of VBN theory indicates its robust cross-cultural applicability[17], while studies on environmental values and norms influencing green consumption intentions validate the framework's explanatory power. Despite these advances, psychological perception of water scarcity—a cognitive variable demonstrating strong correlation with water-saving behavior—has not been systematically integrated into mainstream behavioral frameworks[18-20]. The theoretical positioning of perceived scarcity within behavioral models remains unclear, complete causal pathways linking scarcity perceptions to conservation behaviors lack comprehensive testing, and the incremental contributions of expanded models require systematic evaluation.

In reference to the research gaps specified earlier, this study develops an extended TPB model positioning psychological perception of water scarcity as an antecedent variable. The research examines how perceived scarcity influences water-saving behavior through three mediating pathways—attitudes, subjective norms, and perceived behavioral control—and assesses the incremental explanatory power of the expanded model compared to the original TPB. This provides psychological grounds for water-saving policy formulation and aids in designing targeted interventions by identifying key psychological pathways. Transnational environmentalism scholarship reveals how macro factors influence micro psychology[21,22], while the extended application of protection motivation theory provides a reference framework for this study[23]. Using CGSS 2021 data, this study employs structural equation modeling to test hypotheses and employs Bootstrap methods for mediation effect analysis. This provides psychological grounds for water-saving policy formulation, aids in designing more targeted interventions by identifying key psychological pathways, and contributes behavioral science solutions to alleviating water supply-demand conflicts.

2. Methods

2. 1. Theoretical foundations and research hypotheses

The Theory of Planned Behavior (Ajzen, 1991) is a foundational framework in social psychology for explaining and predicting human behavior. According to this theory, the behavioral intention is the strongest predictor of the behavior. Behavioral intention is jointly determined by three core constructs. Firstly, Subjective Norm is the perceived social pressure from others. Secondly, Perceived Behavioral Control reflects the individual's subjective judgement of the difficulty of being able to perform the behavior. The essence of the TPB is that an individual's behavioral intention will strengthen when they have a positive attitude toward a behavior, they perceive a favourable social norm and they sense efficacy that they can perform the behavior. This increases the likelihood that the actual behavior will occur.

The psychological perception of water shortage is the personal cognition and evaluation of the current and future inadequacy of water supply of an individual. It includes the assessment of severity of water shortage, and the awareness and expectations regarding the same. To conceptulise this TPB antecedent variable has clear theoretical ground: perceived environmental problems are a situational cognition that activates the value judgment and attitude formation of individuals towards environmental protection behaviors; percenived scarcity makes the individual reposition himself to the expectations of social norm for conservation behavior by activating recollection of the crisis of resources; perception of resource constraints also drives the judgement of the individual regarding the efficacy of his behavior.

Based on the theoretical analysis, the study proposes the following research hypotheses. With reference to perceived psychological water scarcity, it highlights the importance and usefulness of undertaking water saving behavior. H1: Perceived psychological water scarcity has a significant positive influence on attitudes towards water conservation. If water is scarce, people are more likely to give in to social norms. Thus, H2: Perceived water scarcity will positively influence subjective norms. When people realise there is less water to go around they have a greater tendency to pick up water saving skills. Hence H3: Perceived Water Scarcity has a significant and positive effect on Perceived Behavioral Control. In relation to the impact of core constructs of TPB on the intention to save water, based on the basic assumptions of TPB we propose that: H4 attitude towards the conservation of water has a significant and positive impact on the intention to conserve water; H5 subjective norms have a significant and positive impact on the intention to conserve water; H6 perceived behavioral control has a significant and positive impact on the intention to conserve water. We suggest that individuals that have an incentive to reduce their water consumption will as a direct result, begin to alter their behaviors that deplete water resources (H7) Moreover, people who think water conservation behaviors are easy to execute will tend to conserve water (H8).

Regarding mediating mechanisms, psychological perceptions of water scarcity may influence water conservation intentions and behaviors by affecting core constructs of the Theory of Planned Behavior (TPB), forming a complete pathway of "perception → cognition → intention → behavior." In light of this, we propose that: H9: Attitude and water-saving intention sequentially mediate the relationship between perceived psychological water scarcity and water-saving behavior; H10: Subjective norm and water-saving intention sequentially mediate the relationship between perceived psychological water scarcity and water-saving behavior; H11: Perceived behavioral control and water-saving intention sequentially mediate the relationship between perceived psychological water scarcity and water-saving behavior. To provide a clear picture of the theoretical relationships and research hypotheses, an extended TPB conceptual model is proposed in this study as shown in **Figure 1**.

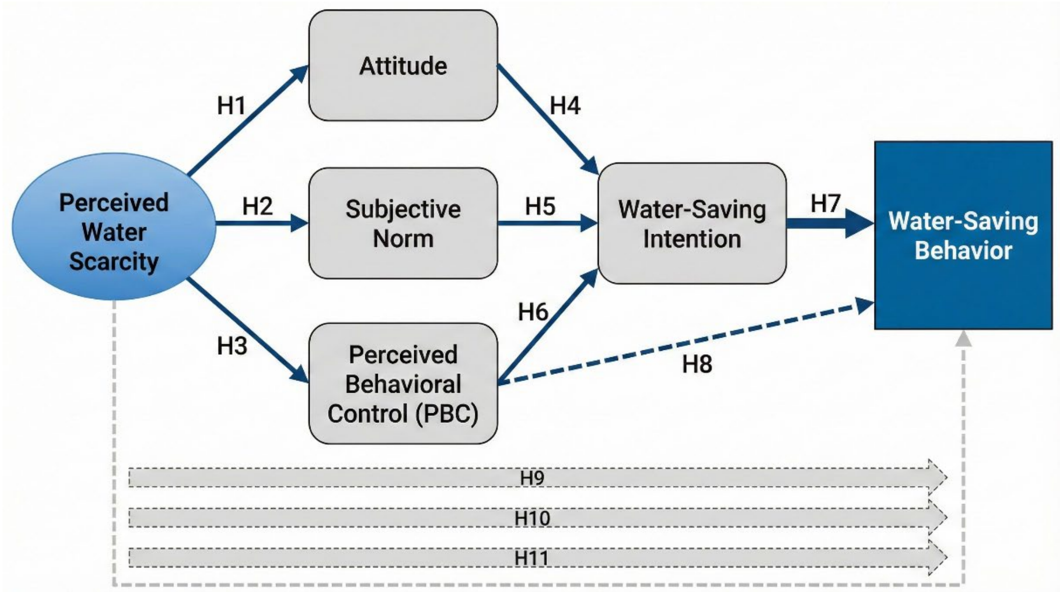

Figure 1. Conceptual model of the extended theory of planned behavior.

Figure 1 presents a theoretical framework illustrating how the psychological perception of water scarcity influences water-saving intentions through three pathways—attitudes, subjective norms, and perceived behavioral control—and subsequently impacts water-saving behavior. H1–H11 denote the corresponding research hypotheses for each pathway.

2.2. Data Sources and Sample Characteristics

The data for this study were sourced from the 2021 Chinese General Social Survey (CGSS 2021; http://cgss.ruc.edu.cn), conducted nationwide by the China Survey and Data Center at Renmin University of China. In the survey, in-person interviews of the household were done with the help of a multistage stratified probability sampling method. The interviews were done on the dimensions of social attitude, behavior patterns and environmental cognition of the residents. We have chosen this dataset mainly for its module on environment cognition and behavior. It contains measure items for the core variables which include perception of water scarcity, attitude for water conservation, intention to conserve water, and water saving behavior. In expanding the Theory of Planned Behavior (TPB) model these elements meet the data requirements.

Samples were excluded based on: (a) missing values on core variables, (b) invalid response patterns, and (c) respondents under age 18. From the initial 8,148 CGSS2021 questionnaires, 6,892 valid samples were retained (84.6% retention rate). The demographic composition of the sample will be presented and discussed for representativeness using descriptive statistics of key demographic variables. The specific distributions are shown in **Table 1**.

Table 1. Demographic characteristics of the sample.

Variable	Category	Frequency	Percentage (%)
Gender	Male	3,358	48.7
	Female	3,534	51.3

Variable	Category	Frequency	Percentage (%)
Age	18-29 years	896	13.0
	30-44 years	1,792	26.0
	45-59 years	2,344	34.0
	60 years and above	1,860	27.0
Education Level	Primary school or below	1,654	24.0
	Junior high school	2,288	33.2
	Senior high school/Technical secondary school	1,764	25.6
	College degree or above	1,186	17.2
Monthly Household Income	Below 3,000 CNY	1,654	24.0
	3,001-5,000 CNY	1,985	28.8
	5,001-8,000 CNY	1,585	23.0
	8,001-12,000 CNY	1,034	15.0
	Above 12,000 CNY	634	9.2
Marital Status	Married	5,266	76.4
	Single	1,006	14.6
	Divorced/Widowed	620	9.0
Household registrationType	Rural hukou	3,687	53.5
	Urban hukou	3,205	46.5
Region	Eastern China	2,743	39.8
	Central China	2,068	30.0
	Western China	2,081	30.2

Table 1. (*Continued*)

According to **Table 1**, the gender distribution in the sample is acceptable (48.7% male and 51.3% female) and the proportions of urban and rural household registrations are equal (agricultural household registration 53.5% and non-agricultural household registration 46.5%). Respondents aged 45 and above represent 61.0% of the total age range and the middle-aged and elderly dominated. This is consistent with the older age characteristic of in-home respondents of the CGSS household surveys. Most (57.2%) do not exceed a junior high school diploma, while 17.2% hold an associate degree or above. Educational attainment is thus heavily concentrated at the lower-middle level, as is the case in the adult population of the nation. According to Household monthly income, 52.8% of Low-to-middle-income groups earned less than 5,000 yuan. The eastern region is slightly higher at 39.8% while the central and western region is balanced out at 30 and 30.2 %. Essentially, the characteristics of a sample under study were correlated to the population of the country.

2.3. Variable measurement

This study examined psychological perception of water scarcity, attitudes toward saving water, subjective norms, perceived behavior control, intention to save water and water-saving behavior as latent variables. All variables were assessed by CGSS 2021 questionnaire items. The psychological perception of water scarcity is measured using three items that assess the respondents' judgments of the severity of water shortages, future supply situation and seriousness of the issue on a five-point Likert scale (1 = "Strongly disagree" to 5 = "Strongly agree"). Four items measured water conservation attitudes, which refer to a person's perception of the usefulness of water saving methods. Three items measuring normative influences from family, friends/colleagues, and the community environment were used to measure subjective norms. The perceived behavioral control was measured by three items assessing participant's knowledge/skills, facility accessibility, and implementation convenience regarding water conservation. Three items examining subjective willingness to conserve water in the future were used to assess intention on water conservation.Water conservation behavior was measured using six items assessing the frequency of specific water-saving behaviors, using a five-point frequency scale (1 = "never" to 5 = "always"). Control variables included gender, age, education level, monthly household income, marital status, household registration type, and residential area. The measurement schemes and reliability coefficients for each latent variable are detailed in **Table 2**.

Table 2. Variable measurement and reliability test.

Variable	Items	Sample Item	Scale	Cronbach's α
Perceived Water Scarcity	3	"I think water shortage is a serious problem in my area"	5-point Likert (1=Strongly disagree to 5=Strongly agree)	0.77
Attitude toward Water-Saving	4	"I believe saving water is beneficial for environmental protection"	5-point Likert (1=Strongly disagree to 5=Strongly agree)	0.82
Subjective Norm	3	"My family members think I should save water in daily life"	5-point Likert (1=Strongly disagree to 5=Strongly agree)	0.73
Perceived Behavioral Control	3	"I have sufficient knowledge and skills to save water"	5-point Likert (1=Strongly disagree to 5=Strongly agree)	0.72
Water-Saving Intention	3	"I intend to reduce my water consumption in the future"	5-point Likert (1=Strongly disagree to 5=Strongly agree)	0.84
Water-Saving Behavior	6	"I turn off the tap while brushing teeth or soaping hands"	5-point Frequency (1=Never to 5=Always)	0.79

Table 2 shows the items of measurement and reliability of all the latent variables. To determine perceived water scarcity, three questions were used on respondents to find out if water shortages were serious, if future water supply looks good and whether it was an urgent problem or not. The four items that capture the cognitive assessment regarding the utility and the value of saving water. We measured subjective norm using three survey items focused on the pressure exerted by family, friends, work colleagues, and the local community. The knowledge and skills relating to water saving, accessibility of the facility, and convenience of implementation made up perceived behavioral control with three items. The three items used to measure water-saving intention referred to the subjective likelihood of carrying out water-saving behavior. Measurement of water-saving behavior was done using a six-item-scale. These six items measure the frequency of practice of some specific water-saving behavior. The statistics for all latent variables ranged from 0.72 to 0.84 for Cronbach's α, all exceeding the threshold of 0.70 which indicates acceptable internal consistency for all scales.

2.4. Analytical strategy

The basic analytical tool used in this study is structural equation modelling. The analysis process consists of descriptive statistics and correlation analysis, measurement model validation, structural model validation, mediation effect testing, and model comparison analysis that uses SPSS 26.0 and Mplus 8.3. Confirmatory factor analysis (CFA) was used to validate the measurement model. Factor loadings were assessed to determine whether they were >0.50. Further evaluation included composite reliability and average variance extracted.

$$CR = \frac{(\sum_{i=1}^{n} \lambda_i)^2}{(\sum_{i=1}^{n} \lambda_i)^2 + \sum_{i=1}^{n} \delta_i} \tag{1}$$

$$AVE = \frac{\sum_{i=1}^{n} \lambda_i^2}{\sum_{i=1}^{n} \lambda_i^2 + \sum_{i=1}^{n} \delta_i} \tag{2}$$

Where λ_i represents the standardized factor loading, δ_i denotes the measurement error variance, CR should exceed 0.70, and AVE should exceed 0.50. Common method bias is examined using Harman's single-factor test and the common method factor control method.

The structural model evaluation was conducted according to the criteria for studies on water-saving behaviors from a psychosocial process perspective, setting $\chi^2 / df < 3.00$, CFI and TLI > 0.90, and RMSEA and SRMR < 0.08.

The mediation effect was tested following the procedure for examining the influence of social norms on pro-environmental behavior[24]. The Bootstrap method (with 5,000 repeated samples) was employed to assess mediation. The formulas for calculating indirect effects and mediation proportions are as follows:

$$\text{Indirect Effect} = a \times b \tag{3}$$

$$\text{Mediation Ratio} = \frac{a \times b}{c' + \sum_{j=1}^{m} (a_j \times b_j)} \times 100\% \tag{4}$$

Among these, *a* represents the standardized path coefficient of the independent variable (psychological perception of water scarcity) on the mediating variable (attitude/subjective norm/perceived behavioral control), *b* denotes the standardized path coefficient of the mediating variable on the dependent variable (water-saving behavior) or the next-level mediating variable (water-saving intention). c' represents the direct effect of the independent variable on the dependent variable after controlling for all mediating variables. *m* paths indicates the total number of mediating paths in the model. a_j and b_j denote the path coefficients from the independent variable to the mediating variable and from the mediating variable to the dependent variable in the *jth* mediating paths, respectively. Indirect effects reflect the indirect influence of the independent variable on the dependent variable through specific mediating variables. The mediation proportion indicates the percentage of the total effect attributable to this indirect effect, serving to evaluate the relative importance of each mediating path. If the Bootstrap 95% confidence interval does not include zero, it indicates that the mediating effect has reached statistical significance.

3. Results

3.1. Descriptive statistics and measurement models

Before establishing the structural equation model, it is crucial to conduct a complete examination of the descriptive statistical characteristics of latent variables. Further, inter-variable correlations assist in the preliminary estimation of the reasonableness of variable distributions and assess the directional expectations of the theoretical hypotheses. Descriptive statistical analysis is intentional, whereby the central tendency and dispersion of each variable are presented. On the other hand, correlation analysis reveals the strength of association between the variables that are subsequently subjected to path analysis, as preliminary evidence. SPSS 26.0 was utilized to determine the mean, standard deviation, and the Pearson correlation coefficient for each latent variable based on a valid sample of 6892. The results are shown in **Table 3**.

Table 3. Descriptive statistics and correlation matrix.

Variable	M	SD	1	2	3	4	5	6
1. Perceived Water Scarcity	3.28	0.96	1					
2. Attitude	3.91	0.74	0.29***	1				
3. Subjective Norm	3.47	0.87	0.22***	0.34***	1			
4. Perceived Behavioral Control	3.39	0.82	0.19***	0.25***	0.23***	1		
5. Water-Saving Intention	3.64	0.78	0.26***	0.41***	0.24***	0.36***	1	
6. Water-Saving Behavior	3.21	0.91	0.19***	0.29***	0.15***	0.32***	0.43***	1

Note. *M = Mean; SD = Standard Deviation; Numbers 1-6 in columns correspond to the variables listed in rows; Correlation coefficients are Pearson's r. ***p < 0.001.*

Respondents reported moderate psychological perception of water scarcity (M = 3.28, SD = 0.96). Furthermore, the respondents had the highest mean for their water conservation attitudes (M = 3.91, SD = 0.74) which was above three. The respondents had an average mean of 3.21 (SD = 0.91) on their water conservation behaviors as well. Inter-variable correlations ranged from 0.15 to 0.43 (all $p < 0.001$), consistent with theoretical expectations.

Measurement model validation is essential in structural equation modeling. Confirmatory factor analysis (CFA) was performed using Mplus 8.3 to ensure each latent variable is adequately measured with the indicator variables. This step was necessary to test the reliability and validity of the measurement model. The six-factor CFA model comprises six latent variables correlated with each other: perceived psychological scarcity of water resource, attitude towards water conservation, subjective norms, perceived behavioral control, intention to conserve water and water conservation behavior. Twenty-two observed variables were attributed to their latent variables. **Table 4** shows the results of indices of the model fit, reliability and validity test.

Table 4. CFA results and validity test.

Variable	Items	Factor Loadings	CR	AVE	√AVE
Perceived Water Scarcity	3	0.59-0.77	0.77	0.52	0.72
Attitude	4	0.62-0.80	0.82	0.54	0.73
Subjective Norm	3	0.56-0.75	0.73	0.51	0.71
Perceived Behavioral Control	3	0.57-0.74	0.72	0.50	0.71
Water-Saving Intention	3	0.67-0.80	0.83	0.56	0.75
Water-Saving Behavior	6	0.58-0.78	0.79	0.51	0.71

Note. *CR = Composite Reliability; AVE = Average Variance Extracted; √AVE = Square root of AVE;*

Table 4 indicates that the six-factor model fits acceptably (χ^2/df = 2.96, CFI = 0.92, TLI = 0.91, RMSEA = 0.054, SRMR = 0.048). Factor loadings ranged from 0.56 to 0.80, with CR values (0.72–0.83) and AVE values (0.50–0.56) generally meeting criteria. The discriminant validity test was passed.

Because all data in this study came from items with self-reported measures from the same questionnaire, it can be stated that common method bias might operate systematically by influencing relationships between variables. Thus, it is important to diagnose and control it. To test this, we performed two complementary tests. The first one used Harman's single-factor test. This is a preliminary test of bias. In unrotated factor analysis, we see the variance of the first factor. Harman's single-factor test, then, looks at the degree of bias being tested. The second method was the common method factor control method. This is a more rigorous test that tests bias. This method looks at how much bias impacted our analysis. Comparison of model fit changes before and after adding the common method factor is what helps us see bias impact. The Harman single-factor technique revealed six factors with eigenvalues greater than 1. The first factor explains 28.3 per cent of variance and is below the critical 40 %. The common method factor model did improve fit somewhat (ΔCFI =0.009, ΔRMSEA =0.005). In conjunction, these results confirm that common method bias had an acceptable impact on the results.

3.2. Structural models and hypothesis testing

After testing the measurement model, a structural equation model was further constructed to examine the pathways of perceived psychological water scarcity influence on water-saving behavior and the mediating role of core TPB construct. The structural model was determined based on the theory and hypotheses: Exogenous perceived water scarcity predicted the three core constructs of the TPB (Ajzen). These three main ideas showed people want to save water. The motivation and ability to conserve water were equal predictors of conservation behavior. Also, gender, age, level of education, monthly household income, marital status, type of household registration and residential region were included as control variables in the model. The technique of maximum likelihood estimation (ML) estimates parameters. **Table 5** shows the path coefficients and the results of hypotheses tests.

Table 5. Path coefficients and hypothesis testing results

Hypothesis	Path	β	S.E.	t-value	p	Result
H1	PWS → ATT	0.31	0.043	7.21	<0.001	Supported
H2	PWS → SN	0.24	0.040	6.00	<0.001	Supported
H3	PWS → PBC	0.22	0.042	5.24	<0.001	Supported
H4	ATT → INT	0.27	0.039	6.92	<0.001	Supported
H5	SN → INT	0.12	0.037	3.24	<0.01	Supported
H6	PBC → INT	0.23	0.038	6.05	<0.001	Supported
H7	INT → BEH	0.36	0.033	10.91	<0.001	Supported
H8	PBC → BEH	0.15	0.047	3.19	<0.01	Supported

Note. *PWS = Perceived Water Scarcity; ATT = Attitude; SN = Subjective Norm; PBC = Perceived Behavioral Control; INT = Water-Saving Intention; BEH = Water-Saving Behavior; β = Standardized path coefficient; S.E. = Standard Error. Control variables included gender, age, education, monthly household income, marital status, hukou type, and region.*

Table 5 indicates that the extended TPB model fits acceptably (χ^2 / df = 2.98, CFI = 0.91, TLI = 0.90, RMSEA = 0.058, SRMR = 0.051), with all eight direct effect hypotheses supported. Perceived scarcity exerted significant positive effects on attitude (β = 0.31, p < 0.001), subjective norm (β = 0.24, p < 0.001), PBC (β = 0.22, p < 0.001). Attitude (β = 0.27, p < 0.001) and PBC (β = 0.23, p < 0.001) significantly predicted water conservation intention. while subjective norm exerted a relatively weaker yet still significant influence (β = 0.12, p < 0.01). Water-saving intention strongly predicted water-saving behavior (β = 0.36, p < 0.001), and PBC also demonstrated a significant direct effect on water-saving behavior (β = 0.15, p < 0.01).

The standardized path coefficients of the associated structural model from the TPB model are graphically represented to show the interrelationship and effect-strength of the variables. The solid arrows indicate significant paths, whereas the thickness of the arrow indicates the effect size. The model paths are indicated with coefficients and significance, while the latent variables have been labelled with R-squares. The diagram of the structural model path coefficient is shown in **Figure 2**.

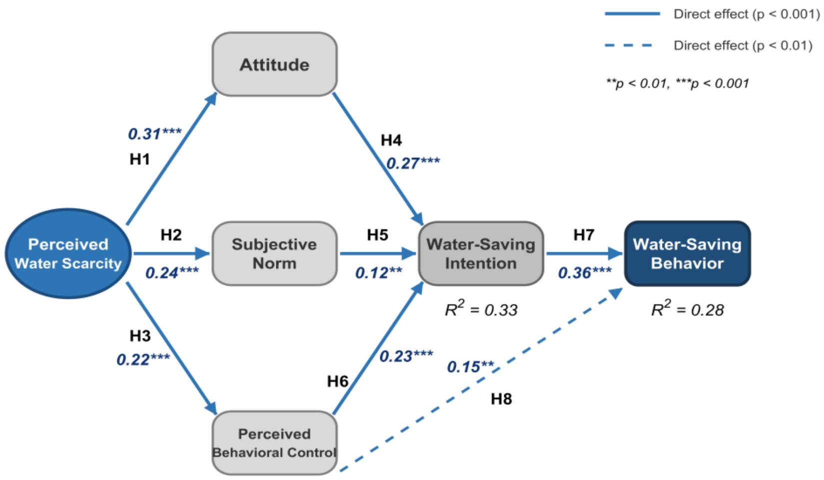

Figure 2. Structural model with standardized path coefficients.

Figure 2 illustrates how perceived water scarcity influences the core constructs of the TPB through three pathways. The model explains 0.33 variance in water-saving intention (R^2) and 0.28 variance in water-saving behavior. While the path effect of subjective norm is relatively weak, it remains statistically significant.

3.3. Driving mechanism verification: Mediating effect analysis

The results of structural model validation confirm the significance of all the paths. However, the process through which perceived water scarcity leads to water-saving behavior requires further investigation through the mediation analysis. Research Hypotheses H9-H11 point to a chained mediation in which perceived scarcity indirectly affects the water-saving behavior of consumers via attitude intention subjective norm intention perceived behavioral control intention. The bias-corrected Bootstrap method (with 5,000 repetitions) was used to test mediating effects by accurately estimating indirect effects and constructing confidence intervals. This approach does not require an assumption of a normal distribution of indirect effects and is useful for statistical inference of mediating effects. Bootstrap test results for the mediating effect are in **Table 6**.

Table 6. Bootstrap mediation analysis results.

Path	Effect	S.E.	95% CI Lower	95% CI Upper	% of Total Indirect
Indirect Effects					
PWS → ATT → INT → BEH (H9)	0.030	0.007	0.019	0.046	50.8%
PWS → SN → INT → BEH (H10)	0.011	0.004	0.004	0.020	18.6%
PWS → PBC → INT → BEH (H11)	0.018	0.005	0.009	0.028	30.5%

Path	Effect	S.E.	95% CI Lower	95% CI Upper	% of Total Indirect
Total Indirect Effect	0.059	0.010	0.042	0.079	100.0%
Direct Effect	0.044	0.016	0.015	0.076	—
Total Effect	0.103	0.018	0.071	0.139	—
Mediation Ratio					57.3%

Table 6. (*Continued*)

Note. *PWS = Perceived Water Scarcity; ATT = Attitude; SN = Subjective Norm; PBC = Perceived Behavioral Control; INT = Water-Saving Intention; BEH = Water-Saving Behavior. Bootstrap sample = 5,000. CI = Confidence Interval. Mediation ratio = Total indirect effect / Total effect × 100%.*

Table 6 shows that all three chained mediation paths are significant: the indirect effect of the attitude path is 0.030 (95% CI: 0.019–0.046), the subjective norm path is 0.011 (95% CI: 0.004–0.020), PBC pathway 0.018 (95% CI: 0.009–0.028), total indirect effect 0.059, with a mediation proportion of 57.3%.

To assess the relative importance of mediation effects of pathway, we calculated the proportion of each pathway's indirect effect to total indirect effect. The attitude mediation pathway has the biggest share of 50.8%, indicating that perceived scarcity → attitude → intention → behavior is the main psychological mechanism of water-saving behavior. The pathway of perceived behavioral control received the second rank (30.5%), while subjective norm pathway contributed weakly (18.6%). This finding is consistent with the low coefficient of the subjective norm pathway in the structural model. The direct effect of perceived scarcity on water-saving behavior was 0.044 after controlling for mediating variables (95% CI: 0.015–0.076) and remained significant. The results indicate that it has a partial mediation effect. In other words, perceived scarcity affects behavior not only through the cognition-intention pathway, but also via other unmeasured mechanisms.

3.4. Model comparison: Extended TPB vs. original TPB.

The theoretical value of perceived water scarcity as an antecedent into the TPB model must be validated through model comparison. To evaluate the additional explanatory power and fit of the extended model specified above as compared to the original TPB model, we estimated the original TPB model (without the scarcity perception variable) and the extended TPB model (with the scarcity perception variable) separately.We conducted comparisons using chi-square difference tests, fit index differences (ΔCFI, ΔRMSEA), and incremental variance explained (ΔR^2). **Table 7** compares the fit indices and explanatory power of the two studied models.

Table 7. Comparison between extended TPB and original TPB models (N = 6,892).

Model	χ^2	df	χ^2/df	CFI	TLI	RMSEA	SRMR	R^2(INT)	R^2(BEH)
Original TPB	1918.53	635	3.02	0.896	0.885	0.065	0.058	0.25	0.21
Extended TPB	1875.86	629	2.98	0.910	0.900	0.058	0.051	0.33	0.28
Δ (Difference)	42.67*	6	0.04	0.014	0.015	0.007	0.007	0.08	0.07

Note. *INT = Water-Saving Intention; BEH = Water-Saving Behavior. Extended TPB includes Perceived Water Scarcity as an antecedent variable. $\Delta\chi^2$ test: $\Delta\chi^2(6) = 42.67, p < 0.001$. ***p < 0.001.*

Table 7 demonstrates that the extended model significantly outperforms the original model: $\Delta\chi^2$ = 42.67 (Δdf = 6, p < 0.001), ΔCFI = 0.014, ΔR^2 for water conservation intention = 0.08, and Water-saving behavior ΔR^2=0.07. This confirms that incorporating the perceived scarcity variable enhances the model's predictive power, although the incremental improvement is moderate.

4. Discussion

This study systematically examined the psychological mechanisms through which perceived water scarcity drives water-saving behavior. The findings confirm that perceived scarcity functions as a significant antecedent of all three TPB constructs, with attitude exhibiting the strongest responsiveness to scarcity cognition. This pattern aligns with research on Iranian residents showing that psychosocial factors significantly predict water conservation intentions and behaviors[25].

Building on these findings, this study clarifies the theoretical positioning of perceived scarcity as an independent antecedent variable. Research employing the TPB framework to predict freshwater conservation intentions confirmed that attitudes and perceived behavioral control are primary predictors of behavioral intentions[26]. By introducing the scarcity perception variable, this study reveals how cognitive evaluation initiates the activation process of TPB's core constructs. An extended TPB study on residents' water conservation intentions indicated that environmental concern and perceived risk enhance the model's explanatory power[27]. The current study parallels this with the finding that perception of scarcity is different as it impacts all the three dimensions simultaneously instead of one construct being impacted. Conceptually, perceived water scarcity differs from related constructs in its activation scope. Perceived risk primarily triggers threat appraisal and protective motivation[23], while environmental concern reflects value-based dispositions toward general environmental issues[15]. In contrast, perceived scarcity combines situational urgency with resource-specific cognition, concurrently activating attitudes, normative perceptions, and efficacy beliefs—a tri-pathway mechanism that justifies its positioning as an antecedent rather than a parallel predictor within TPB.

Regarding the driving effects within the TPB pathways, this study found that the predictive power of water-saving intention on water-saving behavior was strongest ($\beta = 0.36$), with attitude exerting a stronger influence on intention ($\beta = 0.27$) than subjective norm ($\beta = 0.12$). Research on psychosocial determinants of household water conservation behavior reported a similar effect pattern, where individual-level attitude factors explained water conservation intention more strongly than social norm factors[28]. Research on Japanese residents' water-saving behaviors confirmed the robustness of the intention-behavior link by quantifying direct and indirect effects[29]. The present findings in the Chinese context corroborate TPB's cross-cultural applicability. Research integrating TPB with motivational theory to explore residential water-saving behavior emphasizes the facilitating role of intrinsic motivation in behavioral conversion[30]. Although this study did not directly measure motivational variables, the pathway through which perceived scarcity influences intention by affecting attitude partially reflects the activation mechanism of cognitive motivation.

Mediation analysis revealed that perceived scarcity promotes water-saving behavior through distinct psychological mechanisms. The attitude pathway emerged as the dominant mediator, followed by perceived behavioral control, with subjective norm contributing the least. This hierarchy underscores the critical role of evaluative cognition in translating scarcity awareness into conservation action, consistent with research showing that intervention effectiveness depends on individuals' evaluative judgments of water-saving actions[31].

This study confirms from the opposite direction the dominant role of attitude as the core mediating variable in the process of translating perceived scarcity into water-saving behavior. Research on the relationship between environmental responsibility, emotions, and public water conservation behavior revealed the significant role of emotional factors in behavioral decision-making[32]. Although this study focused on the cognitive pathway, both studies collectively indicate that effectively promoting water conservation behavior requires simultaneous attention to both cognitive and emotional psychological dimensions. Research on the influence of water pricing mechanisms and self-efficacy on sustainable water use behavior indicates that perceived behavioral control plays a key mediating role in the transformation of economic incentives into behavioral change [33]The significant indirect effect of the perceived behavioral control pathway in this study validates this perspective, suggesting that policymakers should fully consider enhancing residents' perceived behavioral control and self-efficacy when designing water conservation interventions.

5. Conclusion

This study systematically investigated the psychological mechanisms through which perceived water scarcity drives water-saving behavior using structural equation modeling and Bootstrap methods. The findings indicate that perception of scarcity as a precursor variable in the Theory of Planned Behavior (TPB) has a significant predictive effect on attitude, subjective norm, and perceived behavioral control variables. Perceived scarcity indirectly influences water-saving behavior through the chain of "scarcity perception → cognitive constructs → intention → behavior," with attitude mediation contributing most substantially The new, extended model demonstrates better fit and explanatory power compared to the standard TPB model. This study theoretically contributes to clarifying the meaning of what perceived scarcity is within the framework of behavioral theory and its psychological processes. Essentially, the findings provide evidence-based guidance for targeted interventions. Attitude-focused strategies should emphasize personal and societal benefits through public education campaigns and media messaging. Self-efficacy enhancement can be achieved via accessible skill training and subsidized water-efficient devices. Community-based programs and neighborhood initiatives may strengthen normative influences, particularly in collectivist cultural contexts. Although conducted in China, these psychological mechanisms are likely applicable across diverse water-scarce regions. Areas facing acute water stress, such as the Middle East and South Asia, may particularly benefit from scarcity-awareness campaigns leveraging the attitude pathway identified in this study. Future research should examine cultural moderators that may influence these pathways in different socio-economic contexts.

Conflict of interest

The authors declare no conflicts of interest.

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