Effects of water scarcity awareness and climate change belief on recycled water usage willingness: Evidence from New Mexico, United States

VIASM-HANU 2023 BMF Class

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Abstract

The global water crisis is being exacerbated by climate change, even in the United States. Recycled water is a feasible alternative to alleviate the water shortage, but it is constrained by humans' perceptions. The current study examines how residents' water scarcity awareness and climate change belief influence their willingness to use recycled water directly and indirectly. Bayesian Mindsponge Framework (BMF) analytics was employed on a dataset of 1831 residents in Albuquerque, New Mexico, an arid inland region in the US. We discovered that residents' willingness to use direct recycled potable water is positively affected by their awareness of water scarcity, but only if they believe in the impacts of climate change on the water cycle. Meanwhile, the willingness to use indirect recycled potable water is influenced by water scarcity awareness, and the belief in climate change further enhances this effect. These findings implicate that fighting climate change denialism and informing the public of the water scarcity situation in the region can contribute to the effectiveness and sustainability of long-term water conservation and climate change alleviation efforts.

Keywords: water shortage; potable water; Mindsponge Theory; eco-surplus culture; sustainable development.

> "Nightingale feeds himself sumptuously, gets thirsty, then goes inside the cage. Just when he is drinking the water, the door shuts down. A once-free bird is now a prisoner."
>
> — In "Dream"; *The Kingfisher Story Collection* (Vuong, 2022)

1. Introduction

Water, in general, and potable water, in particular, is indispensable for human beings. Water demand has rapidly increased due to industrialization, urbanization, population growth, and economic development. Due to the excessive water usage, water resources have depleted swiftly. Water scarcity, generally referred to as the condition in which the demand for water by all sectors exceeds the water supply, has become an alarming global issue, drawing much political and public concern.

According to a report published by UNESCO on behalf of UN-Water (UNESCO World Water Assessment Programme, 2023), it is estimated that about 2 billion individuals, accounting for 26% of the global population, lack access to clean drinking water. Additionally, the report highlights that around 3.6 billion people, constituting 46% of the population, do not have access to adequately managed sanitation facilities. Some projections suggest that the number of worldwide urban residents experiencing water scarcity is anticipated to increase twofold, rising from 930 million in 2016 to a range of 1.7 to 2.4 billion by 2050. The increasing prevalence of severe and prolonged droughts also exerts pressure on ecosystems, resulting in grave ramifications for various plant and animal species (UNESCO World Water Assessment Programme, 2023). As a result, the solution for water scarcity and quality is set as the main focus in multiple international, regional, and national organizations, associations, committees, and conferences (Liu et al., 2017; UNESCO, 2016).

Many families in the United States encounter challenges with deficient plumbing infrastructure and substandard water quality. By utilizing data from the American Community Survey and the Environmental Protection Agency, Mueller and Gasteyer (2021) revealed that a total of 489,836 houses are devoid of comprehensive plumbing facilities. One thousand one hundred sixty-five community water systems violated the Safe Drinking Water Act, categorized as Serious Violations, while 9,457 Clean Water Act permittees were in Significant Noncompliance. The study conducted by Flavelle et al. (2023) has recently brought forth significant apprehensions over the future of groundwater resources in the United States. The utilization of groundwater resources significantly transformed the United States into a formidable agricultural force after World War II. Nevertheless, this growth is often accompanied by the overutilization of groundwater resources, resulting in the depletion of aquifers.

Global climate change significantly contributes to the current water scarcity crisis. It is a worldwide issue that impacts the access and quality of water resources, especially potable water sources (Eckert et al., 2008; Ma et al., 2022). Climate change affects the world's water in complex ways. Infectious disease epidemics frequently coincide with extreme weather events, as microorganisms, vectors, and reservoir animal hosts take advantage of the altered social and environmental conditions resulting from such occurrences (McMichael, 2015). Rising temperatures can also lead to the rise in seawater levels and the intrusion of salt water into the coastal aquifers (Misra, 2014), besides facilitating the rise of deadly pathogens in freshwater sources, making the water dangerous for people to drink (Nichols et al., 2018). Climate change can exacerbate water stress in areas with minimal water resources, leading to increased competition for water and even conflicts (Gleick, 2014). In a recent study, Fan et al. (2023) suggest climate change can also affect pipe failures in the US.

With the looming challenges of water scarcity worldwide, unconventional water resources are considered viable alternatives to freshwater, especially in arid and semi-arid areas (Karimidastenaei et al., 2022). These water resources require new technologies and specialized processes to convert them into safe and usable states to complement human life (Ahmed, 2010; Negm, 2019). Karimidastenaei et al. (2022) have identified twelve general types of these unconventional resources, with desalination of saltwater and treatment of wastewater being the most prominent methods. The improvement of technology, analytical methods, and microbiology has allowed wastewater to be recyclable for irrigation practices and indoor applications such as toilet flushing (Gao et al., 2019; Vuppaladadiyam et al., 2019). In certain countries and regions, recycled water quality has reached the drinking water standard (Price et al., 2012). As such, various countries around the globe have implemented multiple initiatives to encourage the use of recycled wastewater to alleviate the burden on freshwater (Vuppaladadiyam et al., 2019).

Yet, public perceptions and acceptance of recycled wastewater are identified as one of the most significant barriers against its usage rather than the technology itself (Vuppaladadiyam et al., 2019). In studying the public response to the usage of reclaimed water, Ormerod and Scott (2013) found that trust in water authorities can significantly impact public attitudes towards recycled water. In exploring the role of emotions in water reuse behavior, Gao et al. (2019) found that the perceptions of recycled water can initiate positive and negative feelings, significantly affecting the initiation, formation, and sustainability of recycled water behavior.

A thorough review by Fielding et al. (2018) identified socio-demographic characteristics, psychological elements, and water characteristics as three major predictors of public acceptance. While most studies found mixed results about how different socio-demographic groups embrace recycled water, studies focused on mental processes found homogenous trends. Specifically, high health risk perceptions led to low acceptance of recycled water. Trust in authorities also appeared as a critical factor, as people living in scarce water areas also do not have the resources to develop their own knowledge about water scarcity and the use of recycled water.

Several studies investigate the link between perceived water scarcity and recycled water acceptance, but the results seem debatable. Hou et al. (2021) discovered that the disclosure of information regarding regional water shortages and the promotion of public awareness regarding the protection of water environments positively impact the acceptance of recycled water by the general public. Additionally, disclosing regional water shortage information indirectly influences public acceptance of recycled water by shaping their awareness of water environment protection. Meanwhile, two studies found no significant relationship (Bruvold & Ward, 1972; Fielding et al., 2018; Garcia-Cuerva et al., 2016). The discrepant findings hint at other factors moderating the relationship between water scarcity awareness and recycled water acceptance. Moreover, while general environmental concerns are found to be related to greater acceptance of recycled water, few studies have investigated the effects of climate change beliefs on recycled water acceptance.

Therefore, our study aims to fill in these gaps by performing Bayesian Mindsponge Framework analytics on a dataset of 1831 residents in Albuquerque, New Mexico, USA, for the following objectives:

- Examine the residents' water scarcity awareness's effect on their willingness to use direct and indirect recycled water.
- Examine the moderation effect of the belief in climate change on the relationship between the residents' water scarcity awareness and their willingness to use direct and indirect recycled water.

The study consists of five main sections. The first section introduces the study's importance, rationale, and objectives. The second section elaborates on the theoretical foundation of the model construction (i.e., Mindsponge Theory) and the materials and methods employed. The third section presents the estimated results using the Bayesian analysis, while the final section discusses the implications of the study's findings.

2. Methodology

2.1. Theoretical foundation

The Mindsponge Theory was utilized as the theoretical foundation for constructing models in this study. The theory was initially the mindsponge mechanism developed by Vuong and Napier (2015) to explain how top managers absorb new values and eject waning ones out of their mindset. The term "mindsponge" is coined by analogizing the mind to a sponge, which expels unsuitable values and absorbs new ones compatible with its core values (Vuong & Napier, 2015). Capitalizing on the new evidence discovered in life, neuro-, and ecological sciences, the mechanism was further developed into Mindsponge Theory to explain better a wider range of processing systems and socio-psychosocial phenomena (Vuong, 2023).

The Mindsponge Theory offers a dynamic perspective on information processing that can help connect the socio-psychological phenomena with the fundamental level of human cognition (e.g., neurons), address intricate aspects of human thinking, and elaborate and enhance existing psychological and social theories and frameworks.

Theory of Planned Behaviour (TPB) is a well-known psychological theory that explains how humans' beliefs are linked to behaviors (Ajzen, 1985, 1991), so it has been employed to study behaviors related to conservation, including water conservation (Gibson et al., 2021; Ho et al., 2015; Howell et al., 2015; Klöckner, 2013). Specifically, TPB was recently used to explore the effects of attitudes, subjective norms, perceived behavioral control, and connectedness to water on behavioral intent related to landscape irrigation among Florida, Georgia, and Alabama residents. Gibson et al. (2023) found that subjective norms, perceived behavioral control, and connectedness to water were positive predictors of behavioral intent and actual behaviors related to water conservation. Although TPB is an effective theory to explain the connection between beliefs, intentions, and behaviors, it lacks the ability to deal with the dynamics of human thinking that we aimed to study in this study: the non-linear relationship between awareness of water scarcity and recycled water usage willingness (moderated by the climate change belief). Thus, the Mindsponge Theory, with its capability to explain the continuous dynamic information absorption-process-ejection mechanisms of the mind, is expected to complement the TPB in reasoning the cognition and behavior-shifting processes.

Mindsponge Theory includes two primary spectrums (Vuong, 2023): the mind, an information collection and processing unit, and the broader environment, encompassing systems like the Earth system, social systems, and the mind. The mind's primary objective is to ensure its system's prolongation in one way or another, including survival, growth, and reproduction. Conceptually, the mind comprises three major components: the mindset, buffer zone (comfort zone), and multi-filtering system. The mindset is defined as a set of highly trusted information (or core values), while the buffer zone temporarily holds information for the multi-filtering process.

The multi-filtering system serves two key functions. When information enters the mind through the absorption of sensory systems, it undergoes two processes. Information consistent with the core values is integrated. However, suppose new information significantly deviates from core values. In that case, it goes through a differentiation process, evaluating the cost and benefit of the information for subsequent acceptance, rejection, or storage for later evaluation. Generally, if new information is seen as potentially beneficial, it is accepted into the mindset, influencing subsequent thinking and behaviors. If it is perceived as costly, it is likely rejected. Information with ambiguous values is stored in the buffer zone for later assessment when sufficient information is available (Vuong et al., 2022).

From the Mindsponge information-processing perspective, the residents' awareness of water scarcity issues can be deemed equivalent to information related to water scarcity issues stored within the mind. With a larger amount of such information in the mind, subsequent information processes, thinking, and behaviors are more likely to be affected. In other words, when residents perceive the water scarcity issues in the region, they are more likely to accept solution-related information into the mindset to minimize the risk of water shortage: using water recycled water directly and indirectly. Therefore, we assume that higher awareness of water scarcity is positively associated with the willingness to recycled water usage.

However, core values (beliefs) can also affect the information process. Awareness of water scarcity does not necessarily make people think the water shortage is a persisting problem, but it depends on the situation. If people believe in climate change's impacts on the water cycle, they might consider water scarcity a persisting problem. Otherwise, the water scarcity might be perceived as temporary and to recover in the future. As a result, we also assumed that the climate change belief moderates the relationship between awareness of water scarcity and recycled water usage willingness.

These assumptions will be tested through models constructed in the following Subsection.

2.2. Model Construction

2.1.1. Variable selection and rationale

Data used in the current study resulted from a large-scale public survey delivered via mail to a random sample of 4000 water-utility account holders in Albuquerque, New Mexico, USA. The survey collection was conducted by Distler and Scruggs (2020b) in collaboration with the Albuquerque Bernalillo County Water Utility Authority (ABCWUA), the sole supplier of water and wastewater services to the broader Albuquerque metropolitan region with over 600,000 water users. The dataset and its description have been peer-reviewed and published in *Data in Brief* (Distler & Scruggs, 2020b). The dataset was also employed in other studies about water consumption behaviors in Albuquerque, New Mexico (Distler, 2018; Distler & Scruggs, 2020a; Distler et al., 2020).

The survey queried ABCWUA account holders about their water knowledge, water consumption habits, attitudes toward water-related issues, and demographic data. The survey was available in four versions, with the only difference being on page five: Version 1 was the control and had no additional content, whereas the other three versions each had a different collection of educational materials on page five since specific sorts of educational materials are thought to alter perceptions and views relating to water reuse. Versions 2, 3, and 4 supply information on “Water Sources and Reliable Supplies,” “Environmental Benefits of Water Reuse,” and “The Urban Water Cycle,” as defined in the codebook and survey instrument, respectively.

Eight focus groups and 12 debriefing sessions were conducted with individual members of the studied population to design the survey. The focus groups took place in July, October, and November of 2016, while the debriefing sessions took place in August, October, and November of the same year. Eight 90-minute focus groups with 7-10 individuals each help test prototype survey questions to improve the survey content. Participants had to be at least 18 years old and ABCWUA clients to be included. Distler and Scruggs (2020b) tested the draft survey on 12 individual members of the sample population in a series of one-on-one survey debriefing sessions halfway through and following the completion of the focus groups. Debriefings helped researchers to check that survey questions and materials were accurately evaluated and comprehended, as well as assess how long it would take to finish the survey.

A random sample of 4,000 accounts was drawn from a database of over 180,000 residential accounts maintained by ABCWUA. Customer names were removed from the sample to safeguard respondent’s privacy, and addresses were deleted once data analysis was completed. Each potential survey participant was assigned a unique random code for anonymous tracking of responses. The sample proportions in each quadrant were compared to those in the customer accounts log to confirm that the sample and population proportions matched (within 1%). The survey was collected through mail and Survey Monkey (online).

The database also supplied information regarding the city quadrant where each customer resided. We ensured the sample's quadrant proportions closely matched those in the overall customer accounts database (within a 1% margin). The survey was administered by mail due to the availability of physical addresses, although respondents were offered the option to complete it online using Survey Monkey through a mailed invitation.

A preliminary test was conducted on 200 water utility customers randomly selected to validate the survey instrument. The pretest had two purposes: it estimated the expected response rate for the main survey, and it evaluated the efficacy of our survey administration techniques. Based on the pretest's results, the survey instrument and administration process were refined and sent to a random sample of 4,000 ABCWUA account holders. Eventually, 1831 responses were obtained, with a response rate of 46%.

Four variables retrieved from the dataset were used in this study to build the model: two outcome variables and two predictor variables. Two outcome variables are *DPR_WILL* and *IPR_WILL*. These two variables represent the respondents' willingness to use recycled water directly and indirectly. *SCARCITY_AWARE* and *CLIMATE* are two predictor variables. While *SCARCITY_AWARE* reflects the respondents' awareness level of water scarcity, *CLIMATE* reflects whether the respondent believes in climate change. Detailed descriptions of these variables are shown in Table 1.

Table 1: Description of variables

Variable	**Description**	**Type of Variable**	**Value**
DPR_WILL	Willingness to accept Direct Potable Reuse	Binary	0 = No 1 = Yes
IPR_WILL	Willingness to accept Indirect Potable Reuse	Binary	0 = No 1 = Yes
SCARCITY_AWARE	Awareness of water scarcity issues	Numerical	1 = Not at all aware 2 = Slightly aware 3 = Moderately aware 4 = Very aware

			5 = Extremely aware
CLIMATE	Belief in the impact of climate change on the water cycle in the next 10-40 years	Binary	0 = No 1 = Yes

2.2.2. Statistical Model

The first model was constructed to examine the effects of $SCARCITY\_AWARE$ on DPR_WILL_3 and the moderation effect of $CLIMATE$:

$$DPR\_WILL\_3 \sim \text{normal}\left(\log\left(\frac{\mu_i}{1-\mu_i}\right), \sigma\right)$$

$$\log\left(\frac{\mu_i}{1-\mu_i}\right) = \beta_0 + \beta_1 * SCARCITY_{AWARE\,i} + \beta_2 * SCARCITY\_AWARE_i * CLIMATE_i$$

$$\beta \sim normal(M, S)$$

The probability around the mean $\log\left(\frac{\mu_i}{1-\mu_i}\right)$ is determined by the shape of the normal distribution, where the width of the distribution is specified by the standard deviation σ. μ_i indicates the probability that the residential account holder i willing to accept drinking recycled water directly. $SCARCITY\_AWARE_i$ indicates the awareness level of the residential account holder i about water scarcity issues. $CLIMATE_i$ indicates whether the residential account holder i believes in the impact of climate change on the water cycle. Model 1 has four parameters: the coefficients, β_1 and β_2, the intercept, β_0, and the standard deviation of the "noise," σ. The coefficients of the variables are distributed as a normal distribution around the mean denoted *M*, with the standard deviation denoted *S*. The logical network for Model 1 is presented in Figure 1.

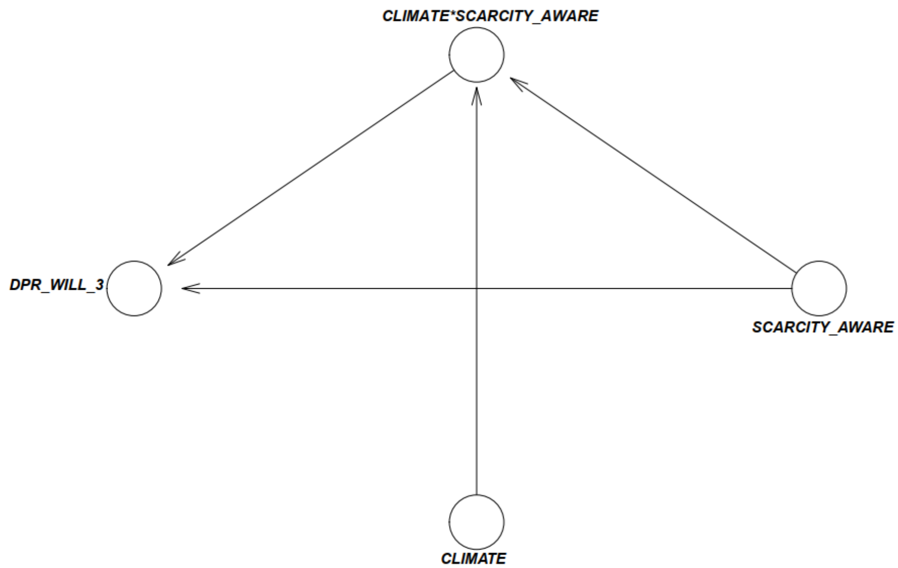

Figure 1: Model 1's logical network

The second model was constructed similarly to Model 1 but with the outcome variable replaced as IPR_WILL_3

$$IPR\_WILL\_3 \sim \text{normal}\left(\log\left(\frac{\mu_i}{1-\mu_i}\right), \sigma\right)$$

$$\log\left(\frac{\mu_i}{1-\mu_i}\right) = \beta_0 + \beta_1 * SCARCITY\_AWARE_i + \beta_2 * SCARCITY\_AWARE_i * CLIMATE_i$$

$$\beta \sim normal(M, S)$$

IPR_WILL_3 indicates the probability that the residential account holder i willing to accept drinking recycled water indirectly. Model 2's logical network is illustrated in Figure 2.

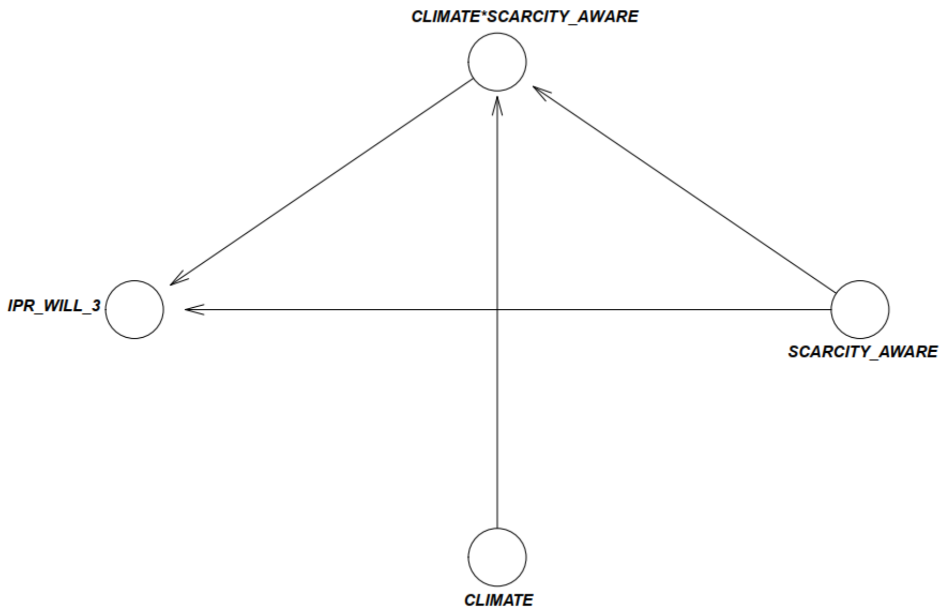

Figure 2: Model 2's logical network

2.3. Analysis and validation

The Bayesian Mindsponge Framework (BMF) analytics is a method combining the strengths of Mindsponge Theory and Bayesian analysis for analyzing data in cognitive, psychological, and social research (Nguyen et al., 2022; Vuong et al., 2022). It is particularly useful in studying psychological processes and mechanisms in several fields, including but not limited to mental health, psychological adaptation, and environmental psychology (Asamoah et al., 2023; Khuc, Dang et al., 2023; Khuc et al., 2022; Khuc, Tran, et al., 2023; Mantello et al., 2023; Nguyen et al., 2021; Nguyen, Le et al., 2023; Nguyen, Nguyen, et al., 2023; Vuong et al., 2023)

BMF was applied in this research for several reasons. First, the method combines the reasoning strengths of Mindsponge Theory with the inferential advantages of Bayesian analysis (Nguyen et al., 2022). Second, Bayesian inference evaluates all attributes probabilistically, allowing reliable predictions with parsimonious models that help improve predictability (Cougle, 2012; Gill, 2014; Simon, 2001). Third, Bayesian inference enables users to use credible intervals for result interpretation instead of the dichotomous decision using *p*-value, which is suggested to be one of the leading causes behind the reproducibility crisis (Halsey et al., 2015; Wagenmakers et al., 2018).

There are two main components in BMF analytics: Mindsponge-based model construction and Bayesian analysis. The former component is presented in Subsection 2.1, while the second component is explained here. Bayesian analysis comprises five main steps (Vuong et al., 2022):

1) Model construction
2) Prior selection
3) Model fitting
4) Result diagnosis and interpretation
5) Model comparison

In the current study, we aim to test the model constructed based on Mindsponge-Theory-induced assumptions, so Step 5 was not implemented. The models built based on Mindsponge Theory are presented in Subsection 2.2.2. As the nature of this study is exploratory, models were constructed with uninformative priors or a flat prior distribution to provide as little prior information as possible for model estimations.

After fitting the constructed models, we employed the Pareto-smoothed importance sampling leave-one-out (PSIS-LOO) diagnostics to check the model's goodness of fit. LOO is computed as follows (Vehtari & Gabry, 2019; Vehtari et al., 2017):

$$LOO = -2LPPD_{LOO} = -2\sum_{i=1}^{n} log \int p(y_i|\theta)p_{post(-i)}(\theta)d\theta$$

The posterior distribution, denoted as $p_{post(-i)}(\theta)$, is calculated based on the data minus data point i. In the R loo package, the PSIS method was used to compute leave-one-out cross-validation k-Pareto values. Commonly, the model is regarded as being fit when a model's k values are below 0.5.

Then, we verified the convergence of Markov chains statistically using the effective sample size (*n_eff*) and the Gelman–Rubin shrink factor (*Rhat*) and visually by trace plots. The Markov chain central limit theorem holds if the Markov chains converge, and the estimated results become reliable and qualified for interpretation. The *n_eff* value represents the number of iterative samples that are not autocorrelated during stochastic simulation. If *n_eff* is bigger than 1000, it is generally considered that the Markov chains are convergent, and the effective samples are sufficient for reliable inference (McElreath, 2018). The *Rhat* value is alternatively referred to as the potential scale reduction factor or the Gelman-Rubin shrink factor (Brooks & Gelman, 1998). It should not exceed 1.1 for convergence to be achieved. Commonly, the model is considered convergent if *Rhat* = 1.

We employed the bayesvl and the ggplot2 R packages to conduct Bayesian analysis and produce appealing visualizations (La & Vuong, 2019). The whole code and dataset employed for this research have been deposited in the Open Science Framework to ensure openness, facilitate future replication, and contribute to lowering scientific costs (Vuong, 2018).

3. Results

3.1. Model 1

Model fitting was performed on R version 4.2.1 ("Vigorous Calisthenics") using four Markov chains, each consisting of 5000 iterations, with 2000 used for the warmup period. The simulation took 201 s to be completed. The simulated results are displayed in Table 2.

First, we checked the goodness of fit between the constructed model and the dataset using the PSIS-LOO test. The test's estimated *k*-values are shown in Figure 3, which shows that most of the *k*-values are below 0.05. These *k*-estimates suggest that the model fits the data reasonably well.

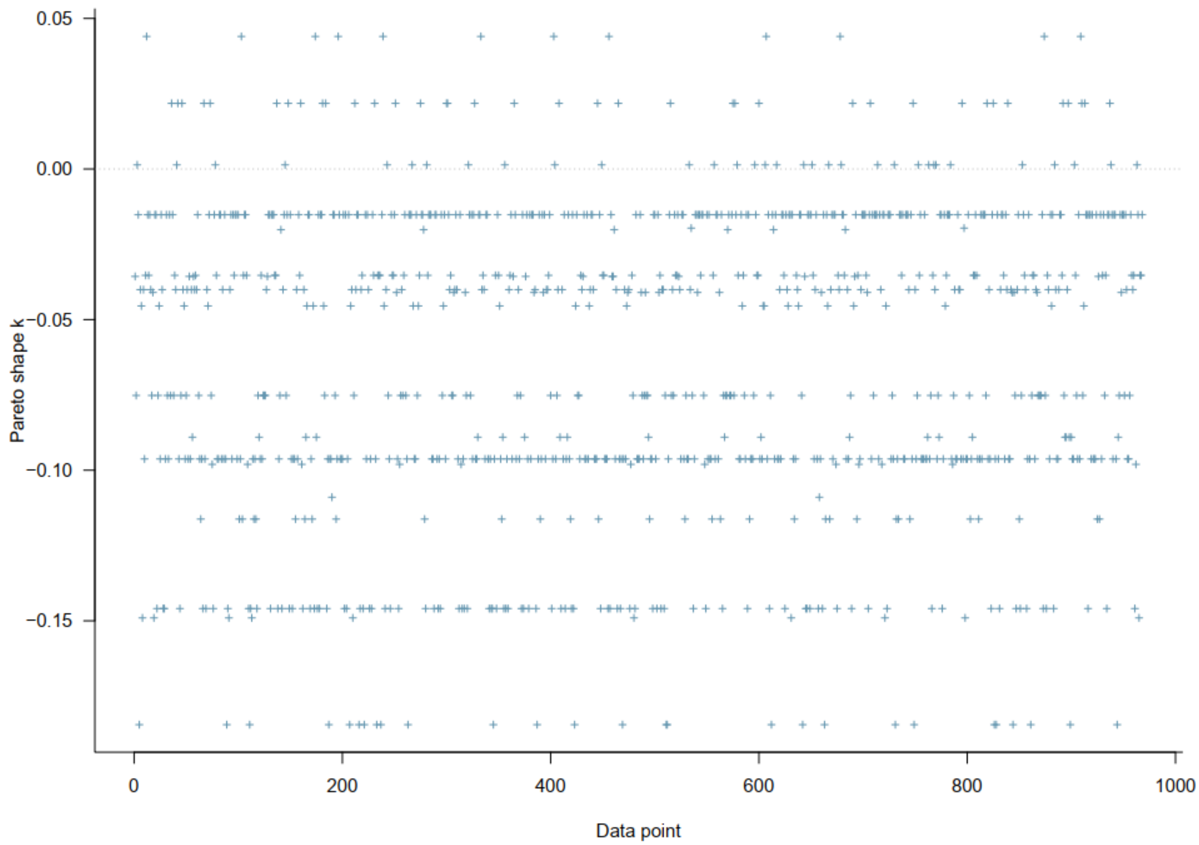

Figure 3: Model 1's PSIS-LOO test

Table 2: Model 1's estimated results

Parameters	Mean	Standard deviation	*n_eff*	*Rhat*
Constant	0.47	0.24	4085	1
SCARCITY_AWARE	0.03	0.08	3638	1

*SCARCITY_AWARE*CLIMATE*	0.09	0.05	4920	1

Then, we proceeded with diagnosing the Markov chain convergence. All the coefficients' *n_eff* values are greater than 1000, and the *Rhat* values are equal to 1, implying that the model's Markov chains have converged well.

We also visualized the trace plots to confirm the Markov chain's convergence (or the Markov chain central limit theorem). Figure 4 illustrates the coefficients' Markov chains are well mixed around an equilibrium, which is a good signal of convergence.

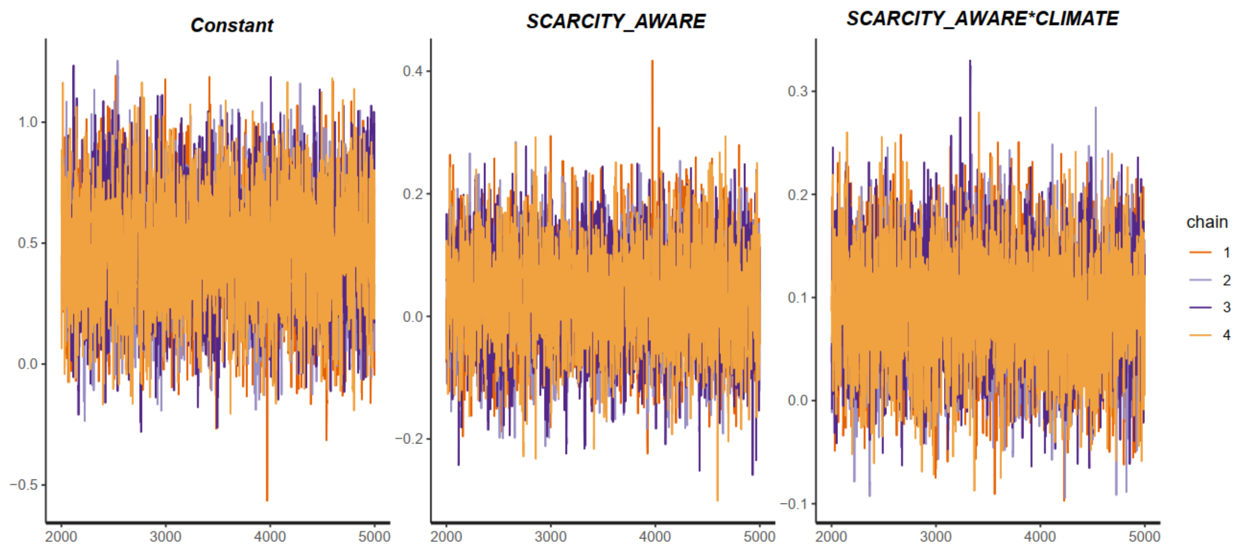

Figure 4: Model 1's trace plots

The simulated results manifest the positive association between *SCARCITY_AWARE*CLIMATE* and *DPR_WILL_3* ($M_{SCARCITY\_AWARE}$ = 0.09 and $S_{SCARCITY\_AWARE}$ = 0.05). The association is reliable as its posterior distribution is located entirely on the positive side of the *x*-axis (see Figure 5). Meanwhile, *SCARY_AWARE* has an ambiguous effect on *DPR_WILL_3* ($M_{SCARY\_AWARE*CLIMATE}$ =0.03 and $S_{SCARY\_AWARE*CLIMATE}$ = 0.08).

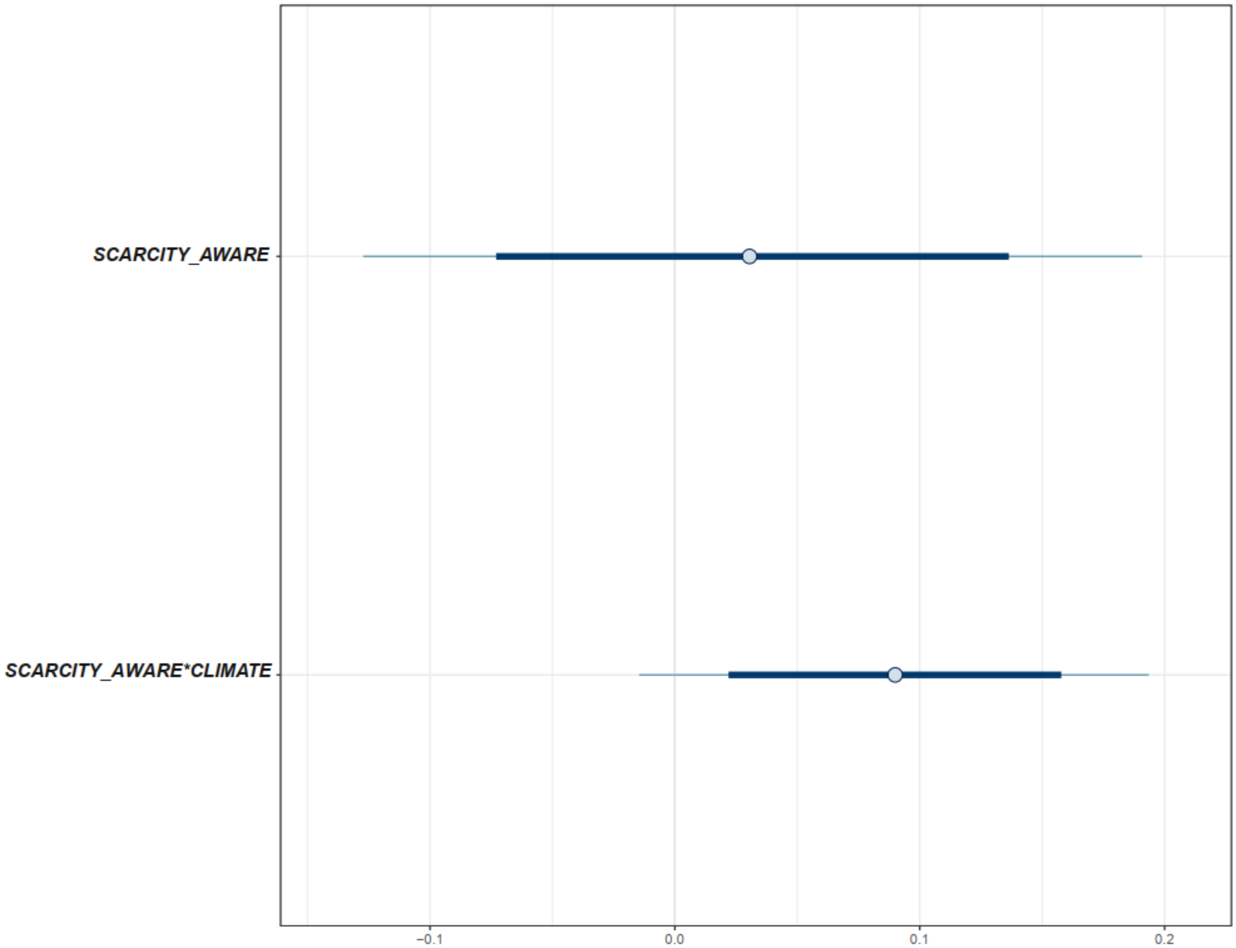

Figure 5: Model 1's posterior distributions

To aid the result interpretation, we estimated the residents' probability of being willing to use recycled water directly based on the posterior coefficients of the model. Figure 6 shows the illustration, where the *y*-axis represents the probability of being willing to use direct recycled water, and the *x*-axis represents the awareness level of water scarcity. The colored lines distinguish whether the people believe in climate change or not. As can be seen, for people without the belief in climate change's impact on the water cycle, the probability of being willing to use direct recycled water is not affected by the awareness level of water scarcity. Meanwhile, the awareness level of water scarcity is positively associated with the probability of being willing to use it when the resident believes in climate change's impact.

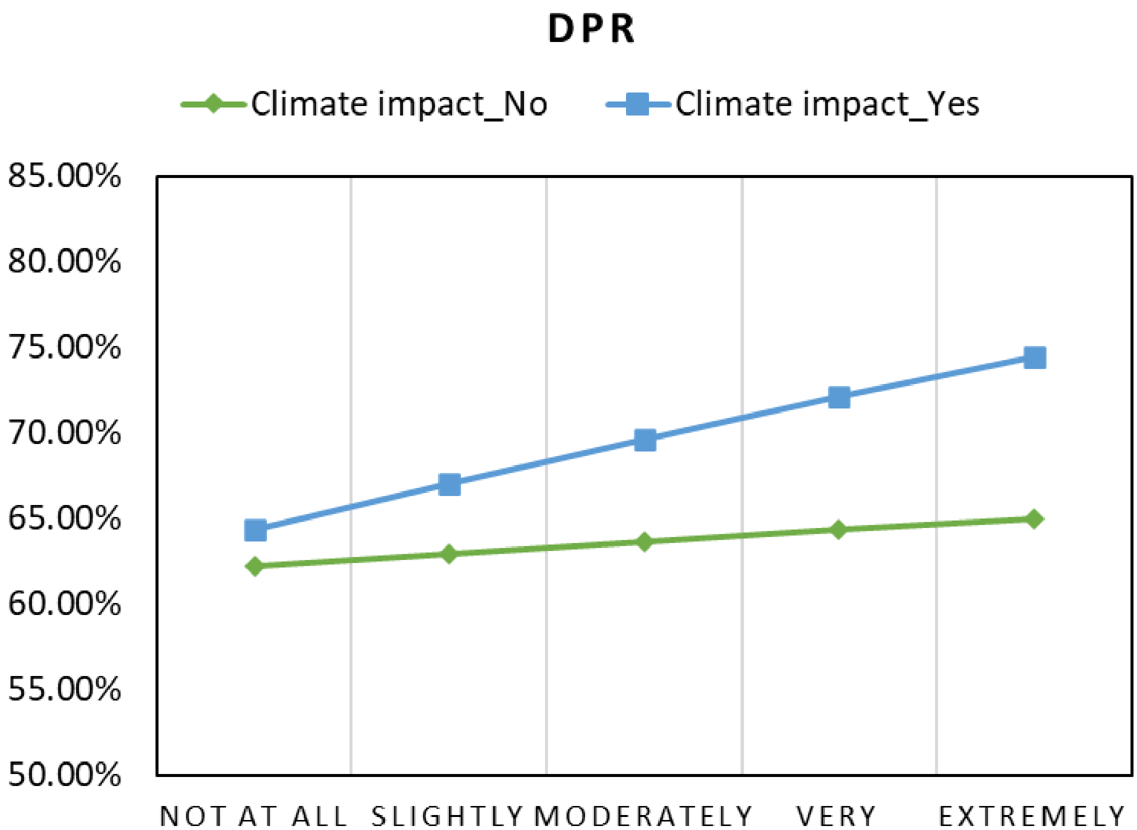

Figure 6: Probability of being willing to use direct recycled water

3.2. Model 2

Model 2 was fitted using a similar setup to Model 1 (i.e., iterations, warmup period, Markov chains). The simulation took 205 seconds to be completed; its results are shown in Table 8.

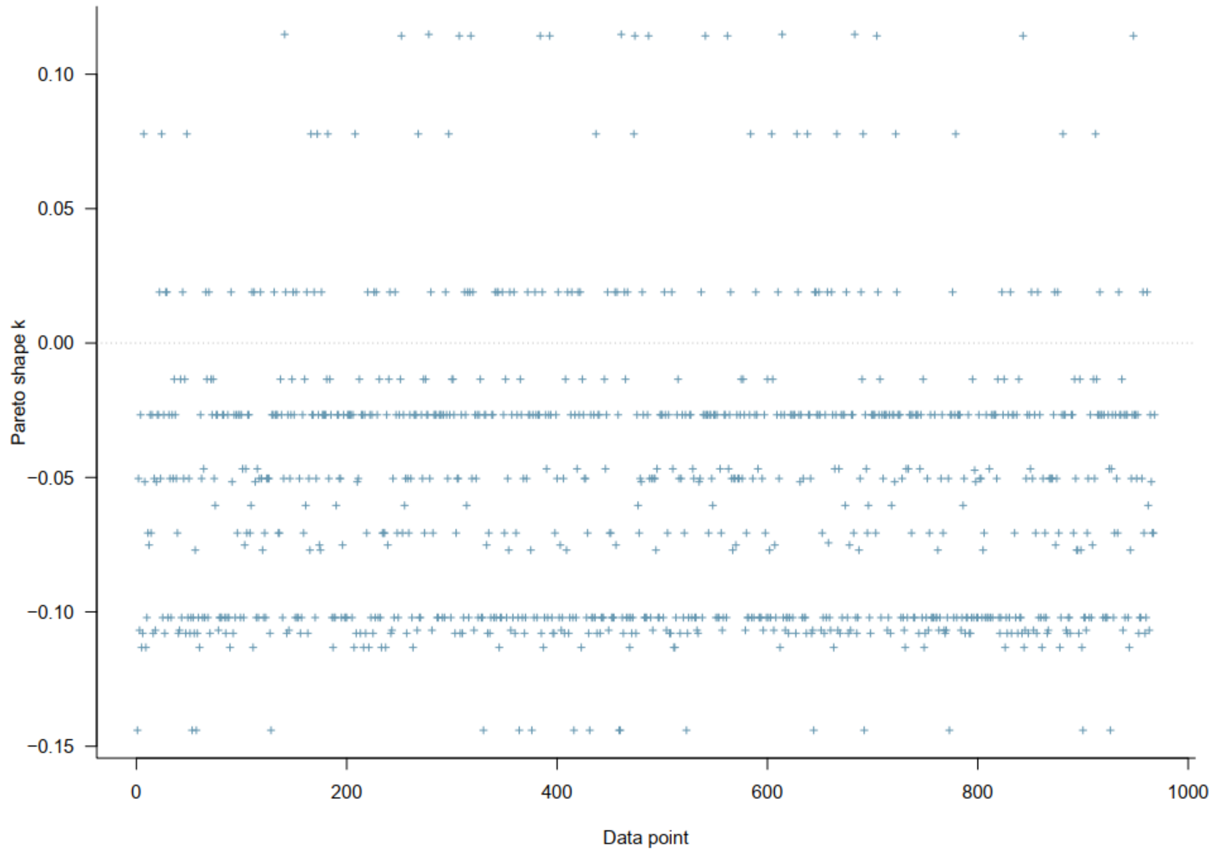

Figure 7: Model 2's PSIS-LOO test

The PSIS-LOO test again shows all *k*-values are below 0.012 (see Figure 7). Such *k*-estimates suggest the model is suitable with the data well.

Table 3: Model 2's estimated results

Parameters	Mean	Standard deviation	n_eff	Rhat
Constant	0.60	0.25	4437	1
SCARCITY_AWARE	0.12	0.09	3970	1
*SCARCITY_AWARE*CLIMATE*	0.05	0.06	5015	1

We also visualized the trace plots to confirm the Markov chain's convergence. Figure 9 illustrates the mixing of all coefficients' Markov chains around an equilibrium, representing a good convergence signal.

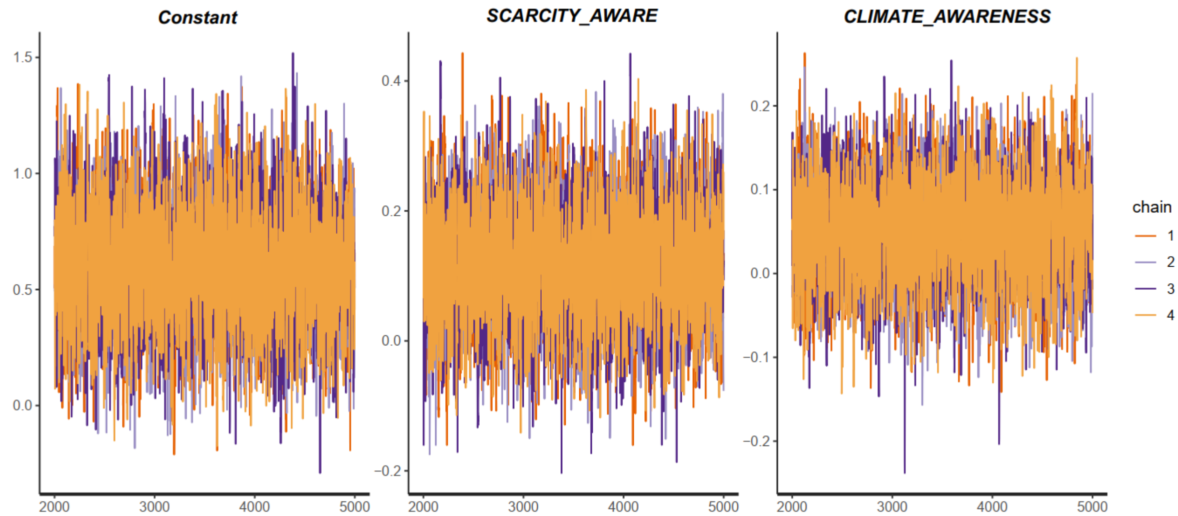

Figure 9: Model 2's trace plots

The simulated results manifest the positive effects of *SCARCITY_AWARE* ($M_{SCARCITY\_AWARE}$ = 0.12 and $S_{SCARCITY\_AWARE}$ = 0.09) and *SCARCITY_AWARE*CLIMATE* ($M_{SCARCITY\_AWARE*\ CLIMATE}$ =0.05 and $S_{SCARCITY\_AWARE*\ CLIMATE}$ = 0.06) on *IPR_WILL_3*. The coefficients' posterior distributions are visualized in Figure 10, confirming the high reliability of the association between *SCARCITY_AWARE* and *IPR_WILL_3* as its posterior distribution is located entirely on the positive side of the *x*-axis. Meanwhile, the effect of *SCARCITY_AWARE*CLIMATE* on *IPR_WILL_3* is only moderately reliable because a small portion of its distribution is still situated on the negative side of the *x*-axis.

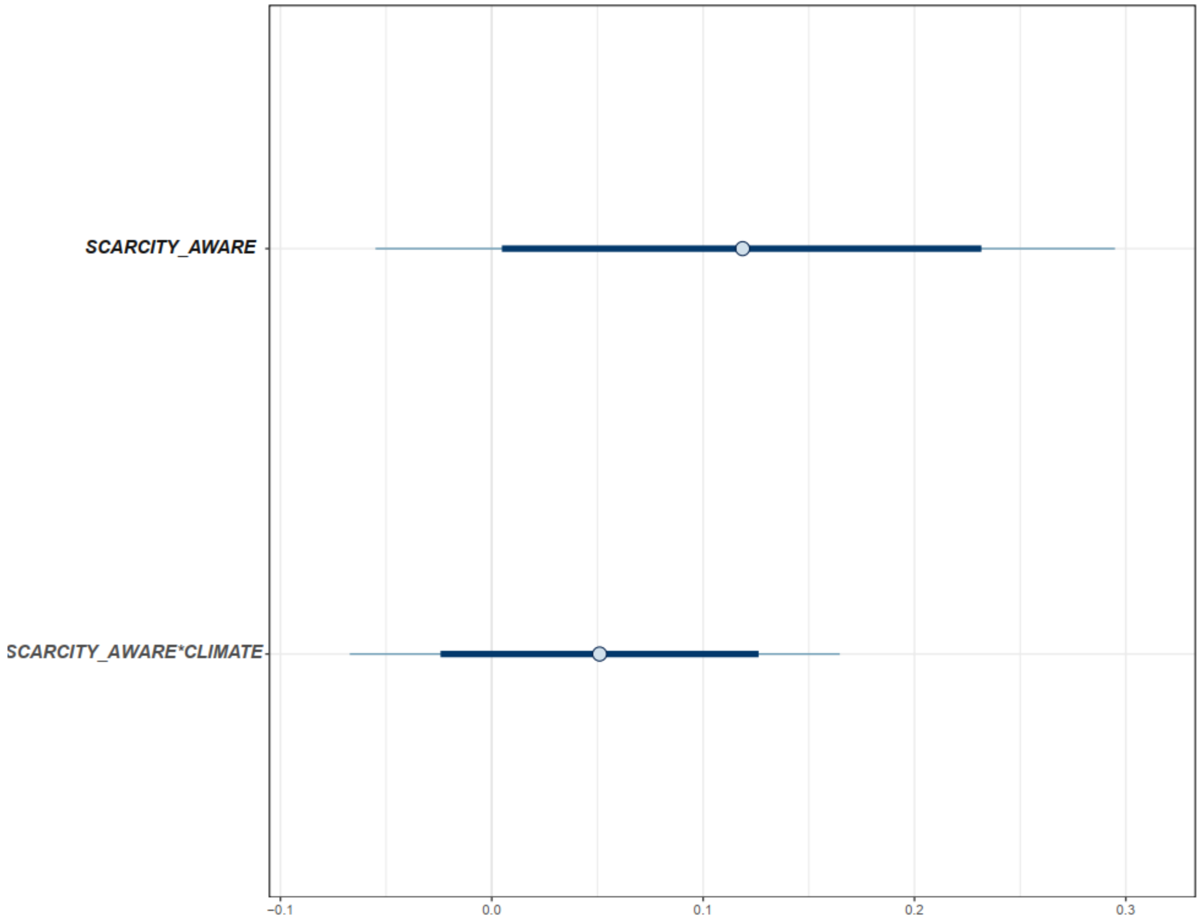

Figure 10: Model 2's posterior distribution

Figure 11, visualized based on the estimated parameters of Model 2, illustrates the residents' probability of being willing to use recycled water indirectly. It shows that the willingness to use indirect recycled water increases regarding the awareness of water scarcity. The effect of water scarcity awareness on indirect recycled water usage willingness is positively moderated by the belief in climate change's impact on the water cycle.

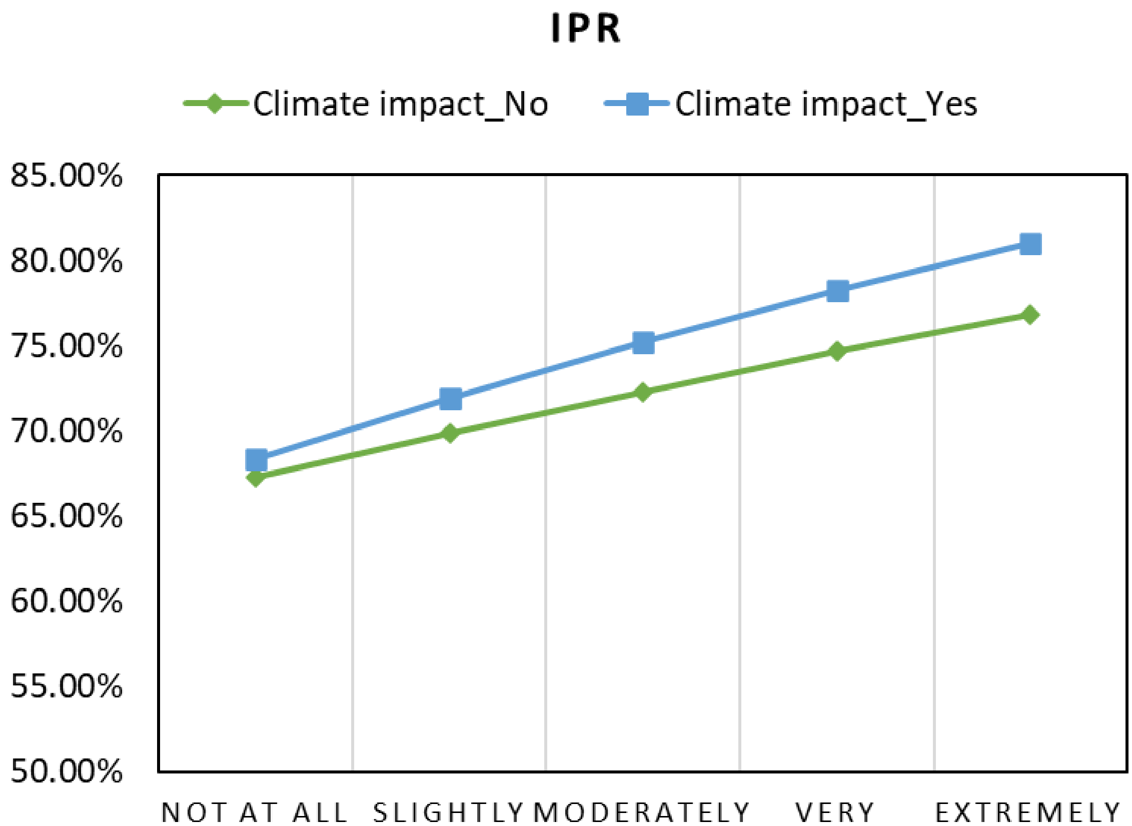

Figure 11: *Probability of being willing to use indirect recycled water*

4. Discussion

The current study employed the Bayesian Mindsponge Framework analytics to examine the effect of residents' awareness of water scarcity on the willingness to use direct and indirect recycled potable water and whether the belief in climate change moderated the relationship. Analyzing the dataset of 1831 residents in New Mexico, USA, we found that for direct recycled potable water, the awareness of water scarcity only has a positive impact on the usage willingness when the residents believe in climate change. Meanwhile, for indirect recycled potable water, water scarcity awareness has a positive impact on recycled water usage willingness, which is further amplified by the belief in climate change.

These results confirm our Mindsponge-based assumptions that the residents' water scarcity awareness (information stored in the mind) can influence their recycled water usage willingness (an outcome of the information process), but the effect is conditional on their status of belief in climate change (core value within the mindset). The person's belief in climate change will make them more likely to perceive the uncertainty of water supply in the future, adding more perceived risks/costs to the water scarcity crises. When water scarcity is perceived to threaten the well-being of the person in the future, they will be more likely to seek, absorb, and accept solution-related information that helps alleviate the crises. As a result, recycled water usage ideation is more likely to emerge in people's minds, making them more willing to use direct and indirect recycled water.

Climate change belief is a crucial factor moderating the relationship between water scarcity awareness and the emergence of recycled water usage ideation (subsequently, the usage willingness). However, climate change denialism is an existing problem in the US, hindering the efforts to motivate people to adopt sustainable water usage practices. People advocating climate change denialism reject scientific evidence of climate change or deny the role of humans as the cause of this crisis (Goldenberg, 2010; Readfearn, 2015). Denialism is so pervasive that it is even embedded in political activities. For example, Florida Governor Ron DeSantis recently rejected $350 million in federal funds to tackle climate change (Otten, 2023). If the climate change denialism issues are not appropriately addressed, they will negatively affect not only climate change but also the water crisis in the US.

Practically, the current study's findings suggest that informing the public about the current water crises and climate change issues can help improve their recycled water usage willingness, facilitating the implementation of recycled water projects. Moreover, building an eco-surplus culture among residents is no less critical as it helps shift their perspectives to be more environment-centered. As a result of this culture, stakeholders' thinking, decision-making, and actions will be influenced to produce more positive values "to reduce negative anthropogenic impacts on environments as well as conserve and restore nature" (Nguyen & Jones, 2022a). Residents with an eco-surplus culture can even go beyond basic sustainability and actively participate in creating environmental surplus impacts, hence improving the effectiveness and sustainability of long-term water conservation and climate change alleviation efforts (Nguyen, Duong, et al., 2023; Nguyen & Jones, 2022b; Pradhananga & Davenport, 2019).

The study has several limitations, so we report them here for transparency (Vuong, 2020). First, residents' willingness to use recycled water was self-reported, so it might not necessarily correspond with actual behaviors. Moreover, the sample size is bounded in Albuquerque city, so it does not represent areas with different geographical and climate characteristics in the US. Future studies should be conducted to validate the effects of water scarcity awareness and climate change belief on recycled water usage willingness in other areas with different geographical and climate characteristics.

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