# Potable Water Reuse Willingness among water users in the United States's arid region: The roles of concerns about local issues

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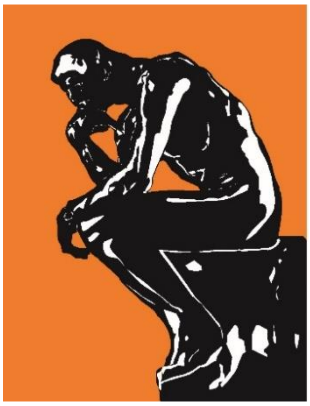

March 22, 2024 [Preprint v.2]

"[…] 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* (2022a).

**Abstract:**

Given the close relatedness of local issues, water scarcity, and sustainability, this research sought to investigate the factors affecting residents' willingness to reuse direct and indirect potable water in the arid region. Utilizing the Bayesian Mindsponge Framework (BMF), an analysis was undertaken with a sample of 1,831 water consumers in the City of Albuquerque, the most populous city in New Mexico, United States. The primary analysis revealed positive associations between local concerns about drought or water scarcity and population growth with residents' willingness to reuse direct and indirect potable water. Conversely, concerns about water quality and water bills were found to be negatively associated with the willingness to utilize directly and indirectly recycled water for drinking. In light of these findings, the study explores the potential of fostering an eco-surplus culture by cultivating a sense of environmental responsibility and acknowledging the relationship between local issues and environmental conditions. Simultaneously, the study proposes collaboration between the government and residents to promote water reuse programs to conserve water resources effectively.

**Keywords:** water resource management, recycled water, concerns, local issues, arid region, Mindsponge theory

## 1. Introduction

Water stands as one of the most vital resources bestowed upon the Earth. The quality of life diminishes significantly in environments afflicted by severe water scarcity. Many factors entwined with economic growth and urban expansion influence water utilization in urban settings. Notably, there has been a progressive surge in the demand for wastewater recycling. However, many remain unfamiliar with the intricacies of the water recycling industry and harbor concerns regarding the potential long-term repercussions of reused potable water. This paper endeavors to explore the associations between residents' concerns about local water issues and their willingness to engage in direct and indirect potable water reuse initiatives in Albuquerque, New Mexico, thereby shedding light on community participation in water recycling endeavors.

Albuquerque, the most populous city in the U.S. state of New Mexico, has a semi-arid climate. Data at the end of 2023 revealed that 96% of New Mexico was experiencing varying degrees of drought (Prokop, 2023), consequently impacting Albuquerque as well. According to the New Mexico Drought Conditions Map published on February 20, 2024, Albuquerque finds itself in a moderate drought, while the western part of the city faces severe drought (PlantMaps, 2024). In light of these circumstances, effective water management is paramount for residents.

Among water management measures, water recycling projects emerge as potential solutions for not only effectively alleviating the longstanding drought challenges in this region but also fostering local development. Advancements in technology, analytical techniques, and microbiology have facilitated the reusability of wastewater for purposes like irrigation and indoor use, such as flushing toilets (Gao et al., 2019; Vuppaladadiyam et al., 2019). In specific nations and areas, the quality of recycled water has even met the standards for drinking water (Price et al., 2012). Consequently, numerous countries and regions worldwide have introduced various initiatives to promote the utilization of recycled wastewater to reduce the strain on freshwater resources (Vuppaladadiyam et al., 2019). Water reuse is also a key component of the long-term resource management strategy of the Albuquerque Bernalillo Water Utility Authority (2022), the sole provider of water and wastewater services to the city of Albuquerque. However, while the Authority has considered direct and indirect potable water reuse in its 100-year water plan (Albuquerque Bernalillo County Water Utility Authority, 2016), under the current water reuse scheme, reused water has only been utilized for non-potable usages, such as on landscapes, parks, golf courses, and open spaces (Albuquerque Bernalillo Water Utility Authority, 2022).

The primary obstacle to adopting recycled wastewater is often attributed to public perceptions and acceptance rather than technological limitations (Vuppaladadiyam et al., 2019). For example, Fielding et al. (2018) conducted an extensive examination. They revealed that socio-demographic traits, psychological factors, and water attributes are three major predictors of public acceptance of recycled water. They also noted that the findings of the associations between socio-demographic features and recycled water acceptance vary across studies. Meanwhile, feeling negative emotions like disgust toward recycled water correlates with lower acceptance, and experiencing more positive emotions is associated with diminished risk perceptions and increased acceptance. Previous research also suggests that relabeling recycled water as a “recycled Product” rather than “treated wastewater” enhances public willingness to purchase and utilize the product (Menegaki et al., 2009). A brief presentation highlighting the benefits of water treatment can enhance farmers’ receptiveness to utilizing recycled water (Tsagarakis & Georgantzis, 2003).

Nevertheless, despite these observations, there remains an unaddressed research gap in the current literature regarding how individual concerns about local matters influence the willingness to use recycled water for drinking. Addressing this research gap in Albuquerque, New Mexico, USA, a region grappling with exacerbated drought conditions and longstanding aridity, is expected to aid local governments in their endeavors to promote the adoption of recycled water for drinking and devise strategies aimed at enhancing public support with essential services through educational and public raising programs. Several investigations have been conducted to explore the factors conducive to the adoption of both direct and indirect potable water reuse in the city of Albuquerque (Distler, 2018; Distler & Scruggs, 2020a; Distler et al., 2020; VIASM-HANU 2023 BMF Class, 2024), but the body of literature remains relatively scarce, and no studies have been conducted to examine the relationship between residents' concerns of local issues and willingness to use recycled water for drinking.

Direct Potable Reuse (DPR) and Indirect Potable Reuse (IPR) are two primary ways of using recycled water for drinking. Both DPR and IPR employ advanced purification technologies to treat effluent from wastewater treatment plants to the level of drinking water quality or better. In DPR, the purified water is directly conveyed to the drinking water treatment facility, where it is typically mixed with natural water sources before undergoing further treatment and distribution to customers of water utilities. IPR differs from DPR in that the treated water is initially directed to an aquifer or reservoir, which remains for some time before being extracted for treatment at the drinking water treatment plant and eventual distribution (Chan, 2014). Perceptually, using recycled water indirectly for drinking is more similar to the natural process than using recycled water directly and, thus, more acceptable.

Therefore, our primary objective is to examine how the residents' concerns about local matters (e.g., local population growth, drought conditions, water bills, and water quality) are associated with their willingness to use recycled water directly and indirectly for drinking. The Bayesian Mindsponge Framework (BMF) analytics will be used for statistical analysis on a dataset of 1831 water utility residential account holders in Albuquerque, New Mexico, USA.

## 2. Methodology

### 2.1. Theoretical foundation and hypotheses

The study adopted the Mindsponge Theory as its theoretical framework to formulate the hypotheses. Vuong and Napier (2015) originally introduced the mindsponge mechanism, which elucidates how senior executives assimilate new values while discarding outdated ones from their mindset. Later, it was developed into Mindsponge Theory, which incorporates new evidence from life and neuroscience (Vuong, 2023). Conceptually, the mindsponge symbolizes the mind as a sponge, capable of shedding unnecessary information and absorbing relevant information aligned with the given mindset and context (Vuong, 2023; Vuong & Napier, 2015). The Mindsponge Theory views the brain as an information collection-cum-processor with specific objectives and priorities determined by system demand. These priorities primarily revolve around ensuring the system's survival, growth, and reproduction (Vuong, 2022b). To achieve these ends and maintain priorities, the mind undertakes subjective cost-benefit analyses to maximize perceived benefits while minimizing perceived costs (Vuong et al., 2022). Essentially, the mind is not a passive recipient of information but an active processor capable of selecting and absorbing information from the environment, filtering out irrelevant data, and generating responses to address challenges and adapt to changing circumstances (Nguyen, Duong, et al., 2023).

According to the Mindsponge Theory, the mindset significantly influences the mind's output, input processing, and filtering mechanisms. It can be deemed a set of highly trusted information, such as beliefs or core values. As the theory is built based on the information-processing scheme, information is considered the most fundamental element in information processing and can be used interchangeably with terms such as idea and value (Davies & Gregersen, 2014; Vuong et al., 2022). For differentiation, idea and value represent the mind's subjective interpretations of conveyed information. The development of mindset primarily stems from the brain's capacity to store information. It is not a fixed set of information or values but constantly interacts with the surrounding environment. As absorbed information traverses through the mind's filtering system, it is integrated into the mindset as trusted values. Consequently, the content of the mindset evolves over time to better align mental representations with reality (Asamoah et al., 2023; Nguyen, Le et al., 2023).

Various factors can contribute to the accumulation of information, knowledge, or values, subsequently influencing an individual's psychology, emotions, and behaviors (Nguyen et al., 2024; Nguyen & Jones, 2022b; Vuong et al., 2022). Among these factors, both information availability and accessibility play crucial roles. Information availability pertains to the physical existence of information in reality, whereas information accessibility refers to whether a person can perceive and obtain the information if it exists. Within this framework, intentions and behaviors emerge as a result of the information optimization process, allowing individuals to interact with their surroundings either proactively (intentionally) or reactively (in response to environmental stimuli) (Nguyen, Le et al., 2023).

Several local environmental and societal elements have been identified as motives for people to engage in water conservation initiatives. These include water scarcity caused by drought and resource shortage, rising demand, worries regarding water quality, and community welfare-related water bills (El Kharraz et al., 2012; Gill et al., 2010; Hannibal et al., 2019; Hou et al., 2021)

In this context, residents' willingness to use recycled water (either directly or indirectly recycled) depends on how the information is mentally processed. Specifically, it depends on the set of information existing in the mind. When people are concerned about water shortage that can significantly impact their lives and lifestyles, it is equivalent to the existence of information associated with such concerns in their mindsets. Thus, they will be used as benchmarks to influence the subsequent information-seeking, -absorbing, and -filtering processes for maximizing the perceived benefits. In this context, activities that help alleviate the water shortage crisis will be considered beneficial, and those that exacerbate the crisis will be deemed costly. Following this reasoning, the willingness to use recycled water (either directly or indirectly recycled) will be considered beneficial.

The question is: how can the information associated with concern about water shortage appear in the mindset?

Concern can be considered a form of fear but less intense emotion. Together with fear and anxiety, concern is often labeled as "negative" due to their unpleasant nature (Pihkala, 2020). It tends to stimulate, rather than hinder, a more thorough cognitive and analytical examination of risk information (Smith & Leiserowitz, 2014). While scientists have not yet arrived at a unanimous definition of fear, they propose that the antecedents (i.e., signals giving rise to fear) and consequents (i.e., objectively observable behaviors) should be fundamental components of a comprehensive definition of fear (Mobbs et al., 2019). Based on the Mindsponge Theory, antecedents can be categorized into two groups: external antecedents, involving perceived risks from the surrounding environment, and internal antecedents, which encompass anticipated risks based on past knowledge and memory (Adolphs, 2013; Vlaeyen et al., 2016).

Therefore, we hypothesized that residents' concerns about issues associated with water in the local environment (e.g., local population growth, drought conditions, water bill, and water quality) would affect their water shortage perceptions, subsequently influencing their willingness to use recycled water for drinking.

**H1:** Residents' concern about drought is positively associated with their willingness to use recycled water for drinking directly and indirectly.

**H2:** Residents' concern about population growth is positively associated with their willingness to use recycled water for drinking indirectly and indirectly.

**H3:** Residents' concern about water quality is negatively associated with their willingness to use recycled water for drinking directly and indirectly.

**H4:** Residents' concern about water bills is negatively associated with their willingness to use recycled water for drinking indirectly and indirectly.

## 2.2. Model construction

### *2.2.1. Variable selection and rationale*

In this study, we utilized a dataset comprising 4000 water-utility account holders in Albuquerque, New Mexico, USA, to examine our hypotheses. The dataset was compiled by Distler and Scruggs (2020b) and is available in *Data in Brief*. Distler and Scruggs conducted the survey collection in collaboration with the Albuquerque Bernalillo County Water Utility Authority (ABCWUA) to gain insights into water knowledge, consumption habits, attitudes toward water-related issues, and demographic information. This dataset has been previously employed in research focusing on water consumption behaviors in Albuquerque, New Mexico (Distler, 2018; Distler & Scruggs, 2020a; Distler et al., 2020).

Eight focus groups and 12 debriefing sessions were organized to develop the survey with participants aged 18 years or older and clients of ABCWUA. They actively participated in testing prototype survey questions within focus groups and providing valuable feedback in subsequent debriefing sessions. A random sample of 4000 accounts was selected from over 180,000 residential accounts to ensure that the proportions closely resembled those in the overall customer accounts database. The survey, conducted through mail and SurveyMonkey, received 1831 responses, resulting in a 46% response rate.

In the present study, we employed six variables to construct the model, including two outcome variables and four predictor variables. The outcome variables, *DPR_WILL* and *IPR_WILL*, serve as indicators of respondents' willingness to use directly and indirectly recycled water as potable water, respectively. To comprehensively address the research objective, we integrated four predictor variables capturing respondents' concerns about local issues: *DROUGHT_CONCERN*, *POPULATION_CONCERN*, *WATERBILL_CONCERN*, and *WATERQUALI_CONCERN*. These variables offer insights into the extent to which respondents express concern regarding drought, human population growth, water bills, and water quality, respectively. Descriptions of the variables are provided in Table 1.

**Table 1.** Variable description

| Variables | Description | Type of Variable | Value |
|---|---|---|---|
| *DPR_WILL* | The extent of willingness to reuse direct potable water | Numerical | Refuse to drink = 1<br>Prefer to avoid = 2<br>Neutral = 3<br>Generally OK = 4<br>Very willing to drink = 5 |
| *IPR_WILL* | The extent of willingness to reuse indirect potable water | Numerical | Refuse to drink = 1<br>Prefer to avoid = 2<br>Neutral = 3<br>Generally OK = 4<br>Very willing to drink = 5 |
| *DROUGHT_CONCERN* | Level of concern with drought | Numerical | Not at all concerned = 1<br>Slightly concerned = 2<br>Moderately concerned = 3<br>Very concerned = 4<br>Extremely concerned = 5 |
| *POPULATION_CONCERN* | Level of concern with population growth | Numerical | Not at all concerned = 1<br>Slightly concerned = 2 |

| | | | |
|---|---|---|---|
| | | | Moderately concerned = 3<br>Very concerned = 4<br>Extremely concerned = 5 |
| *WATERBILL_CONCERN* | Level of concern with the amount paid on the water bill | Numerical | Not at all concerned = 1<br>Slightly concerned = 2<br>Moderately concerned = 3<br>Very concerned = 4<br>Extremely concerned = 5 |
| *WATERQUAL_CONCERN* | Level of concern with local drinking water quality | Numerical | Not at all concerned = 1<br>Slightly concerned = 2<br>Moderately concerned = 3<br>Very concerned = 4<br>Extremely concerned = 5 |

*2.2.2. Statistical models*

To test the associations between residents' concern about water-related local issues and their willingness to reuse potable water directly, we formulated Model 1 as follows:

$$DPR\_WILL \sim normal(\mu, \sigma) \quad (1.1)$$

$$\mu_i = \beta_0 + \beta_1 * DROUGHT\_CONCERN_i + \beta_2 * POPULATION\_CONCERN_i + \beta_3 * WATERBILL\_CONCERN_i + \beta_4 * WATERQUAL\_CONCERN_i \quad (1.2)$$

$$\beta \sim normal(M, S) \quad (1.3)$$

The probability around $\mu$ is determined by the form of the normal distribution, whose width is specified by the standard deviation $\sigma$. $\mu_i$ represents the extent of willingness to reuse direct potable water of water users $i$ ; $DROUGHT\_CONCERN_i$ indicates water user $i$ 's level of concern about drought/water shortage; $POPULATION\_CONCERN_i$ indicates water user $i$'s level of concern about population growth and development; $WATERBILL\_CONCERN_i$ indicates water user $i$'s level of concern about the amount paid on the water bill; $WATERQUAL\_CONCERN_i$ indicates water user $i$'s level of concern about local drinking water quality. Model 1 has six parameters: the coefficients, $(\beta_1 - \beta_4)$, the intercept, $\beta_0$, and the standard deviation of the "noise", $\sigma$. The coefficients of the predictor variables are distributed normally, with the mean being denoted $M$ and the standard deviation, $S$.

Similarly, we constructed Model 2 to investigate the associations between residents' concerns about water-related local issues and their willingness to reuse indirect potable water.

$$IPR\_WILL \sim normal(\mu, \sigma) \quad (2.1)$$

$$\mu_i = \beta_0 + \beta_1 * DROUGHT\_CONCERN_i + \beta_2 * POPULATION\_CONCERN_i + \beta_3 * WATERBILL\_CONCERN_i + \beta_4 * WATERQUAL\_CONCERN_i \quad (2.2)$$

$$\beta \sim normal(M, S) \quad (2.3)$$

$\mu_i$ represents the extent of willingness to reuse indirect potable water of water users $i$.

### 2.3. Analysis and validation

The Mindsponge Framework (BMF) analytic is employed in this study because it combines the inferential advantages of Bayesian analysis with the logical reasoning capabilities of Mindsponge Theory, making it highly suitable for our purposes (Nguyen et al., 2022). Although Bayesian analysis accommodates complex models such as multilevel and nonlinear regression frameworks well (Dunson, 2001), it can still enable the prediction of parsimonious models constructed based on Mindsponge Theory's reasoning, as Bayesian inference probabilistically treats all properties, known and unknown (Csilléry et al., 2010; Gill, 2014).

Compared to the frequentist method, Bayesian inference offers several advantages, including using credible intervals for result interpretation instead of confidence intervals and *p*-values (Halsey et al., 2015; Wagenmakers et al., 2018). The selection of suitable priors is crucial in constructing a Bayesian model. In this study, we employed uninformative priors or a flat prior distribution to minimize prior information available for model estimation due to the study's exploratory nature (Diaconis & Ylvisaker, 1985).

After successfully fitting the model, we utilized Pareto-smoothed importance sampling leave-one-out (PSIS-LOO) diagnostics to assess the goodness of fit (Vehtari & Gabry, 2019; Vehtari et al., 2017). LOO is calculated as follows:

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

The posterior distribution $p_{post(-i)}(\theta)$ is derived from the minus data point $i$. The *k*-Pareto values are utilized in the PSIS method for calculating leave-one-out cross-validation, which helps identify observations with a significant impact on the PSIS estimate. Observations with *k*-Pareto values exceeding 0.7 are considered influential and may pose challenges in accurately estimating leave-one-out cross-validation. It is standard practice to regard a model to have an acceptable fit with the data when the *k* values are below 0.5.

We proceed to convergence diagnostics and result interpretation if the data aligns well with the model. Statistical and visual methods are employed to verify the convergence of Markov chains. Statistically, the effective sample size (*n_eff*) and the Gelman–Rubin shrink factor (*Rhat*) are used to assess convergence. Convergence is generally established if *n_eff* exceeds 1000, ensuring adequate iterative samples for reliable inference (McElreath, 2018). Additionally, the *Rhat* value is the potential scale reduction factor. If *Rhat* surpasses 1.1, the model does not converge; a value of 1 indicates convergence (Gelman & Rubin, 1992). Visual validation of Markov chains' convergence utilizes trace plots, Gelman–Rubin–Brooks plots, and autocorrelation plots.

The Bayesian analysis was conducted using the open-access package **bayesvl** in R, which offers excellent visualization capabilities (La & Vuong, 2019). The analysis involved four Markov chains and 5000 iterations for each chain. The initial 2000 iterations were allocated for warmup. To enhance transparency and reduce scientific costs, all data and code snippets from this study were deposited on an Open Science Framework (OSF) server (Vuong, 2018).

## 3. Results

### 3.1. Model 1

Before interpreting the results, it is essential to evaluate the goodness of fit of Model 1 with the data. As illustrated in Figure 1, all the estimated *k*-values are below the 0.5 threshold, indicating a good signal of fit between the model and the data.

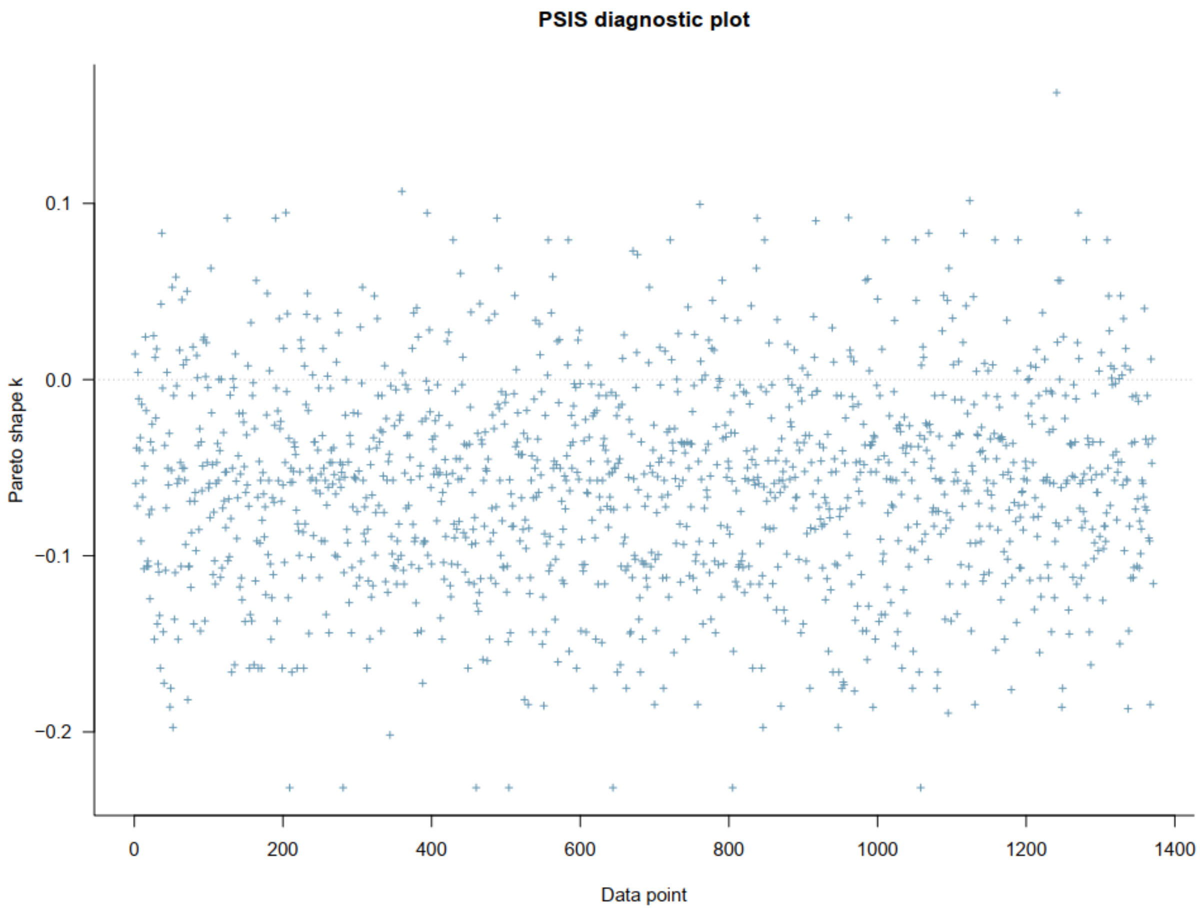


**Figure 1.** Model 1's PSIS-LOO diagnosis

The statistics for the posterior distributions of Model 1 are displayed in Table 2. All *n_eff* values exceed 1000, and *Rhat* values are equal to 1, indicating that Model 1's Markov chains converge well. The convergence of the Markov chains is also evident in the trace plots shown in Figure 2. Specifically, the values of all chains fluctuate around a central equilibrium after the 2000th iteration.

**Table 2:** Estimated results of Model 1

| Parameters | Mean | SD | n_ff | Rhat |
|---|---|---|---|---|
| *Constant* | 3.54 | 0.13 | 8923 | 1 |
| *DROUGHT_CONCERN_DPR_WILL* | 0.17 | 0.03 | 9483 | 1 |
| *POPULATION_CONCERN_DPR_WILL* | 0.04 | 0.03 | 10203 | 1 |
| *WATERBILL_CONCERN_DPR_WILL* | -0.16 | 0.03 | 9899 | 1 |

| | | | | |
|---|---|---|---|---|
| *WATERQUAL_CONCERN_DPR_WILL* | -0.14 | 0.03 | 9194 | 1 |

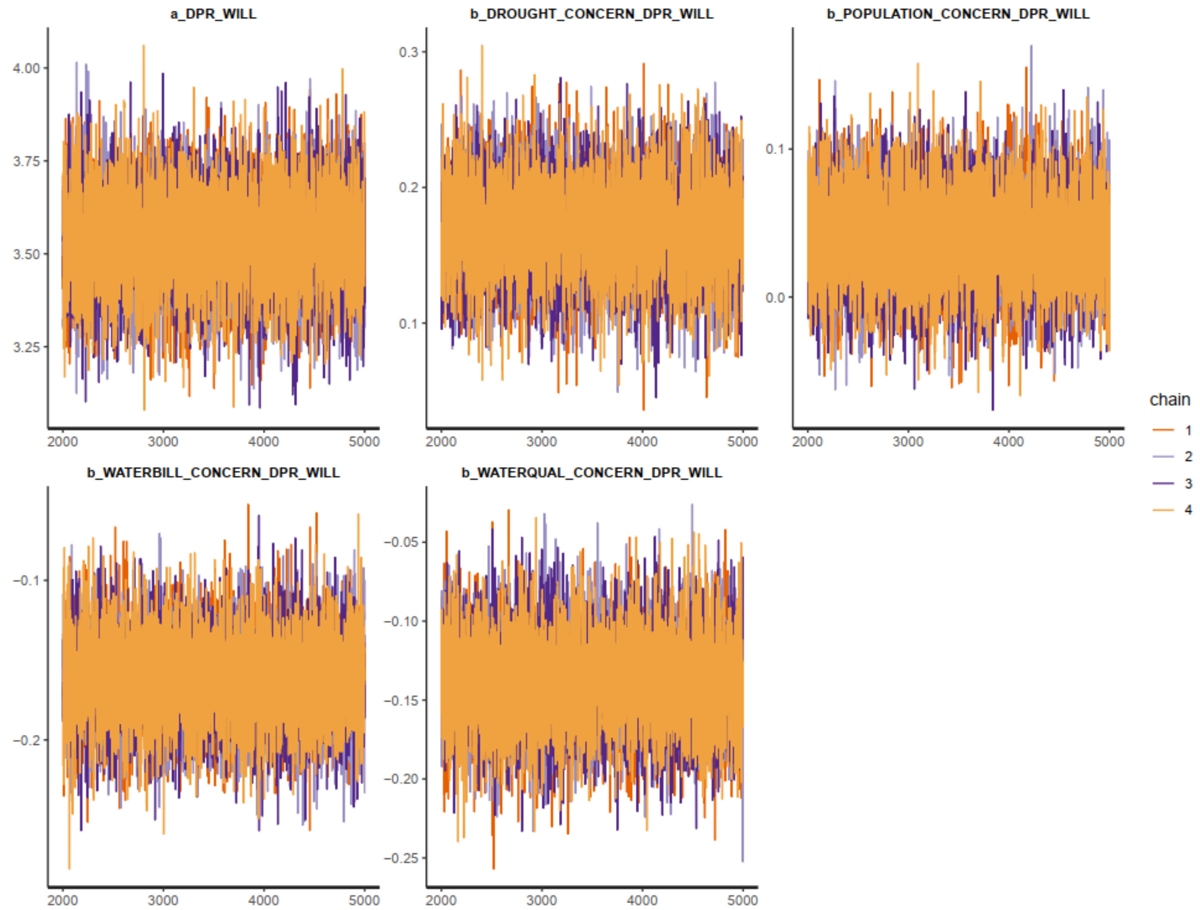


**Figure 2.** Model 1's trace plots

The Gelman-Rubin-Brooks and autocorrelation plots also indicate the good convergence of Markov chains. The Gelman-Rubin-Brooks plots are utilized to evaluate the ratio between the variance among Markov chains and the variance within chains. The *y*-axis represents the shrink factor (or Gelman-Rubin factor), while the x-axis depicts the iteration order of the simulation. In Figure 3, the shrink factors of all parameters rapidly decrease to 1 before the 2000th iteration (during the warmup period). This observation suggests that there is no divergence among Markov chains.

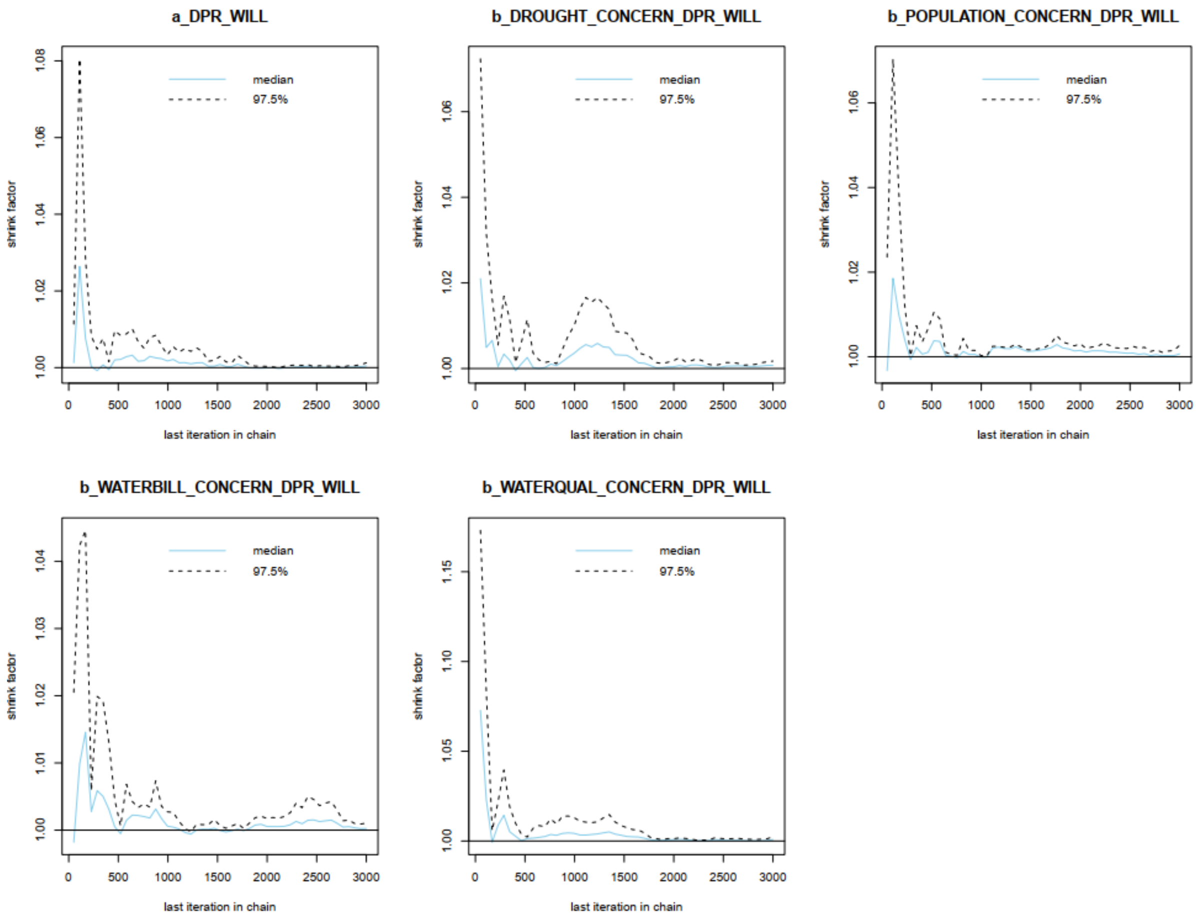


**Figure 3.** Model 1's Gelman-Rubin-Brooks plots

The Markov property signifies the memoryless characteristic of a stochastic process. Put differently, the successive values are not correlated with the previous values. Autocorrelation plots are used to assess the levels of autocorrelation among successive values. The charts in Figure 4 display the average autocorrelation of each Markov chain on the *y*-axis and the lag of the chains on the x-axis. Visually, the autocorrelation levels of all the Markov chains rapidly decrease to 0 after a small number of lags (less than 5), indicating that the Markov property is satisfied and the Markov chains are well-convergent.

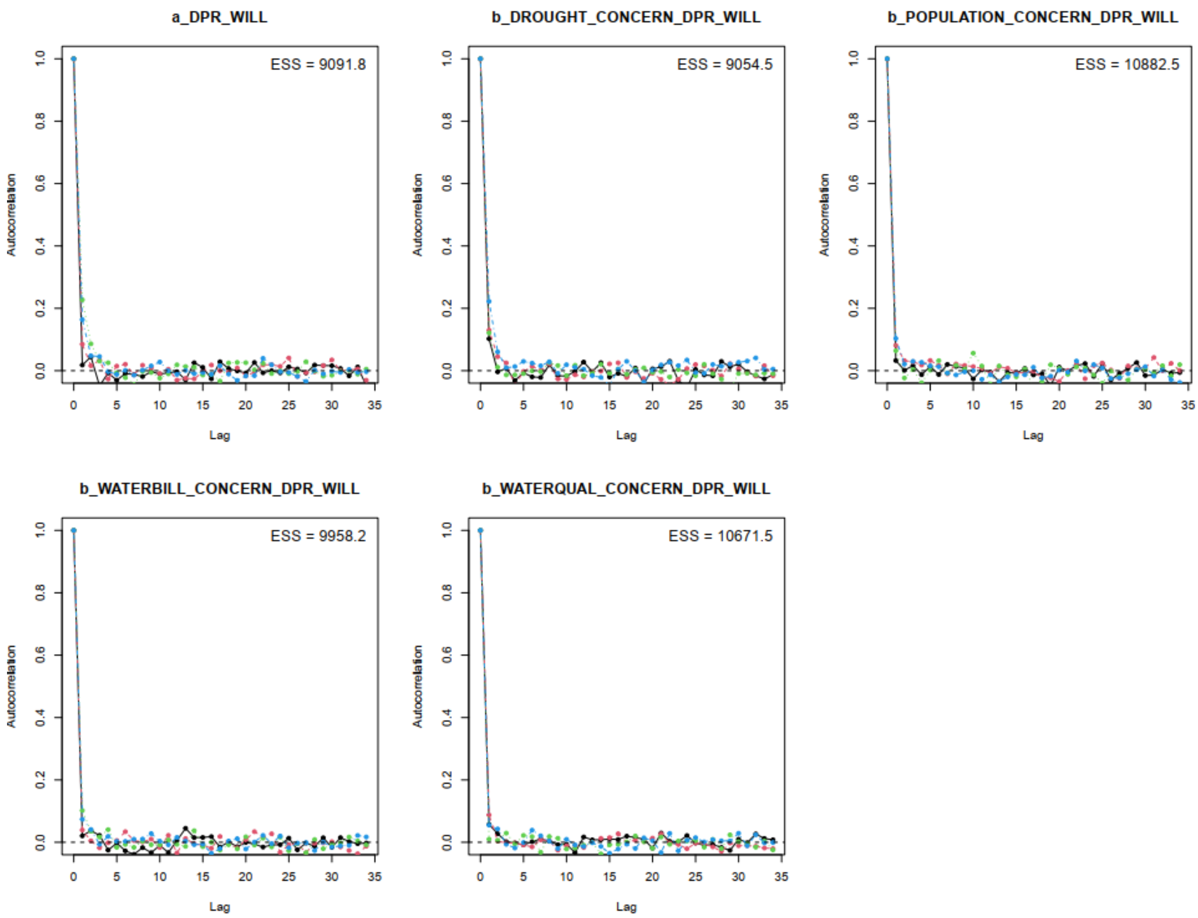


**Figure 4.** Model 1's autocorrelation plots

Since all the diagnostics confirm the convergence of Markov chains, the simulated results are eligible for interpretation. The estimated results of Model 1 show that residents' concerns about drought and population growth are positively associated with their willingness to use recycled water directly ( $M_{DROUGHT\_CONCERN\_DPR\_WILL}$ = 0.17 and $S_{DROUGHT\_CONCERN\_DPR\_WILL}$ = 0.03; $M_{POPULATION\_CONCERN\_DPR\_WILL}$ = 0.04 and $S_{POPULATION\_CONCERN\_DPR\_WILL}$ = 0.03), while concerns about water quality and water bills are negatively associated with the willingness ( $M_{WATERBILL\_CONCERN\_DPR\_WILL}$ = -0.16 and $S_{WATERBILL\_CONCERN\_DPR\_WILL}$ = 0.03; $M_{WATERQUAL\_CONCERN\_DPR\_WILL}$ = -0.14 and $S_{WATERQUAL\_CONCERN\_DPR\_WILL}$ = 0.03). All the Highest Posterior Density Intervals (HPDI) of the coefficients in Figure 5, except for that of $POPULATION\_CONCERN\_DPR\_WILL$, lie entirely on either the negative or positive side of the origin (on the x-axis), suggesting the high reliability of the results. Although all HPDI of $POPULATION\_CONCERN\_DPR\_WILL$ is not located on the positive side, a majority of it does, so its estimated positive value can be deemed moderately reliable.

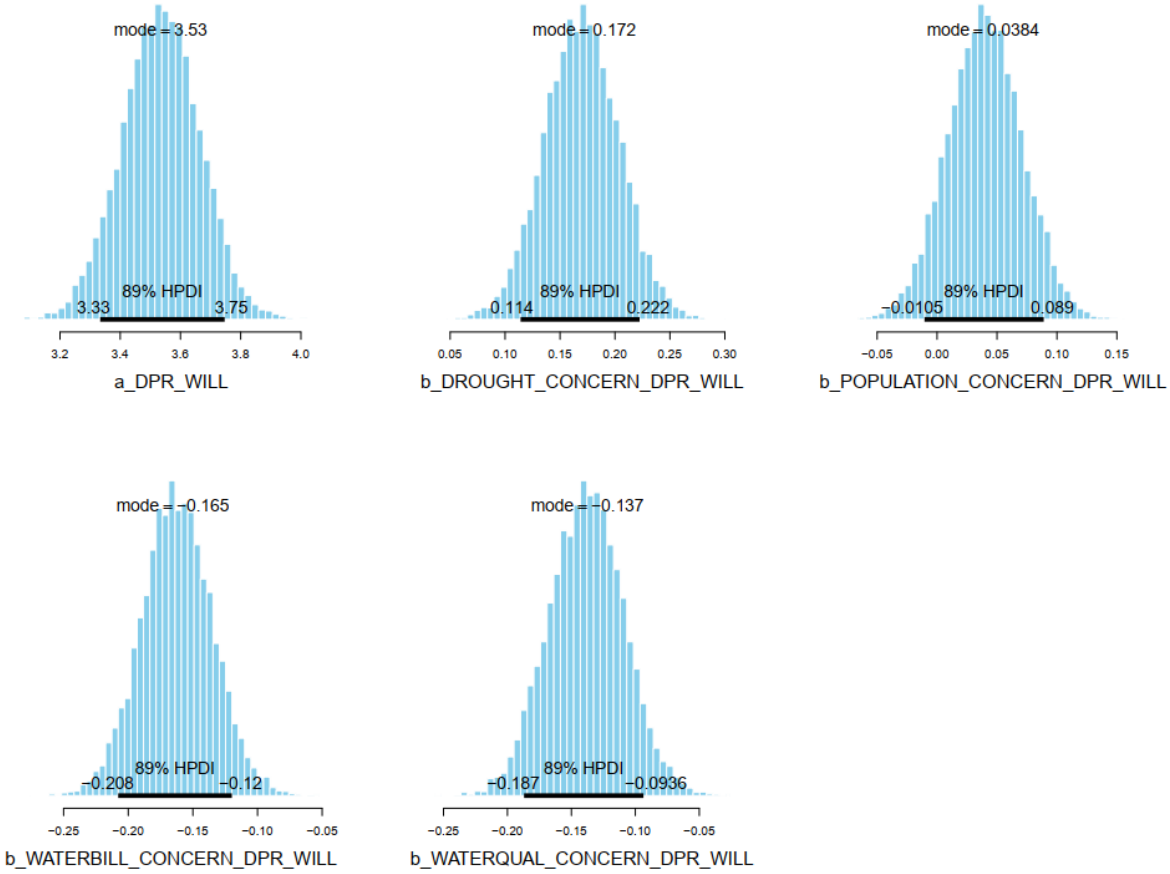


**Figure 5.** Model 1's posterior distributions

### 3.2. Model 2

The PSIS-LOO test of Model 2 is shown in Figure 6. All the estimated *k*-values are below the 0.5 threshold, so the model's goodness of fit with the data is considered to be acceptable.

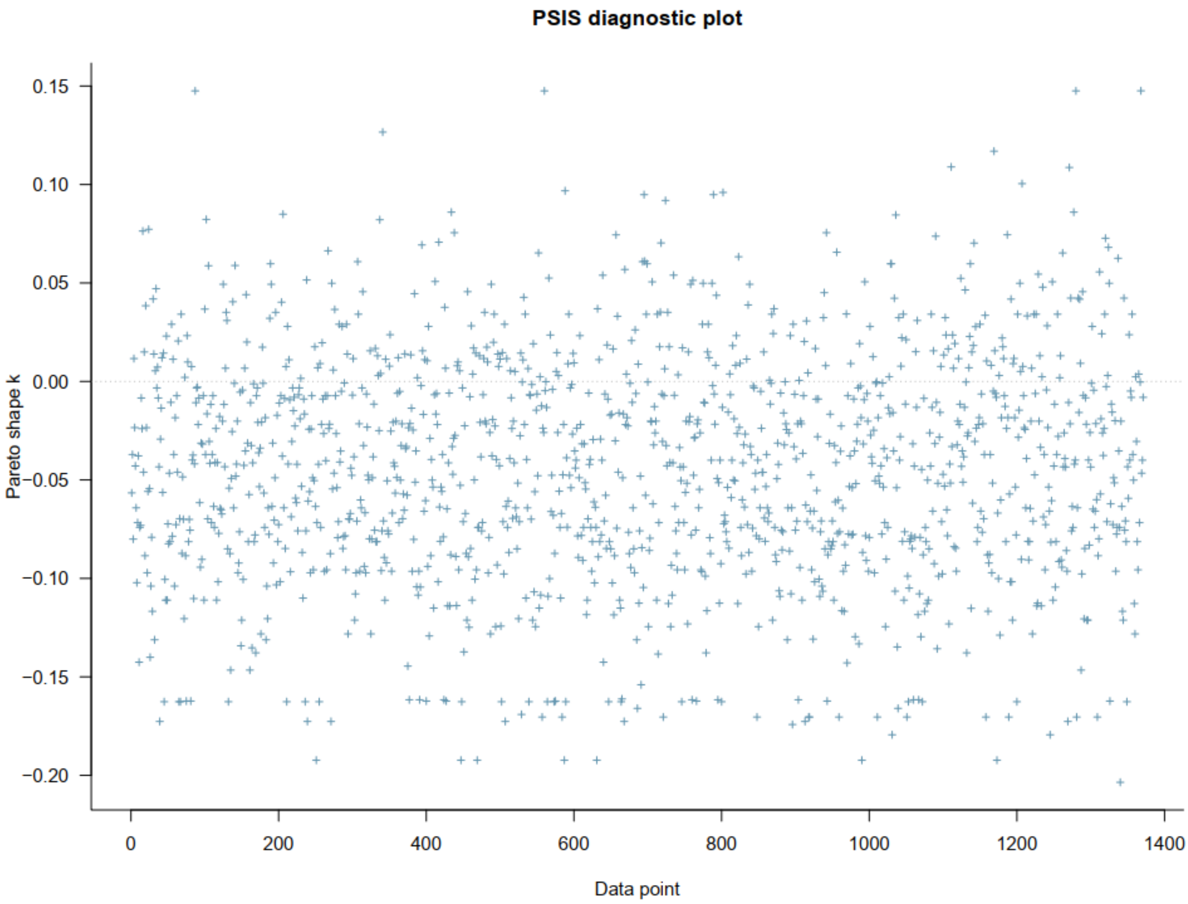


**Figure 6.** Model 2's PSIS-LOO diagnosis

The statistical values of *n_eff* (larger than 1000) and *Rhat* (equal to 1) in Table 3 imply the convergence of Model 2's Markov chains. The trace plots, Gelman-Rubin-Brooks plots, and autocorrelation plots also confirm the convergence (see Figures A1-A3). Thus, the simulated results of Model 2 are eligible for interpretation.

**Table 3:** Estimated results of Model 2

| Parameters | Mean | SD | n_ff | Rhat |
|---|---|---|---|---|
| *Constant* | 3.84 | 0.12 | 8244 | 1 |
| *DROUGHT_CONCERN_IPR_WILL* | 0.18 | 0.03 | 8692 | 1 |
| *POPULATION_CONCERN_IPR_WILL* | 0.04 | 0.03 | 10652 | 1 |
| *WATERBILL_CONCERN_IPR_WILL* | -0.17 | 0.03 | 9408 | 1 |
| *WATERQUAL_CONCERN_IPR_WILL* | -0.15 | 0.03 | 9828 | 1 |

The simulated results of Model 2 in Table 3 suggest that residents' concerns about drought and population growth are positively associated with their willingness to use recycled water indirectly ($M_{DROUGHT\_CONCERN\_IPR\_WILL}$ = 0.18 and $S_{DROUGHT\_CONCERN\_IPR\_WILL}$ = 0.03; $M_{POPULATION\_CONCERN\_IPR\_WILL}$ = 0.04 and $S_{POPULATION\_CONCERN\_IPR\_WILL}$ = 0.03), whereas concerns about water quality and water bills are negatively associated with this willingness ( $M_{WATERBILL\_CONCERN\_IPR\_WILL}$ = -0.17 and $S_{WATERBILL\_CONCERN\_IPR\_WILL}$ = 0.03; $M_{WATERQUAL\_CONCERN\_IPR\_WILL}$ = -0.15 and $S_{WATERQUAL\_CONCERN\_IPR\_WILL}$ = 0.03). Similar to Model 1's results, the HPDI of all coefficients are located entirely on either the positive or negative side of the origin (on the x-axis). However, the small proportion of $POPULATION\_CONCERN\_IPR\_WILL$'s HPDI still lies on the negative side. These suggest that the association between $POPULATION\_CONCERN$ and $IPR\_WILL$ is moderately reliable, while others' associations are highly reliable.

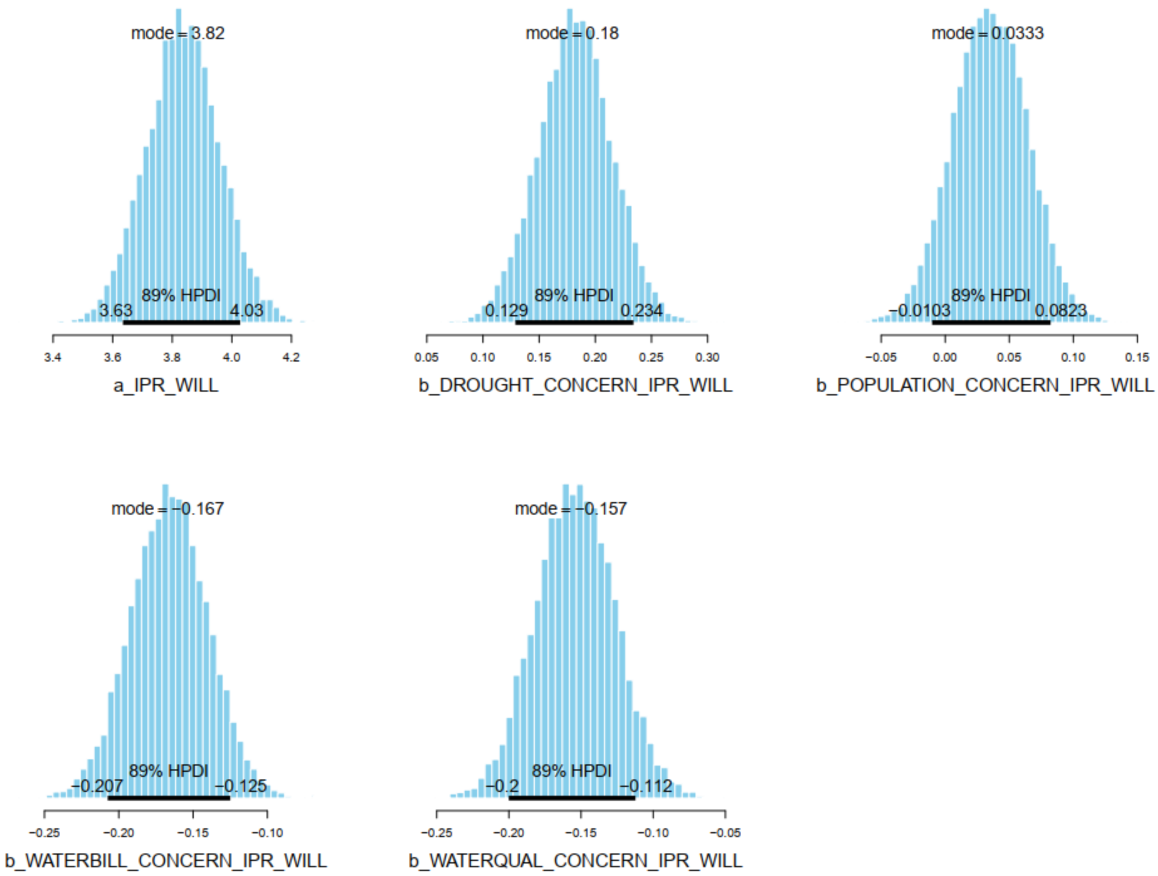


**Figure 7.** Model 2's posterior distributions

## 4. Discussion

BMF analytics was utilized in this study to examine the associations between concerns of local issues and the willingness to use recycled water for drinking directly and indirectly. By sampling the New Mexicans, especially in the city of Albuquerque, this study acknowledges the regional problems of dryness and economic dependence on water supply. We found positive associations between concerns about drought or water shortage, population growth, and the willingness to use recycled water for drinking directly and indirectly. These findings underscore the influence of environmental challenges on human behavior as a survival response. They also support earlier findings on the correlation between drought or water shortage and efforts to conserve water resources in arid regions (Qadir & Sato, 2016). Such efforts include water reclamation, recycling, and rain harvesting (Gude, 2017).

Population growth has induced the development of megacities, climate change, and rapid technological developments influencing water supply (Angelakis et al., 2018). Industrial development coupled with improving living standards following excess population growth have caused unprecedented need for freshwater around the globe (Gude, 2017). When the amount of fresh water is finite and the act of ensuring fresh water is considered the most essential and basic need for humanity, the continuous population growth raises discrepancies between water supply and demand, inducing water scarcity-security issues and water reuse action (UN-Water, 2017). Therefore, residents concerned about the population growth in the local areas might assess the risks of population growth (i.e., water shortage) more carefully, making them perceive the benefits of water conservation behaviors (i.e., using recycled water for drinking). However, this discovered association is merely from a subjective perspective. It is essential to explore deeper into the relationships between water reuse and objective indicators of population, such as numbers of births, deaths, and migrants, population density, land development, and urban expansion, to better understand how population growth can influence the willingness to utilize reused water in arid regions.

Conversely, concerns about water quality and bills were found to impact the willingness to utilize recycled water negatively. We need to be cautious with these negative associations because they may challenge the adoption of water sustainability methods, especially in arid regions. People generally want access to water at an affordable price. Water recycling decisions can require large budgets to build water treatment plants and purchase water filtration equipment. Those costs would come from residents' tax dollars or the unit price of after-treatment water used by residents. Consequently, utility companies often face a dilemma: they must decide between establishing high rates that cover expenses but discourage water reuse or implementing low rates that encourage customers but transfer the financial burden to other stakeholders. When regulations prohibit utilities from pricing recycled water fairly (such as by banning cross-subsidies), they may opt to forego water recycling entirely (Raucher, 2018).

To deal with the hindrance of water bill concerns, it is necessary to reduce the perceived overall cost of water usage by instructing them on water conservation methods. By providing information related to water conservation methods at the collective level, the amount of wasted water will be reduced, decreasing the total bill of the residents. Therefore, governments must broaden the information channels to disseminate water conservation methods to the residents. Another approach is providing financial subsidies to decrease monthly water bills and increase the willingness to utilize recycled water, which the government may facilitate (Garcia-Cuerva et al., 2016).

On the other hand, concerns about the quality of reused water and its impact on human health may arise due to a lack of understanding about wastewater treatment. Wastewater treatment is crucial because there is a direct link between wastewater disposal and public health. Diseases can spread throughout river basins, from upstream towns to downstream areas (Salgot & Folch, 2018). Wastewater treatment serves two main purposes: sanitation and water reuse. Water reuse aims to convert wastewater into a safe form for reuse. Wastewater treatment involves complex technological processes, ranging from traditional activated sludge treatment methods to the latest membrane bioreactors (MBR) and other advanced techniques available in the industrial market (Salgot & Folch, 2018). Glick et al. (2019) further identified that the information that more firmly targets the regards to discharge and scientific tools would play a more critical role in easing the anxiety among the public that water treatment activities triggered. A research paper conducted in the United Kingdom discovered that the video focused on the specific water treatment technologies to mostly remove the pollutant can effectively raise the degree of acceptance of the recycled water (Goodwin et al., 2018). Therefore, by being informed of sufficient information about advanced wastewater treatment technologies, individuals can update their understanding and core values regarding wastewater treatment processes, alleviating residents' concerns about declining health due to consuming contaminated water.

Findings from this study have the potential to support and promote eco-surplus culture by acknowledging local issues associated with environmental conditions among residents of arid regions. Increasing public awareness of local issues induced by water shortage, population growth, and environmental problems (e.g., climate change) can foster a sense of responsibility for environmental sustainability, gradually developing the eco-surplus culture within the community (Nguyen & Jones, 2022a; Vuong & Nguyen, 2023, 2024). People with an eco-surplus mindset will be likely to pay for the additional cost induced by recycled water, thus reducing the magnitude of the negative effect of water bill concern on the willingness to use recycled water for drinking (Attaran & Celik, 2015; Boyer et al., 2017; Lazaridou et al., 2019; Nguyen & Jones, 2022a). When an eco-surplus mindset exists in residents' minds, the semiconducting principle of monetary and environmental exchange may be achieved. This principle suggests that environmental value surplus can be exchanged for monetary values, but not vice versa (Vuong, 2021).

This study is not without limitations, so they are presented here for transparency (Vuong, 2020). The study sample is limited to Albuquerque, so the generalization of the findings to other arid regions and even to various geographical conditions across regions should be cautious. Population growth was measured through the residents' self-reported concerns, subject to perceptual biases. Future studies should be conducted to explore the relationships between the willingness to use recycled water for drinking and other objective measurements of population growth for a more comprehensive understanding. Qualitative studies may be conducted to explore public attitudes on population growth and development regarding possible negative consequences on human and environmental sustainability. Finally, experimental studies need to be conducted to validate the eco-surplus mindset on expressed human behavior or real actions at home regarding water conservation methods or water-saving strategies. By doing so, world scientists may contribute to an existing body of knowledge on sustainable water management practices globally.

## Appendix

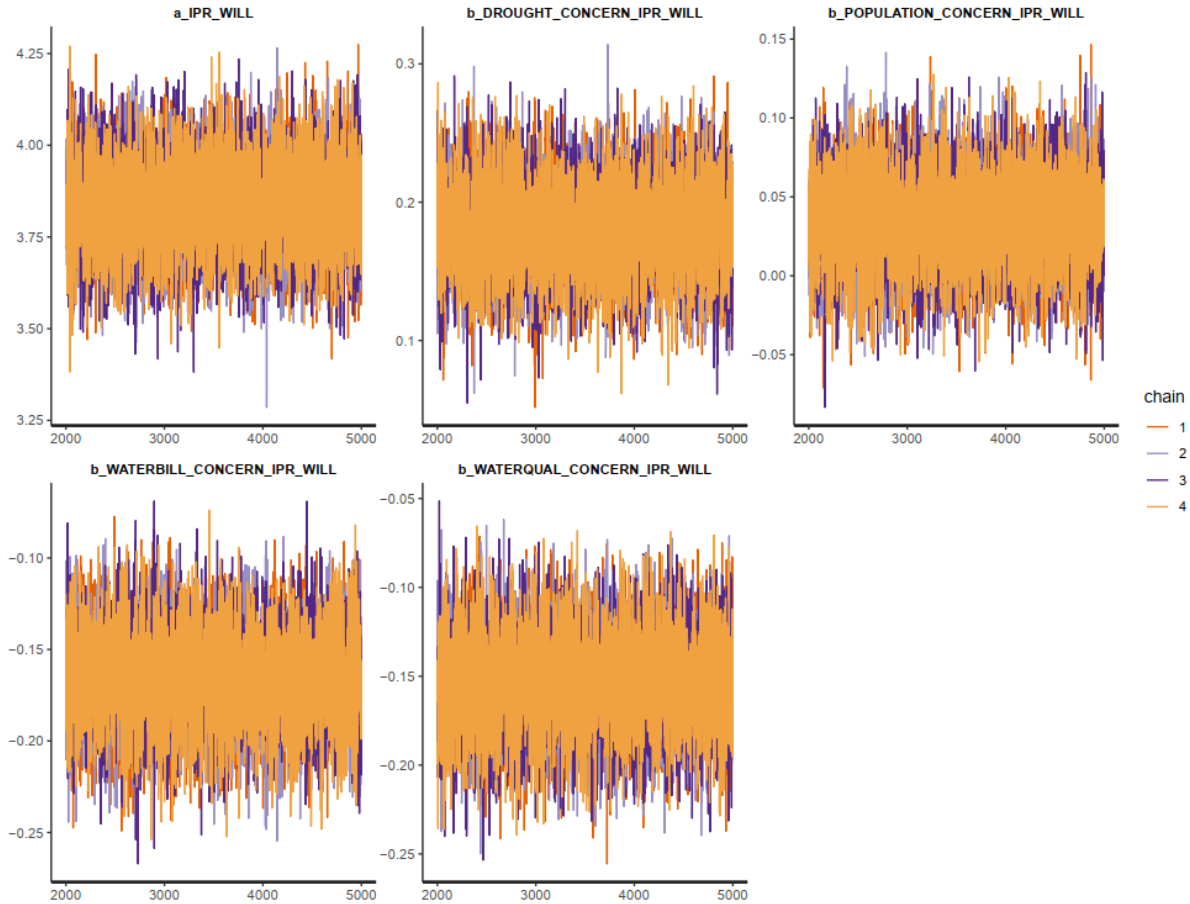


**Figure A1:** Model 2's trace plots

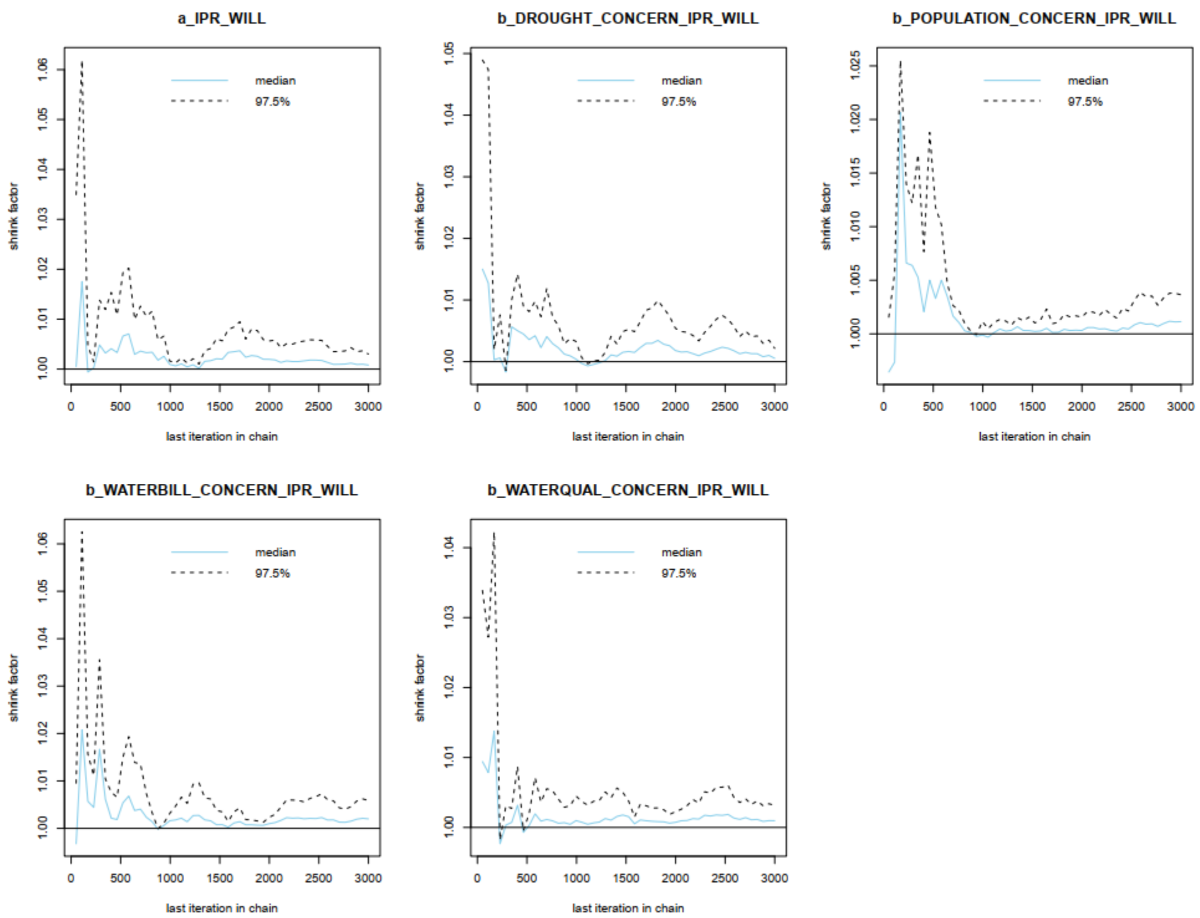


**Figure A2:** Model 2's Gelman-Rubin-Brooks plots

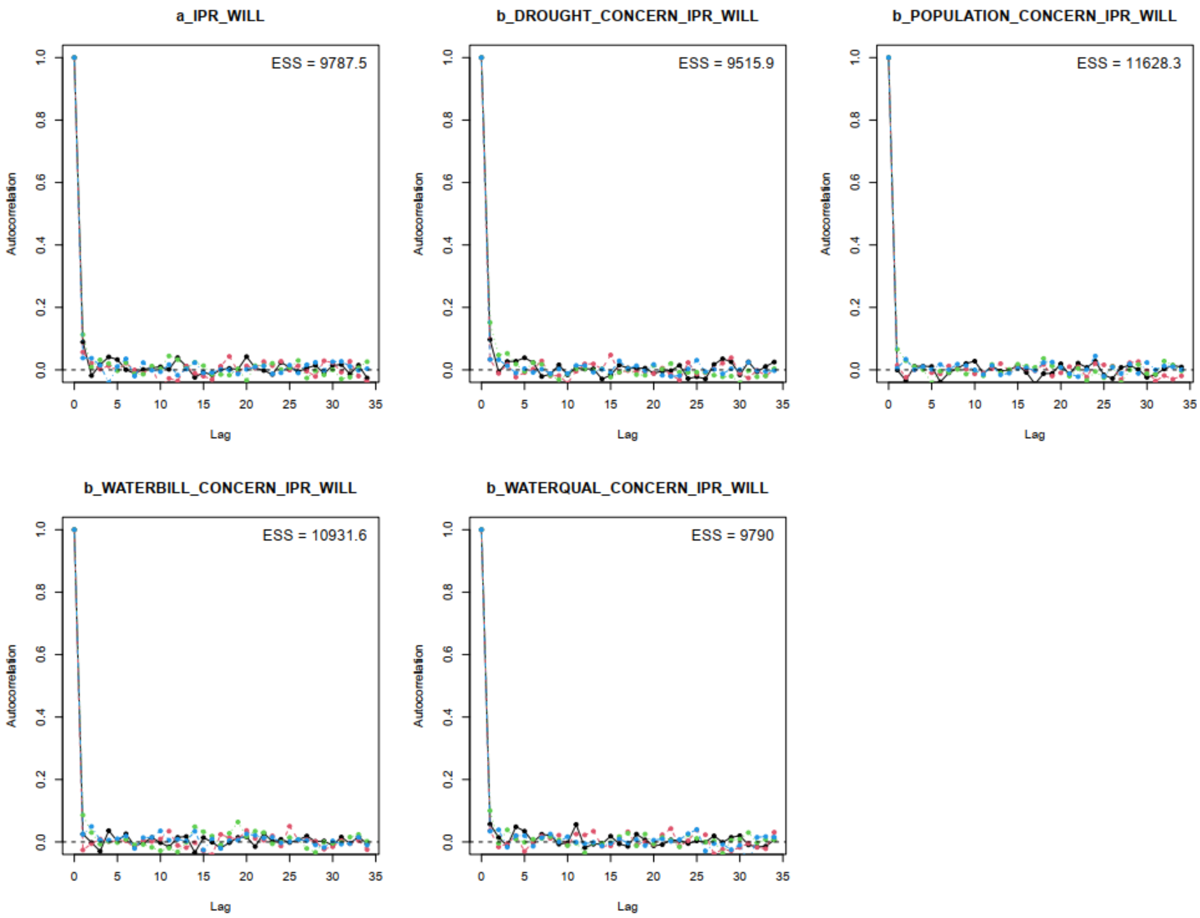


**Figure A3:** Model 2's autocorrelation plots

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