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Downstream Willingness to Pay for Upstream Nature-Based Solutions to Improve Water Security in a Thirsty Brazilian Megacity

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Key Points:

- A majority of a clustered sample of residents in São Paulo is willing to pay extra for upstream NbS to improve downstream urban water security
- Recent experiences with water restrictions and rationing increase public support and reduce protest
- Willingness to pay for NbS suffices to support continuation and expansion of the existing Payments for Environmental Services scheme

Supporting Information:

Supporting Information may be found in the online version of this article.

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Abstract This is the first study to assess public attitudes and willingness to pay (WTP) for water security in one of the global mega-cities facing Day Zero by taking Nature-based Solutions (NbS) in the upstream basin feeding the city. Data were collected using in-person interviews in the São Paulo Metropolitan Region (SPMR) in Brazil. The survey included a state-of-the-art discrete choice experiment (DCE) to estimate WTP for a wide range of possible water security improvement scenarios. Public recollection of past water supply disruptions gradually fades over time as does its impact on choice behavior in the DCE until people remember the extreme restrictions and rationing experienced during the close to Day Zero episode in the SPMR between 2014 and 2015. The latter sparks a significantly higher renewed interest in and WTP for improved water security. Public WTP for a reduction of 10% in frequency and 12 hr in duration of future water shortages is US$8 per month to implement agroforestry in the Jaguari basin. The increase in respondents' water bill corresponds to almost 1% of their disposable household income for the most consequential improvement in water security, indicating that water security is a high priority. The estimated WTP values show that there is sufficient support to provide the critically needed additional financial resources to continue and expand the existing Payments for Ecosystem Services scheme "Conservador das Águas" in the upstream basin feeding the SPMR.

Plain Language Summary Forested watersheds around the world play a key role in supplying water to thirsty cities. Based on a survey in the São Paulo Metropolitan Region (SPMR), we evaluate residents' willingness to pay for the implementation of nature-based solutions, in particular agroforestry and afforestation, in the upstream basin feeding the city to improve water supply reliability. We show how experiences with water restrictions and rationing in the past affect public preferences for these water conservation measures. Most SPMR residents are willing to pay a higher water bill to improve water security in the coming 10 years. The sampled households in the SPMR are willing to pay between US$8 and US$10 extra per month to reduce the frequency of future water shortages and decrease the duration of future water supply interruptions. Recent recollection of water shortages and extreme events like the close to Day Zero event in 2014–2015 when the city almost ran out of water are especially important in motivating people to pay a higher water bill to improve their current water security situation. Our findings help address the financial challenges facing the existing Payment for Environmental Services program "Conservador das Águas" feeding the SPMR.

1. Introduction

Large precipitation deficits propagate to all components of the hydrological cycle, triggering hydrological droughts (Huang et al., 2017). This kind of drought may cause a decline in water supply and, along with increasing water demand, exacerbate water inequalities around the world and weaken the global economy (Munich Re, 2015). Furthermore, the effects of climate change have been noted by the increase in frequency and severity of droughts worldwide (UNCCD—United Nations Convention to Combat Desertification, 2022) and, consequently, raised uncertainty about future water availability. To address water insecurity, more sustainable and cost-effective Nature-based Solutions (NbS) have emerged to complement or even substitute conventional (i.e., gray) water infrastructure in water policy frameworks (e.g., Ovando & Brouwer, 2019). According to the International Union for Conservation of Nature (IUCN), NbS are actions that mimic nature and are designed to protect, manage, and restore natural or modified ecosystems (Cohen-Shacham et al., 2016). However, NbS still only account for a relatively small share (less than 1% in 2018) of global water infrastructure investments for water management

(Connor et al., 2018). Public perceptions of water insecurity and support for NbS are expected to play a key role in their adoption, especially in what Anderson et al. (2022) refer to as host communities, but there is limited research in this area. Interactions and feedback loops between society and drought impacts are still not fully understood even though studies on the interconnected natural and social systems have increased in the last few years (e.g., Jaeger et al., 2019; Savelli et al., 2022).

The ultimate goal of NbS is to tackle social, economic, and environmental challenges while providing human well-being, ecosystem services, resilience and biodiversity benefit (United Nations Environment Programme, 2022). Brazil has incorporated NbS in environmental policies but does not explicitly mention it in the National Policy on Water Resources, which provides a legal milestone in Brazilian water resources management (Brazil, 1997). A more recent associated plan approved in 2020 (National Plan on Water Security) still relies on traditional gray infrastructure to ensure water security, lacking mechanisms to integrate water management and the environment through NbS. Considering the potential of NbS, it has been estimated that Brazil and Indonesia together would be able to account for 50% of the world's climate mitigation potential (Griscom et al., 2020). This is particularly critical as nearly two-thirds of the climate mitigation potential in Brazil is related to avoiding deforestation (Leavitt et al., 2021). In this context, setting aside land for afforestation and integrating crop and livestock farming with forestry (agroforestry) are important potential NbS to improve water security, while mitigating climate change at the same time.

The main objective of this study is to assess public attitudes and willingness to pay (WTP) for NbS such as afforestation and agroforestry using a discrete choice experiment (DCE) to improve water security in one of the global cities that faces Day Zero, that is, the day that the city runs out of drinking water. Data were collected by surveying residents in the São Paulo Metropolitan Region (SPMR), in which inhabitants face water restrictions and rationing and were close to Day Zero between 2014 and 2015 (Sousa et al., 2022). As far as we know, this is an unprecedented study using a DCE to investigate public preferences for specific NbS, as well as how these preferences are affected and shaped by experiences with water restrictions and rationing and perceptions of the effectiveness and co-benefits of NbS, in a global Day Zero city.

An increasing number of studies focus on public WTP for NbS. However, many if not most of these studies focus on the developed world, in particular Europe and USA, and typically zoom in on urban greenery such as parks and green roofs (e.g., Bockarjova et al., 2022; Cristiano et al., 2025; Thompson et al., 2023). At the same time, a limited number of studies have applied stated preference studies to elicit public WTP for Payments for Ecosystem Services (PES). In these studies, the focus is usually on (forest) land conservation and the provision of bundled ecosystem services, e.g., water quality and wildlife (e.g., Do et al., 2022; Ureta et al., 2022). In this study, we elicit public support and preferences for specific upstream NbS that complement the existing Cantareira water supply system, the largest water supply network of reservoirs and interconnected waterways in South America that provides water to the SPMR in Brazil (Zuffo et al., 2023). The outcome of this study informs policy and decision-making around feasible increases in downstream beneficiaries' water bill.

In a meta-analysis of stated preference studies focusing on public demand (WTP) for improved water access, mainly in the global South, Van Houtven et al. (2017) synthesize the existing literature and identify primarily contingent valuation (CV) studies, of which none zoom in on NbS to protect water sources. Most of the reviewed studies either refer to traditional measures like grey infrastructure and technology (e.g., piped water supply) or do not specify the available type of measures or strategies to achieve the water supply improvements involved. Neither do most of these studies assess the impact of previous water restrictions or rationing on WTP. In a cross-country comparison between drought-prone countries in South-Europe and Australia, Brouwer, Job, et al. (2015), Brouwer, Martin-Ortega, et al. (2015) show that public experiences with water use restrictions significantly drive public WTP for water conservation measures, but these experiences appear to influence public attitudes differently across different countries, possibly because experiences were more positive in some countries and more negative in others. In more recent studies, Anderson et al. (2022) contribute to our understanding of how public perceptions of the effectiveness of NbS affect public preferences for measures in a grey-green spectrum, but without the use of stated preference models. Other CV studies focus more specifically on the role of attitudinal factors in explaining public WTP for continuous urban water supply, in both the Developing (e.g., Tenaw & Assfaw, 2022) and Developed world (e.g., Wilson et al., 2021).

Here, we are interested in testing how experiences with water use restrictions and rationing influence people's willingness to contribute to nature-based water conservation measures in the watershed supplying the SPMR with water and improving their water security. Our findings provide important insight into the impact of drought-related experiences on public demand for water security and inform water conservation policies using NbS in the environmental, political, and socioeconomic context of a global mega-city with approximately 21 million inhabitants in Brazil. Thus, our study contributes to the existing literature in two distinct ways. First, our study is among the first to incorporate specific NbS such as afforestation and agroforestry as a way to achieve more reliable water supply in a megacity in a DCE. Second, we account for how respondents' experiences with water supply disruptions in the past shape their preferences for water supply security in the future. Additionally, we control for public perceptions of the effectiveness of the proposed NbS.

The remainder of this paper unfolds as follows: in Section 2 we describe the case study in more detail and the existing payment for environmental services program (PES); in Section 3 the survey development and methodological steps are described; in Section 4 the main results are presented and discussed; and our main conclusions are highlighted in Section 5.

2. Case Study

This study is carried out in the SPMR, which has an estimated population of nearly 20.8 million (Seade, 2023b), distributed over 39 municipalities including the city of São Paulo, and is responsible for 19% of Brazil's Gross Domestic Product (GDP) (Haddad & Teixeira, 2015). The population living in the SPMR receives a large share of their water supply from remote river basins, most importantly the Jaguari river basin. This basin (970 km^2) is located in the neighboring State of Minas Gerais and is the main water source of the Cantareira water supply system (about 46%), which consists of five interconnected reservoirs that provide water to about 6.2 million people in the SPMR (SABESP, 2021). This is the largest system responsible for supplying water to 11 municipalities: Barueri, Caieiras, Carapicuíba, Francisco Morato, Franco da Rocha, Guarulhos, Osasco, Santo André, São Caetano do Sul, São Paulo, and Taboão da Serra (Whately & Cunha, 2007). Several studies have raised concerns regarding the impact of environmental degradation and climate change on water quality (e.g., Taffarello et al., 2018; Tercini et al., 2021) and quantity (e.g., Gesualdo et al., 2019; Sone et al., 2022) within the basins comprising the Cantareira system. Between 2014 and 2015, the SPMR experienced one of the driest and hottest years on record. As a consequence, the reservoir levels in the Cantareira system were at only 10% of its full storage capacity for several consecutive months, leading to the widely publicized almost Day Zero in the SPMR. This unprecedented drought (Melo et al., 2016; Nobre et al., 2016) caused an estimated economic loss of US$ 5 billion in 2014 (Munich Re, 2015), the fifth largest in the world by overall losses due to droughts in that year.

The Jaguari basin has a Payment for Environmental Services (PES) program to protect and conserve aquatic ecosystem services by providing financial incentives to local farmers (Richards et al., 2015). The PES program, called "Conservador das Águas," was initiated by the municipality of Extrema in the State of Minas Gerais in 2005. The initiative emerged due to a pressing need to address the depletion of natural vegetation, particularly riparian forests, and to counteract the adverse effects of inappropriate soil management practices in the basin's agricultural areas. A detailed description of the program's legal framework and its first 10 years in operation can be found in Richards et al. (2015). Deforestation and poor agricultural practices jeopardize water security not only in Extrema, but also in the SPMR. The program encourages local farmers and landowners to adopt best management practices and protect native vegetation using financial incentives. These financial incentives aim to promote the adoption of soil conservation practices to reduce soil erosion, implement rural wastewater collection and treatment, and establish and maintain so-called Permanent Protection Areas and Legal Reserves.

The primary funding sources for the program include at municipal level Extrema's City Hall, at state level the State Bureau of the Environment and Sustainable Development of Minas Gerais, and at the federal level the Brazilian Water and Sanitation Agency. Non-governmental organizations, such as The Nature Conservancy, and watershed advisory committees, which raise funds through water use charges, also contribute to the PES program. From 2007 to 2017, the PES program invested about 5.2 million BRL (about 2 million USD in 2017 prices) in fencing of forest fragments, reforestation of permanent protection areas, and implementation of soil conservation practices such as terracing (Pereira, 2017). Over this period, the number of contracts with local farmers increased to 238 participants and covered an area of 6.5 thousand hectares, with an average annual payment of 53 USD per hectare. However, this rate of payment varied substantially between 2011 and 2017, showing a decreasing trend. A common problem in PES programs like the "Conservador das Águas" is the instability of payments (Le et al., 2024). Particularly in Brazil, discontinuity in payments is due to changes in policies and funding streams as all programs mostly rely on local and Federal institutions (Mamedes et al., 2023). In this context, the Jaguari's PES program would benefit from a more continuous funding stream through our proposed payment scheme to increase the adoption of NbS in the Jaguari basin feeding the SPMR.

3. Materials and Methods

3.1. Survey Design and Implementation

The questionnaire was designed to investigate people's WTP for nature-based conservation measures, as well as their experiences with past drought events. The questionnaire was divided into four parts: (a) respondents' general water-use characteristics, (b) their water shortage experiences, (c) their WTP for water conservation measures, and (d) their sociodemographic background characteristics. The first section included questions about household water consumption and drinking water sources. The second section contained attitudinal questions about water-saving measures and questions about water shortage experiences such as past water use restrictions and rationing episodes. For the third part, we developed a choice experiment to test whether the respondents are willing to pay for the implementation of nature-based conservation measures to improve their future water security. The last section collected information about, among others, respondents' age, education level, household composition and income.

The questionnaire was pretested on a sample of 25 respondents in the city of São Paulo, using a random street-intercept method. The pretest resulted in a limited number of modifications of the questions, which are partly based on similar tested survey design applied in Brouwer, Job, et al. (2015), Brouwer, Martin-Ortega, et al. (2015). The main changes in the questionnaire after the pretest related to the choice experiment design, which was updated using the outcome of a multinomial logit regression model based on the attributes only. The cost attribute levels were doubled to avoid attribute non-attendance (Holmes et al., 2017) and ensure the coefficient estimate for the water bill increase is statistically significant and negative in the estimated choice model in line with economic welfare theory.

The survey was implemented in November 2021 by a local professional survey company, interviewing a total of 400 people using the same in-person random street-intercept procedure. We focused on the four main municipalities supplied by the Cantareira water supply system in the metropolitan area (SABESP, 2021): São Paulo with a sample of 295 persons and Guarulhos, Osasco, and Santo André with a sample of 35 persons each due to limited financial resources (Figure 1). Almost 70% of the total population of the SPMR lives in these four municipalities: 55.2% in São Paulo, followed by 6.2% in Guarulhos, 3.6% in Osasco, and 3.6% in Santo André according to the 2022 census. Pedestrians were randomly selected as they passed by to answer the questions in the questionnaire. Respondents were asked to confirm their consent in participating in the survey by signing a consent form before answering the questions. The survey protocol was reviewed and approved by the Brazilian Research Ethics Board (approval no. 5113450). The questionnaire used in the survey is provided in Text S1 in Supporting Information S1.

3.2. Discrete Choice Experiment Design

A choice experiment is a stated preference method to estimate public preferences for new products, technologies, or policy programs (Johnston et al., 2017). This study aimed to elicit public preferences for specific NbS to be implemented over a time horizon of 10 years to reduce the frequency of future water supply shortages and the duration of these future water supply interruptions. Thus, the good on offer, for which respondents were asked to pay, was improved water supply reliability or water security through the implementation of NbS such as agroforestry, afforestation, and water harvesting in the main river basin feeding the SPMR, the Jaguari river basin. In the introduction to the choice experiment, respondents were informed about the expectation that water supply disruptions would occur more frequently in the next 10 years and last longer on average. The three proposed nature-based measures were introduced and described to address future water shortages. Respondents were also informed that the nature-based practices would be implemented in the Jaguari basin, and it was explained to respondents that taking extra measures would come at a cost that would then have to be shared between all water users in the SPMR (see Section 3 in the questionnaire included in Supporting Information S1). To financially support the necessary investments in these specific measures and guarantee the public benefits from improved water security, respondents were informed that an extra monthly payment on top of their household water bill would be required for the next 10 years.

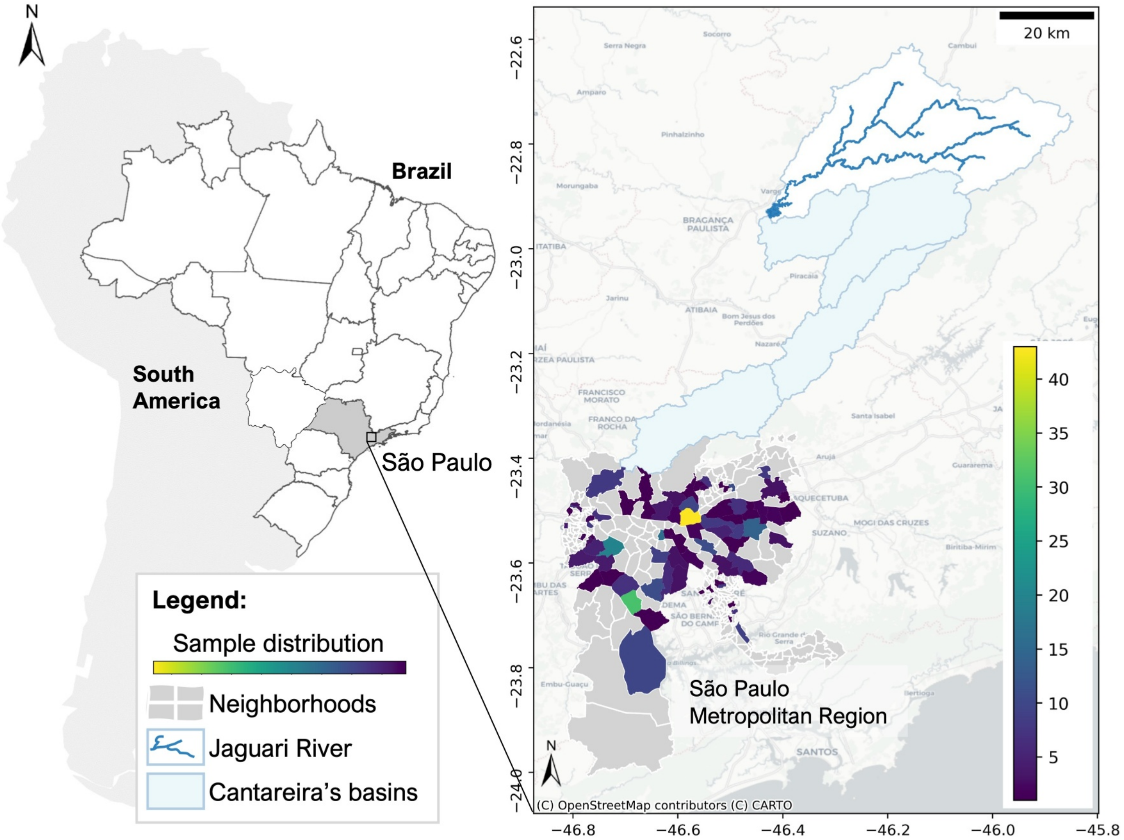

Figure 1. Map with the sample distribution and location of the São Paulo Metropolitan Region and the Jaguari River Basin and sample distribution.

Table 1
Description of the Attributes and Their Levels in the Discrete Choice Experiment

Attributes	Attribute levels
Frequency of future water shortages	Once in the next 10 years
	Twice in the next 10 years
	Four times in the next 10 years
	Five times in the next 10 years (*opt-out*)
Duration of future water supply interruptions	12 hr
	24 hr
	36 hr
	48 hr (*opt-out*)
Water conservation measures	Agroforestry
	Afforestation
	Water harvesting
	No new measures (*opt-out*)
Increase in monthly water bill[a]	100 BRL
	50 BRL
	20 BRL
	0 BRL (*opt-out*)

[a]The average exchange rate in November 2021, when the survey was implemented, was 0.18 USD for 1 BRL (IMF, 2021).

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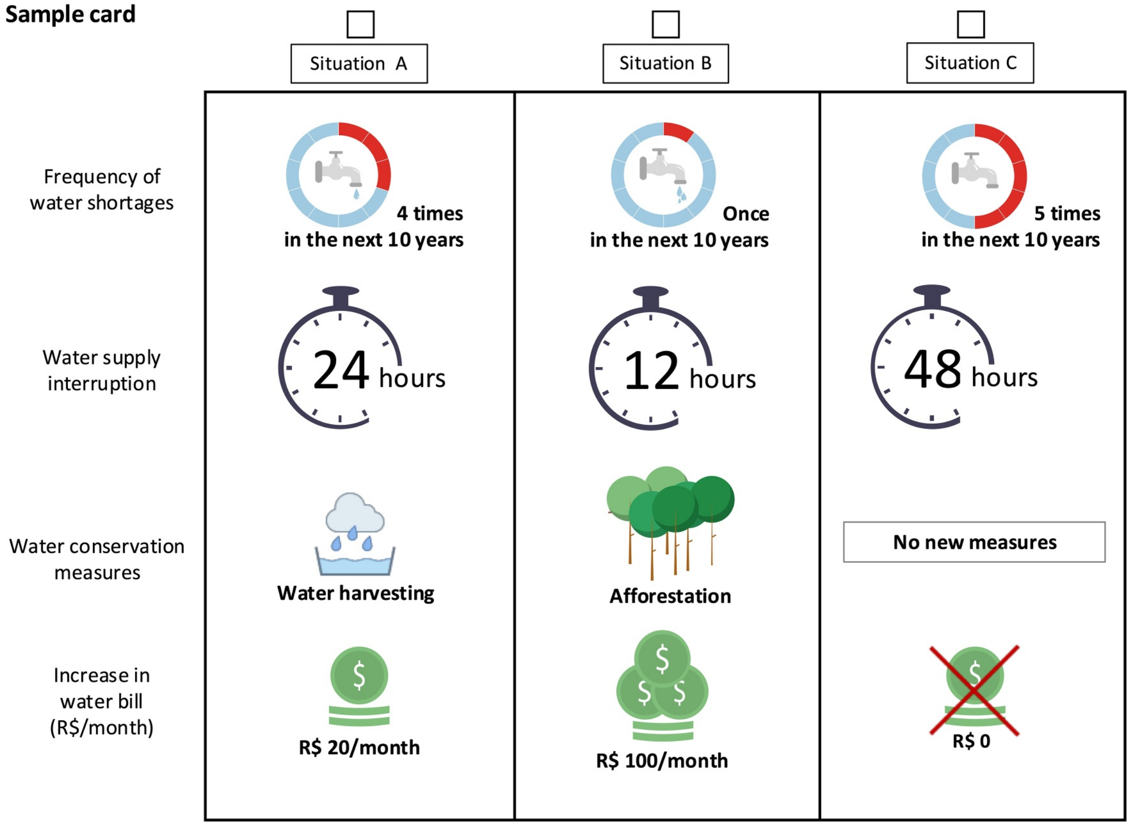

Figure 2. Example of a choice card. Situations A and B represent 2 hypothetical valuation scenarios to improve water security in the São Paulo Metropolitan Region and situation C is the opt-out, i.e. the expected future situation where water supply disruptions are expected to increase and last longer, no extra measures are taken to reduce the water supply disruptions and hence respondents also do not pay a surcharge on their water bill.

The description of the proposed measures and other two water security attributes is shown in Table 1. Improvements in water security were characterized by (a) frequency of future water shortages, (b) duration of future water supply disruptions, and (c) nature-based water conservation measures. The frequency and duration attributes capture the reliability of future water supply, and their expected future levels are designed based on observed water shortage events reported in the literature (Naumann et al., 2021; Nobre et al., 2016) and reports issued by São Paulo's water company SABESP (SABESP, 2017, 2021). The three proposed NbS are complimentary to the management practices already adopted within the "Conservador de Águas" program, such as terracing and restoration of degraded native. We were interested in gauging the preferences of the SPMR residents for three specific nature-based water conservation practices (agroforestry, afforestation, and water harvesting) besides those commonly adopted by PES schemes in Brazil (Mamedes et al., 2023).

The alternative scenarios were composed of four attributes and generated by arranging the levels of the attributes using a Bayesian D-efficient fractional factorial design (Sándor & Wedel, 2001) based on a multinomial logit model (MNL) (McFadden, 1974), as the respondents are not able to answer all possible combinations of attributes and levels in a full factorial design. To specify an appropriate prior distribution and minimize the D-error, we used the results from the pretest of the DCE using the sample of 25 respondents in the city of São Paulo. The final design comprised 28 different choice tasks that were pooled into seven blocks of four tasks, each consisting of two alternative hypothetical scenarios and the opt-out as illustrated in the example card in Figure 2. The first two alternative situations A and B are hypothetical future water security scenarios for which respondents were asked to pay extra. Before the choice exercise, we emphasized that choosing the opt-out would imply an increase in future water insecurity with water supply disruptions every other year and an increase in their average duration of 48 hr, with no new measures taken to address these water supply disruptions, and hence no extra costs and surcharge to the current water bill. The first choice card was shown again at the end as choice task 5 without telling respondents to test choice consistency and potential preference learning (Brouwer et al., 2010).

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Following the DCE, respondents who chose one of the two hypothetical alternatives (i.e., situation A or B) in the fifth (last) choice card were asked their maximum WTP for their preferred hypothetical alternative in an open-ended question (OE WTP). This follow-up question allowed respondents to reconsider their WTP and state either a lower or higher maximum WTP. Respondents who consistently chose the SQ alternative (situation C) across all choice cards were asked questions about their underlying reasons. The answers to these questions were subsequently used in the analysis to identify so-called protest respondents (e.g., Brouwer & Martín-Ortega, 2012; Dziegielewska & Mendelsohn, 2007). Protest respondents refuse to choose between the alternatives for reasons that are not directly related to their preferences for improvements in their situation, but to the perceived validity of the framing of the question.

3.3. Choice Modeling Approach

Choice experiments are based on multi-attribute utility theory (Lancaster, 1966), which states that a good or service can be characterized based on its attributes and the values that these attributes take. Given that some attributes may go unobserved or are only observable with an error, choice experiment data are analyzed using random utility theory (McFadden, 1974), breaking down the indirect utility function into a deterministic (observable) component and a stochastic (unobservable or error) component as follows:

$$U_{\text{nit}} = \text{ASC} + \beta_n' x_{\text{nit}} + \varepsilon_{\text{nit}} \tag{1}$$

where **ASC** is the alternative-specific constant for the opt-out and captures the utility of the situation "without extra measures," hence avoiding biased welfare estimates (Scarpa et al., 2005); x_{nit} is the vector of observed attributes in alternative i by respondent n in choice task t, and β_n is the corresponding vector of coefficients that are assumed to vary randomly over respondents using a mixing distribution $f(\beta)$ or are kept fixed as in a conditional multinomial logit (MNL) model in which case β_n becomes β. The error term ε_{nit} is assumed to be independently and identically distributed following an extreme-value type I distribution (i.e., homoscedastic error terms). Based on this assumption, the probability P_{nit} for the respondent's choices for alternative i in a choice task t can be written as the integral over the logit of probabilities $L_{\text{nit}}(\beta_n)$ that respondent n chooses alternative i in choice set t:

$$P_{\text{nit}} = \int L_{\text{nit}}(\beta_n) f(\beta)\, d\beta \tag{2}$$

where $f(\beta)$ is the density function.

The former logit probability is equal to the exponential of choosing a specific alternative and combination of observable attribute levels over the sum of all possible alternatives and observable attribute levels:

$$L_{\text{nit}}(\beta_n) = \frac{e^{\beta_n' x_{\text{nit}}}}{\sum_i e^{\beta_n' x_{\text{nit}}}} \tag{3}$$

Here, we approximate these choice probabilities by using a pseudo-Monte Carlo method with 1,500 draws. This provides a better unbiased and consistent estimator of the actual individual choice probabilities than Halton draws, which should not be used with more than five random coefficients (Bhat, 2003). The model was estimated using the Apollo package in R Studio (Hess & Palma, 2019). We employ the quasi-Newton hill-climbing technique known as the Broyden-Fletcher-Goldfarb-Shanno (BFGS) method to estimate the random parameters mixed logit model. The proposed conservation measures are included using dummy coding whilst the others (frequency and duration of future water shortages and cost) are treated as continuous variables in the model.

To account for heterogeneous preferences among respondents, the ASC, frequency of future water shortages, duration of future water supply interruptions, and the three proposed measures are modeled as being randomly distributed across respondents. The three continuous attributes follow a normal distribution while the dummy variables for the measures follow a uniform distribution as recommended by Hensher, Rose, and Greene (2005). Besides capturing unobserved preference heterogeneity through randomized coefficients, we introduce covariates interacting with the choice attributes to control for observable differences between respondents. This extension of the attributes-only model provides additional insights into the sources of preference heterogeneity. Most importantly, we are interested in testing for the impacts of (a) public experiences with water use restrictions or rationing, accounting for memory effects by introducing recent (2021) and less recent experiences over different time periods (2019–2020, 2016–2018, 2013–2015, 2010–2012); (b) public perception of future water shortage episodes; (c) public opinions on the effectiveness of the proposed NbS; and (d) household income on preferences for water security and WTP.

3.4. Modeling Protest Behavior

To better understand the protesters' decision process, we also estimated a probit model using the *Statsmodel* package in Python (Seabold & Perktold, 2010). Protest behavior is specified as a binary response variable, that is, dummy coded where protesters are assigned the value 1 and non-protesters the value 0. Thus, the dependent variable describing the likelihood of a given respondent $\boldsymbol{i}$ to cast a protest vote $\boldsymbol{Y_i}$ is a function of different explanatory variables and specified as:

$$\boldsymbol{Y_i = \alpha_0 + \alpha x_i' + \varepsilon_i} \tag{4}$$

where $\boldsymbol{\alpha_0}$ is a constant term and $\boldsymbol{\alpha}$ a vector of coefficients associated with the variables in $\boldsymbol{x_i'}$. The latter variables are similar to the ones used in the choice model, that is, restrictions and rationing experiences over the last 10 years; perceptions of future water shortages; effectiveness of NbS; and a number of socio-demographic respondent characteristics such as gender, income, and education. The error term $\boldsymbol{\varepsilon_i}$ is assumed to be normally distributed with a mean of zero and standard deviation ($\boldsymbol{N(0, \sigma^2)}$). The probability that a respondent $\boldsymbol{i}$ is a protester is then estimated as:

$$\boldsymbol{P[Y_i = 1] = P[Y_i^* > 0] = \phi(\alpha x_i')\alpha} \tag{5}$$

where $\boldsymbol{\phi}$ is the normal distribution.

4. Results

In this section, we first provide an overview of the sample population's socioeconomic and water use characteristics and their experiences with water use disruptions and restrictions. Subsequently, we analyze the factors influencing individuals' refusal to participate in the simulated market to implement NbS to improve water security in the SPMR and better understand what drives their decisions to protest. This section ends with a comprehensive evaluation and discussion of public preferences and WTP for NbS to enhance the reliability of water supply in the SPMR.

4.1. Sample Characteristics

The 400 face-to-face interviews were conducted over 2 weeks (including weekends) with adults older than 18 years, whose houses are located in one of the four selected municipalities in the SPMR and connected to the public water supply system. Table 2 shows the socioeconomic characteristics and water experiences of the respondents. Most respondents (59%) are higher educated women with an average age of 41 years (19–75 years). Compared to the 2022 census carried out in the State of São Paulo by the State Foundation for Data Analysis (Seade), the survey is representative in terms of gender, age, household size, and monthly income per capita (Seade, 2023a, 2023b), with average sample records close to the population living in the municipalities of São Paulo, Guarulhos, Osasco, and Santo André. Approximately 52% of these residents are women. The average age in these cities (37.4 years) is close to the average in the surveyed sample presented in Table 2, as well as average monthly income per capita (1,836 BRL). The sample's median and mean income per capita is 1,500 and 2,100 BRL, respectively. The average household size observed in the sample and the Seade census are also the same. Note that the survey data has been pooled across the four municipalities because of the relatively low number of observations in three of them, and the relatively small differences between these four municipalities. Where differences are significant, this will be highlighted explicitly in this section.

Our sample has a relatively high share of individuals with high school or higher education compared with the last state-wide census carried out by the Brazilian Institute of Geography and Statistics (IBGE) in 2021, which reports

Table 2
Sample Characteristics in the São Paulo Metropolitan Region

Description	Statistic
General sociodemographic characteristics	
Mean age (years) (st. dev.)	41 (12)
Share male respondents (%)	40.8
Share with no education or incomplete primary education (%)	0.5
Share completed primary school (%)	7.5
Share completed secondary (%)	59
Share completed higher education (%)	24
Mean household size (persons) (st. dev.)	3 (1)
Median monthly income per person (thousand BRL) (25th–75th percentiles)	1.5 (1.0–2.6)
Water use and shortage experiences	
Share using tap water as the only source of drinking water (%)	62.0
Mean daily water consumption per person (liters) (25th–75th percentiles)	158 (67–175)
Median ratio of monthly water bill to monthly income (%) (25th–75th percentiles)	2.0 (1.3–3.2)
Share facing water restrictions in the past (%)	72.3
Share of whom faced water restrictions (%):	
• In 2021	20.1
• Between 2019 and 2020	23.5
• Between 2016 and 2018	17.3
•Between 2013 and 2015	6.57
• Between 2010 and 2012	2.77
• 1–5 times in the last 10 years	73.4
• Every year for the last 10 years	16.3
Share facing water rationing in the past (%)	66.0
Share of whom faced water rationing (%):	
• In 2021	28.8
• Between 2019 and 2020	32.2
• Between 2016 and 2018	17.4
• Between 2013 and 2015	2.27
• Between 2010 and 2012	0.38
• 1–5 times in the last 10 years	71.2
• Every year for the last 10 years	16.3
Share taking water saving measures at home (%)	92.3
Share storing water at home in anticipation of water shortages (%)	68.5

a share of 58.5%. Similarly, the sample includes a substantially smaller share of respondents with no education or incomplete primary education (IBGE, 2022). These differences may be due to the lack of disaggregated data at municipality level but may also reflect the fact that education levels are generally higher in metropolitan areas in the State of São Paulo (IBGE, 2011). Based on the latest data and information for 2010, Seade (2021) estimated that on average 60% of the population in the four surveyed municipalities had at least completed secondary education.

Turning to the water use and water shortage experiences, the median amount of water consumption per person per day is nearly 160 L. This is slightly (10%) higher than the average amount of daily water consumption per capita (144 L) in Europe in 2015 (EEA, 2018) and considerably lower than average water consumption for example, in

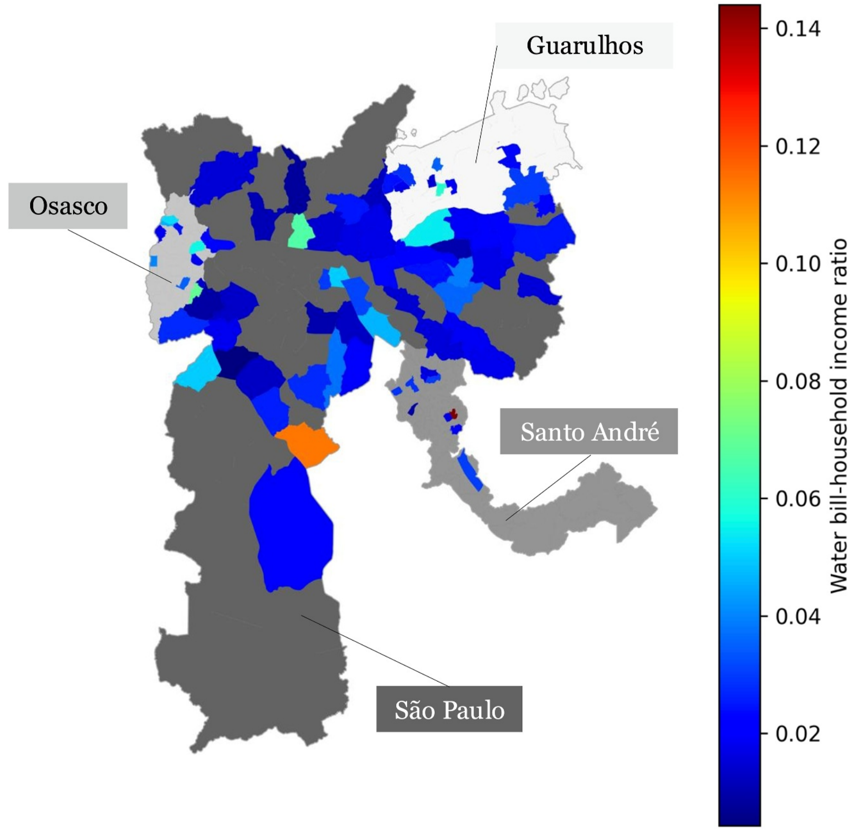

Figure 3. Spatial distribution of the median ratio of the monthly household water bill to monthly disposable household income across the surveyed São Paulo Metropolitan Region. Note that different shades of gray represent non-sampled city areas.

Canada (223 L per capita per day in 2021) (Statistics Canada, 2021). More than 60% of the respondents only drink tap water. A considerable share of 38% indicate that they also use other drinking water sources, mostly bottled water (37%) (Table 2). The median ratio of a respondent's monthly water bill to their monthly disposable income is about 2% across all four cities, except Osasco with a relatively higher ratio of almost 4%. This seems relatively high compared to, for example, the average share of both water supply and sanitation expenditures in GDP across European member states (MS). Most European MS spent 1% or less of GDP on water and sanitation (OECD, 2020). When examining the spatial distribution of this ratio in Figure 3, most neighborhoods exhibit median ratios between 2% and 4%, but in the cities of São Paulo and Santo André, certain neighborhoods display considerably higher ratios as depicted by the green to red spectrum.

Around three quarters (72%) of the sample faced at least one episode of water restriction in the last decade. Furthermore, nearly two thirds of the sampled population (66%) also faced water rationing. Altogether, nearly half of the sample have experienced both restrictions and rationing. When analyzing the duration of these restrictions and rationing (not presented in Table 2), 85% experienced rationing and 69% restrictions that lasted on average up to a week. More than a quarter (28%) experienced water use restrictions in the past that lasted longer than a month, while this was 14% in the case of water rationing. This most likely explains the very high share of respondents taking water saving measures at home and storing water in anticipation of future water shortages (Table 2).

Finally, not included in Table 2 but discussed in more detail here are respondents' expectations regarding future water security. Most respondents (78%) believe that the number of dry years has increased over the last 10 years and as a result the number of water shortage episodes (79%). In the next 10 years, a similar share (79%) believe water shortages will increase. This corroborates the considerable share of respondents (97%) who believe that climate change is real. A high share of respondents (89%) furthermore considers water companies responsible for safeguarding water supply in the SPMR, followed by the local municipal government (22%). Interestingly, just over a fifth (22%) believes that the responsibility is shared among all local actors, including water companies and local government.

Regarding the proposed nature-based measures, most respondents (63%) believe that NbS will contribute to reducing the frequency of future water shortages. However, 42% are unsure whether the specific NbS agroforestry and afforestation are as effective compared to more traditional water harvesting, while only half of the respondents are convinced that the nature-based measures will be implemented.

4.2. Discrete Choice Experiment Results

As expected, the two unlabeled hypothetical alternatives in the DCE did not generate any selection bias, and choices were equally distributed between the two alternatives. In the entire sample, the first alternative was chosen in 28% of the choice occasions and the second alternative in 26% of the choice occasions. Also, respondent choices appeared consistent as 91% of the respondents chose the same alternative in the identical first and last (fifth) card. This is substantially higher than the choice consistency rates found in other studies (e.g., Brouwer et al., 2010; Tarfasa et al., 2017). Nearly two-thirds (64%) of the responders are willing to pay extra for the water conservation measures to improve their water security while 5% are either not interested in reducing water shortages and their duration using NbS or cannot afford to pay extra. The latter two reasons can be linked to economic theory where respondents with a zero preference for the proposed change in water security and lack of income to pay are classified as legitimate zero bidders. Hence, together, those who showed either a positive or legitimate zero WTP make up 69% of the sample.

The remaining 31% of the respondents refused to choose between the two hypothetical alternatives to improve water security and pay for the proposed NbS based on protest reasons. This share varied between the four municipalities. In São Paulo and Guarulhos, around a quarter of the sample was qualified as protesters, while 31% was seen to protest in Santo André and as many as 83% in Osasco. The most common protest reason (65% of the protesters) is that respondents lack trust that their money will be spent on the proposed nature-based measures. A similar protest rate was also found when eliciting public preferences for forest conservation in Brazil (Bakaki & Bernauer, 2016). Additionally, a large share of the protest sample (around 60%) considers it the government's responsibility to pay for the implementation of the proposed measures, whereas 10% believe farmers should pay.

4.2.1. Understanding Protest Behavior

A probit model was estimated to explain possible reasons for protest behavior, and the results are presented in Table 3. Despite relatively low pseudo-R-squared, demographic characteristics like age and education significantly affect the likelihood of protesting, the response variable of the regression. Older individuals who have only completed elementary education have a significantly higher likelihood of protesting against the proposed increase in their water bill to improve water security by taking water conservation measures in the Jaguari basin. No significant effect can be detected for gender, income, or the water bill respondents already pay. Furthermore, respondents who have faced water use restriction or rationing exhibit a reduced likelihood of protesting and, therefore, a higher likelihood of showing a positive WTP for improved water security. Conversely, those who are unsure whether the number of dry years has increased over the past decade are more likely to protest while respondent expectations of whether water shortages will increase in the future do not have a significant impact on protest behavior. Moreover, respondents' perception of the effectiveness of the proposed NbS significantly increases the likelihood of protesting. Not unexpectedly, those respondents who do not believe that implementing NbS in the Jaguari basin feeding the SPRM will effectively reduce water insecurity are more likely to refuse to pay for them. Therefore, understanding residents' perceptions and beliefs is paramount for the design of effective public awareness raising campaigns based on the available scientific evidence of the cost-effectiveness of NbS to improve water security (Anderson et al., 2022; Lalonde et al., 2024).

4.2.2. Explaining Choice Behavior

Choice behavior is explained in two estimated models: a mixed multinomial logit (MMNL) model containing only the choice attributes and the same MMNL model extended with covariates of key interest in this study as explained in Section 3.3 (Table 4). While the first model only considers unobserved preference heterogeneity, the second model with additional covariates also accounts for observable preference heterogeneity. Both models

Table 3
Estimated Probit Regression Model to Explain Protest Votes

Variables	Estimate	Standard error
Constant	−0.9200**	0.4428
Gender (1 = male respondent)	0.1152	0.1416
Age (years)	0.0112*	0.0057
Elementary education (1 = yes)	0.4643*	0.2538
Born in the SPMR (1 = yes)	0.1717	0.1470
Current water bill (BLR/month)	0.0009	0.0013
Experienced restrictions or rationing (1 = yes)	−0.8325***	0.2868
Does not know if dry years increased in the past 10 years (1 = yes)	0.5663*	0.3367
Believes water shortages will increase in the future (1 = yes)	0.1975	0.1948
Believes NbS are not effective (1 = yes)	0.5713***	0.1389
Log-likelihood	−225.68	
Pseudo R^2	0.09	
Number of protesters	124	
Number of observations	400	

Note. The dependent variable is whether or not a respondent protests the proposed increase in their water bill to implement NbS in the Jaguari basin to improve water security in the SPMR (1 = protester). * 10%, ** 5%, and *** 1% significance level.

include the five choices, i.e. include the repeated choice task at the end, to increase the number of observations after excluding the protesters, which is common practice in stated preference research (e.g., Brouwer & Martín-Ortega, 2012), and estimate robust standard errors. No significant differences are found when estimating the choice models with or without the fifth choice due to the high level of consistency between the first and fifth choice. Although the adjusted R^2 is only marginally higher for the extended choice model compared to the choice model with the choice attributes, and the log-likelihood function only improves by 2.4%, the two models are statistically significantly different from each other based on the Likelihood Ratio test (LR test statistic = 42.26, $p < 0.001$). An important difference between the first and second model in Table 4 is that the dummy variables for afforestation and rainwater harvesting are not statistically significant in the former, only in the latter extended choice model. Otherwise, the coefficient estimates for the choice attributes are very similar between the two models, with only minor differences. The baseline category for the dummies is the situation where no extra water conservation measures are taken in the Jaguari basin feeding the SPMR. The increase in the water bill is fixed to enable the estimation of constant utility of income WTP welfare measures. Different distributional assumptions around the attributes' mean coefficient estimates were tested, but this did not lead to significant improvements in the estimated models' fit. We therefore relied on a normal distribution for the ASC and the continuous linear attributes (frequency and duration of water shortages) and a uniform distribution for the three NbS dummy variables, as recommended by Hensher, Rose, and Greene (2005). These distributional assumptions also showed strong consistency in the ranking of the NbS between the attributes only and extended model with covariates.

As expected, all the coefficient estimates are negative and highly significant, except for the three water conservation measures, where we expect positive signs compared to the baseline category of not taking any extra measures in the Jaguari basin to enhance water security. The negative sign for the ASC indicates that respondents prefer a change away from the expected future situation if no extra measures are taken to improve water security, that is, reduce the frequency of water supply disruptions and their duration. The negative cost coefficient signals that the higher the increase in the respondents' water bill, the less likely they will choose one of the two hypothetical alternatives to improve water security. Likewise, alternatives with higher return periods of water shortages and longer durations of water supply disruptions have a lower utility and hence likelihood of being chosen. In other words, respondents prefer (to pay for) less frequent water shortages in the next 10 years and shorter water supply interruptions. Both models agree that agroforestry is the most preferred water conservation measure. Based on the Wald test, its coefficient estimate is significantly higher (more than two times) than the one for afforestation and water harvesting in the extended model. The difference between the latter two is not

Table 4
Estimated Mixed Logit Choice Attributes-Only Model and Extended With Additional Covariates

	Attributes-only model		Extended model	
Attributes and covariates	Coef. est.	Rob. s.e.	Coef. est.	Rob. s.e.
ASC	−2.3450***	0.5930	−2.2480*	1.2452
Choice attributes				
Frequency of water shortages	−0.2624***	0.1131	−0.2837***	0.1041
Duration of supply interruption	−0.0519***	0.0181	−0.0572***	0.0162
Water conservation measures (base: no new measures)				
Agroforestry	3.3935***	0.8565	6.8221***	1.2549
Afforestation	1.0629	0.8443	2.9020***	0.8766
Water harvesting	0.6613	0.5972	2.4709***	0.7077
Monthly payment (BRL)—Cost	−0.0938***	0.0145	−0.0929***	0.0115
Standard deviation of the coefficients' distribution				
ASC	4.4442***	2.7539	5.1504**	2.4166
Frequency of water shortages	0.7027***	0.5106	0.6350***	0.1509
Duration of supply interruption	0.1753***	0.1053	0.1662***	0.0236
Water conservation measures (base: no new measures)				
Agroforestry	0.6192	2.3092	3.1665*	1.7944
Afforestation	5.5290**	1.8127	5.1020***	1.4916
Water harvesting	6.9517***	1.5055	6.5028***	1.2579
Covariates				
Cost-Income elasticity	–	–	0.0505	0.0969
ASC × Age (years)	–	–	0.0226	0.0176
ASC × Gender (1 = male respondent)	–	–	−0.3627	0.2370
ASC × Experienced restrictions/rationing in 2021	–	–	−2.1075**	0.9144
ASC × Experienced restrictions/rationing in 2019/2020	–	–	−1.0300**	0.4120
ASC × Experienced restrictions/rationing in 2016/2018	–	–	−0.3935*	0.2312
ASC × Experienced restrictions/rationing in 2013/2015	–	–	−2.8157**	1.3187
ASC × Experienced restrictions/rationing in 2010/2012	–	–	−0.2793	0.5195
ASC × Believes that water shortages increase in the future	–	–	−0.8378**	0.3655
Nature-based solutions[a] × Believes NbS are not effective	–	–	−0.2266	0.6444
Model summary statistics				
Log-likelihood	−870.13		−848.91	
Adjusted ρ^2	0.40		0.41	
Number of observations	1,380		1,380	

Note. Coef. est and Rob. s.e. are coefficient estimates and robust standard errors, respectively. [a]If the water conservation measure was either agroforestry or afforestation. *10%, **5%, and ***1% significance levels.

statistically significant based on the same test despite the fact that the coefficient estimate for afforestation, and hence its utility, is almost 20% higher than for rainwater harvesting. Interestingly, all choice attributes in the extended model are characterized by significant preference heterogeneity, implying that there exist significant differences among respondents as to how much they value the different choice attributes.

The included covariates are similar to the ones in the probit model presented before, with the difference that the restriction and rationing experiences are split across the different time periods in which they occurred to test for possible (fading) memory effects. As a result, public perception of whether the number of dry years has increased over the past decade is not included in the extended choice model with covariates to avoid multicollinearity, nor are education levels included due to their correlation with income. The sociodemographic respondent characteristics do not significantly affect the choices respondents made during the DCE. Although age significantly affects protest votes (Table 3), we do not observe a significant effect of age on the public's preferences for alternative nature-based practices to improve water security in the SPMR. Additionally, no significant effect was found for gender regarding public preference to move away from the status-quo baseline scenario to one of the hypothetical alternatives. Various income specifications were used to test the effect of different income levels on public WTP. This includes the use of a continuous income variable per capita or per household, dummy variables reflecting higher or lower income groups than the mean or median income level in the sample, or the use of quartiles and quintiles. None of these income specifications and interactions with the cost attribute yielded a significant effect, suggesting that respondents prioritized water security so highly that their WTP was not significantly constrained by the height of their income. Table 4 presents the results of the inclusion of the income elasticity of WTP, because this is one of the most commonly used measures for WTP sensitivity to income variability and easy to interpret. It measures how a respondent's WTP for water security changes in response to a change in their income. As can be seen, this elasticity is also not statistically significant, indicating that WTP does not vary across different income levels.

Experiences with water use restrictions or rationing significantly increases the likelihood that respondents are willing to pay for a reduction of future water shortages and their duration, that is, moving away from the expected future situation if no extra measures are taken as captured by the ASC. Of most interest here is the fact that the coefficient estimates gradually decrease over time from the most recent episode with restrictions and rationing in 2021, when we conducted the survey and SPMR faced a significant dry spell, until 2016–2018 (over the past 5 years), and then soars in 2013–2015, the period in which SPMR faced unprecedented water shortages that almost led to a Day Zero situation. Based on the Wald test, the 2021 coefficient estimate significantly doubles compared with 2019–2020 and is nearly five times higher than the one for 2016–2018. This suggests that public recollection of drought events fades rather quickly over a short period of five years. Notably, the 2013–2015 coefficient estimate is not statistically different from the one for 2021, indicating that extreme droughts shape choice behavior long after they occur despite the fading effect of milder events. Thus, the significant high impact of public experiences with restrictions and rationing during the close to Day Zero crisis shows that stringent measures 7–8 years earlier remain influential in decision-making. Water use restrictions and rationing before 2012 do not have any significant effect on respondent choices during the CE.

Finally, respondent perceptions of increasing water shortages in the future significantly influence their choices to shift away from the *status-quo* baseline situation to one of the hypothetical alternatives that help improve water security in the SPMR. This finding shows that public willingness to invest in the water conservation measures to improve water security depends on both their experiences with water restrictions and rationing in the past and their future risk perception. Contrary to the results presented in the previous section, once protest voters are removed from further analysis of the choice data, respondents' perception of how effective NbS are to increase water security does not play a role anymore when they made their choices in the DCE. On the other hand, respondents' experiences with water use restrictions and rationing significantly reduce the likelihood of protest paying for water conservation measures in the Jaguari basin in the neighboring State of Minas Gerais and significantly increase the likelihood of a positive WTP for such extra water security measures. This latter effect is particularly strong when these experiences are recent or tied to a severe drought event.

4.2.3. Public Willingness to Pay for Improved Water Security

Marginal WTP values are derived from the attributes-only model in Table 4. Marginal WTP for a one-level reduction in the frequency of future water shortages, that is, one year less in the next 10 years or a 10% reduction, is 2.80 BRL or 0.50 USD per household per month with a standard error of 0.99 BRL. Marginal WTP for a one-hour reduction of future water supply interruptions is 0.55 BRL per household per month (standard error of 0.15), which is equal to 0.10 USD. Residents of the SPMR furthermore express a positive marginal WTP of 36.19 BRL or 6.50 USD with a standard error of 10.15 BRL to increase their monthly water bill to implement agroforestry in the Jaguari basin, the most preferred NbS. Combining these marginal WTP values to increase water security based on agroforestry in the Jaguari basin, mean WTP for a relatively small reduction of 10% in future water shortages from five to four episodes in the next 10 years and a 12 hr decrease in the duration of each episode (from 48 to 36 hr) equals 43.12 BRL per household per month (7.75 USD) with a standard error of 9.94. A relatively large reduction of 40% in water shortages from five times to only once in the next 10 years and a 36 hr decrease in duration from 48 to 12 hr yields a mean WTP of 57.25 BRL per household per month (10.30 USD) with a standard error of 10.68. In relative terms, compared to the average current water bill, this implies an increase of 40%–53% for the smaller and larger increase in water security in the SPMR, respectively. Compared to average monthly household income, this is equivalent to an increase of 0.73% and 0.97%, respectively. Both comparisons suggest that water security is a high priority for the families in our sample.

Following their last (fifth) choice in the DCE, respondents were asked for their maximum WTP in an open-ended question based on their preferred alternative in the last choice task. The follow-up question aimed to confirm whether respondents are indeed willing to pay the proposed increase in their monthly water bill in their preferred alternative to reduce possible hypothetical bias. To this end, they were also able to state a lower amount. Sixty-four percent stated a maximum WTP that was equal to or higher than the water bill increase in their preferred alternative, and hence 36% reconsidered their choice and stated a lower WTP. Due to the limited numbers of observations across the whole scala of possible policy scenarios, we were only able to compare mean WTP based on the open-ended WTP question with the DCE-based WTP for the increase in water security using agroforestry, where water supply disruptions are reduced to four times over the next 10 years and their duration to 36 hr. The mean open-ended WTP including both higher and lower stated values are in that case 27.70 BRL with a standard error of 3.06. This estimation is 35% lower than the DCE-based WTP value presented above. Although this finding is in line with previous comparisons of open-ended and DCE-based WTP values in the literature (e.g., Brouwer, Job, et al., 2015; Brouwer, Martin-Ortega, et al., 2015; Ryan & Watson, 2009), the difference in this case is mainly due to the large share of respondents who modified their stated maximum WTP downwards compared with what they said they would be willing to pay to achieve their most preferred outcome in the final choice task.

5. Discussion

Although the survey was pretested, a substantial number of respondents (31%) protested against the proposed payment scheme, most importantly because they lacked trust that their money would actually be spent on improving water security in the SPMR. This suggests that there exists deep institutional mistrust. Systematic issues with framing the proposed NbS and payment vehicle such as the applied surcharge to the water bill did not play a significant role in our study, even though respondent belief that the proposed NbS are not effective in improving water security was a significant driver underlying protest behavior as shown in Table 3. Most respondents (60%) believe the measures will reduce water shortages and water supply disruptions. However, less than half (45%) are convinced the extra money raised through higher water bills will be used for implementing the specific NbS.

In DCEs focusing on water supply and quality, it is common practice to propose increases in the existing water bill (Brouwer, Job, et al., 2015; Brouwer, Martin-Ortega, et al., 2015; Brouwer et al., 2023; Gordon et al., 2001; Griffin & Mjelde, 2000; Hensher, Shore, & Train, 2005; Martin-Ortega et al., 2011; Tarfasa & Brouwer, 2013; Van Houtven et al., 2017), and there were also no concerns related to the payment mode in this study. Surcharges to existing bills instead of the creation of new, hypothetical payment vehicles or voluntary donations have been shown to result in less protest (Meyerhoff & Liebe, 2010). Respondents were furthermore asked in a follow-up question about their certainty that they would pay the surcharge stated in the last choice card. On a scale from 0 to 10, where 0 means not certain at all and 10 completely certain, most respondents (65%) stated a certainty level between 8 and 10. When considering a certainty level from 6 to 10, this share increases to more than 75%. This suggests that our study does not seem to suffer from hypothetical bias and the proposed surcharge in our design is perceived as realistic by respondents.

Excluding these protesters, 69% of all the respondents were willing to pay a significant increase in their current water bill, demonstrating how important water security is for most of the SPMR residents, to the extent that we were not able to detect a significant income effect in the estimated choice model. This implies that everyone wanted to pay more irrespective of the income group in which respondents fall. The mentioned follow-up question that tried to account for possible hypothetical bias showed that when given the opportunity to change their WTP response in the DCE, more than a third would actually reduce it. Using this latter more conservative open-ended WTP estimate for a 10% reduction in water supply disruption frequency and a 25% reduction in disruption duration over the next 10 years and extrapolating this unit value (27.7 BRL or 5.0 USD/household/

month) over the entire SPMR population receiving their water from the Jaguari basin, that is, almost 4 million people or 1.35 million households after excluding protest and legitimate zero bidders, this results in an annual total economic value of approximately 449 million BRL or 81 million USD. This is many times more (for a relatively small change in water security) than what the current PES scheme annually paid the approximately 240 participating farmers and landowners for the just over 6.5 thousand hectares of land under contract in 2017 (735 thousand BRL or 222 thousand USD). Divided by this area in the Jaguari basin under contract in the existing PES scheme, this would be almost 69 thousand BRL or 12,400 USD/ha/year compared to the average 120 BRL or 53 USD/ha/year they received between 2007 and 2017 through their participation in the PES scheme "Conservador das Águas." Besides reducing payment insecurity and providing the critically needed additional financial support for the continuation and expansion of the existing PES scheme, our findings act as an example of citizen-science research collaboration, where the downstream beneficiaries inform the upstream scheme operators about their preferred type of measures (i.e., agroforestry) and the specific watershed service (i.e., water provision) for which they are willing to pay.

The aggregated annual WTP value of 81 million USD is a conservative estimate since more conservative WTP values were used where respondents were given the opportunity to rethink their WTP. Moreover, this lower WTP value was subsequently only aggregated across the share of the total population connected to the Cantareira water system who agreed to pay a positive amount of money extra over and above their existing water bill in the sample. An important concern regarding the transfer of the hypothetical payments from downstream urban water customers to upstream rural landowners in the Jaguari basin is related to respondents' skepticism about the accountability of government agencies. This may have biased the results, even though we removed all protest voters from the WTP analysis. This is somewhat in line with findings in the literature. An international review by Garrick et al. (2019) of rural-urban water transfers shows that such transfers often involve informal processes that are difficult to track. A quarter of the published documents do not explicit decision-making processes regarding water reallocation, while only 14% of the other 75% have water transactions based on collective negotiation (Garrick et al., 2019). The framing of more trustworthy transfer mechanisms, ensuring the effective and equitable distribution of the risks and benefits related to water security upstream and downstream is an important avenue for future research. This is expected to increase insight into mutual trust and preferences of urban drinking water users and rural farmers and landowners for the institutional-economic underpinning of the transfers involved. Consequently, this would allow for changes in the flow of costs and benefits to be better understood across upstream and downstream donors and recipients.

6. Conclusions

This is one of the first studies globally and the first one in Brazil to elicit public preferences for NbS to improve water security in increasingly urbanizing watersheds. Based on a DCE, we tested how experiences with water supply restrictions and rationing in the SPMR, which receives a large share of its source water several hundreds of kilometers upstream from the Jaguari basin in the neighboring state Minas Gerais, affect SPMR residents' WTP to invest in these land use change and management solutions through the existing PES scheme "Conservador das Águas." Additionally, we focused on public perception of their effectiveness in safeguarding water supply and public perception of future water supply shortages.

Most recent experiences and those related to extreme restrictions and rationing, such as the closer to Day Zero experience in SPMR between 2014 and 2015, significantly influence public choices and hence WTP for NbS. Public recollection of water supply disruption quickly fades after several years as does its impacts on choice behavior in the DCE until people remember the severe restrictions and rationing experienced during this close to Day Zero episode. The latter sparks a significantly higher renewed interest in water security. Moreover, public risk perception and the expectation that water shortages will increase in the future also play a significant role, resulting in a significant shift away from expected future water supply disruptions, also when this means that respondents have to pay extra. Interestingly, public perception of the effectiveness of NbS in securing water supply plays a key role in explaining protest behavior, but once these protesters have been removed from further analysis, this did not affect choice behavior in the DCE anymore.

Conflict of Interest

The authors declare no conflicts of interest relevant to this study.

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Data Availability Statement

For the protection of privacy sensitive information, the interview data are not available for public release. The questionnaire is attached as Text S1 in Supporting Information S1.

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