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Midterm impacts of a water drought experience: evaluation of consumption changes in São Paulo, Brazil

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ABSTRACT

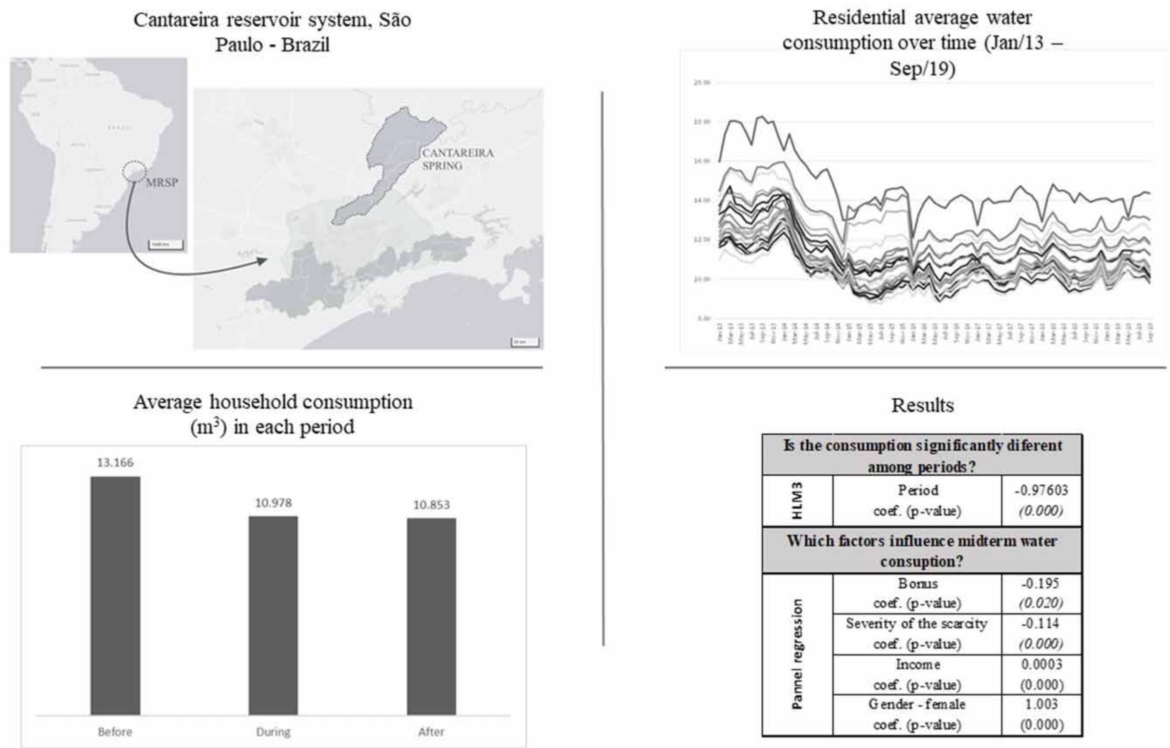
From late 2013 until the beginning of 2015, the metropolitan region of São Paulo, Brazil, experienced a severe water shortage. During that period, economic incentives were implemented by the regional water provider in a successful attempt to reduce water consumption. We aimed to investigate whether such incentives, as well as the experience of a scarcity period itself, had a persistent impact on consumer behaviour after the water crisis was over. This study was conducted by means of a hierarchical linear model with three levels (HLM3) to verify if the reduction effect remained in the midterm and a regression using panel data to understand which factors influenced water consumption behaviour change before, during, and after the local severe water drought. The results indicate that the average water consumption level subsequent to the rain scarcity period was significantly lower than before and that, in addition to the economic incentives, the severity of the scarcity event explained the behaviour change verified in water consumption.

Key words: Conservation behaviour, Public policy, Water economics, Water scarcity

HIGHLIGHTS

- People more directly affected by droughts tend to consume less water.
- Economic incentives may be a successful instrument in shaping consumption.
- Income, gender, and drought severity helped build up new behaviour in the midterm.
- Evidence indicates that resilience may be built during a water crisis, leading to new water consumption practices.
- New consumption practices should be encouraged in times of global water availability uncertainties.

GRAPHICAL ABSTRACT



INTRODUCTION

Freshwater is a fundamental natural resource, and as such, water must be consumed in a sustainable manner (Gilbertson *et al.*, 2011). In the 21st century, many experts and scholars have called for the public's attention concerning the problem of water resources, as many countries suffer from water shortages or deteriorating water quality (Wang *et al.*, 2019). Cities around the world struggle to manage water resources in the face of population increases, consumer demand for water-intensive services, and increasing costs (including environmental costs) of developing new supplies (Olmstead & Stavins, 2009).

In the metropolitan region of São Paulo ('MRSP'), Brazil, the water scarcity situation is a concerning matter, as it is a highly populated area that suffers from problems such as lack of sewage collection for a part of its population and struggles with illegal occupations near water springs. From late 2013 until the beginning of 2015, this area experienced a severe water shortage. During this period, the level of Cantareira, the most important reservoir in the region, supplying water for nearly 8 million people in 2013 (40% of the total population of the MRSP), had a significant volume decrease. Figure 1 shows the location of the Cantareira reservoir system in the MRSP, São Paulo, Brazil.

Fig. 1. | Location of the Cantareira reservoir system. *Source*: Sabesp's hydro maps.

In this water scarcity context, the regional water operator Sabesp[1] was authorized to establish a programme that provided a financial bonus on water bills for every household that reduced its water consumption and, on the other hand, applied an economic penalty to households that increased their consumption (Arsesp, 2014a, 2014b). This 'bonus and financial burden' programme was based on the water consumption increase/decrease compared to the average consumption for each household from February 2013 to January 2014. After more than 2 years, the programme was terminated, and the economic incentives were withdrawn.

Water managers can implement water conservation policies based on economic incentives (Gilbertson *et al.*, 2011; Sousa & Fouto, 2019). Such incentives provide rewards for consumers who act in accordance with the public interest. Even when water prices and allocations across sectors are inefficient, water conservation policies based on economic incentives are more cost-effective than prescriptive policies (Olmstead *et al.*, 2005). Similarly, market-based regulations encourage behaviour through market signals rather than through explicit directives to individual households, and such mechanisms are more cost-effective than implementing non-price conservation programmes (Olmstead & Stavins, 2009).

In São Paulo, the economic incentives adopted by the regional water provider were effective in reducing water consumption in the short term (Sousa & Fouto, 2019). However, what about when the scarcity period is over, and the incentive is withdrawn? Do populations continue to use less water for their daily activities?

[1] Regional company responsible for the provision of water services and sewage treatment of 375 cities. It is one of the biggest sanitation companies in the world in terms of supplied inhabitants: 28.1 million people supplied with water and 24.5 million people with sewage collection (in the year 2021). It is a mixed capital company that has São Paulo State Government as its main shareholder, and stocks traded on the New York Stock Exchange (NYSE) and on the São Paulo Stock Exchange (BM&Fbovespa). More information is available at http://site.sabesp.com.br/site/Default.aspx.

Considering this scenario, in this study, we aimed to analyse whether the scarcity period and the bonus and financial burden programme implemented in São Paulo had a midterm impact on local consumption behaviour, as well as to understand the relevance of other factors on residential water consumption levels in the MRSP. The proposed study is an opportunity to continue the evaluation of drought consequences and innovates by filling a research gap in assessing the effects of the scarcity phenomenon on water consumption behaviour changes in the midterm.

Although there are numerous works on behaviour towards water consumption, as Grover & Lucinda (2020) point out, most prior research on drought response effectiveness has focused on developed country contexts, such as those in Spain, Australia, and the USA (California, Arizona). This paper addresses this gap by promoting such analysis in Brazil.

METHOD

To evaluate the changes in behaviour by the population of the MRSP, we used information about water consumption per household provided by Sabesp, made available through the citizens' information service. The information collected included the monthly average consumption of 21 districts (Table 1) from January 2013 to September 2019, adding up to 81 months. This means that the data include information from before, during, and after water scarcity, considering that the implementation of the bonus/financial burden programme was used as a proxy for the period in which the drought lasted.

First, to identify whether there was a significant difference among the periods and whether there were intragroup and intergroup effects, we created a hierarchical linear model with three levels (HLM3). A three-level hierarchical model has three submodels, one for each analysis level of a nested data structure (Raudenbush *et al.*, 2004; Fávero & Belfiore, 2017; Hair & Fávero, 2019).

For the first level, we considered the period of consumption, which could be (i) before the implementation of the bonus programme, (ii) during the bonus/financial burden programme, and (iii) after the bonus programme ended. In this case, we considered the duration of the bonus as a proxy for the duration of the drought. The second level of the model is the reservoir used for supplying each district of the region. Finally, the third level is the district itself.

The linear trend model with random intercept and slope expression can be written as follows:

$$\text{Consumption}_{tjk} = \gamma_{000} + \gamma_{100} \cdot \text{period}_{jk} + u_{00k} + u_{10k} \cdot \text{period}_{jk} + r_{0jk} + r_{1jk} \cdot \text{period}_{jk} + e_{tjk} \quad (1)$$

where γ_{000} is the general intercept, γ_{100} is the period variation on water consumption, j is the reservoir used for water supply, k is the district, u_{00k}, r_{0jk}, and e_{tjk} are the error terms (for each level).

Table 1. | Twenty-one districts considered in this study

Americanópolis	Ipiranga	Santana
Arthur Alvim	Itaim Paulista	Santo Amaro
Butantã	Jardins	São Mateus
Campo Limpo	Mooca	Sao Miguel
Capela do Socorro	Penha	Sé
Freguesia do Ó	Pirajussara	Vila Maria
Guaianazes	Pirituba	Vila Mariana

Two important reservations must be addressed regarding the periods. First, the number of months is different for each period. Second, the extension of the programme is also different according to the reservoir used in each region; the programme began for the population supplied by Cantareira 2 months before it began for the population supplied by the other reservoir. From the 21 districts analysed, nine were supplied by the Cantareira reservoir system and 12 by another reservoir (Guarapiranga or Alto Tietê). That information is summarized in Table 2.

After evaluating whether there was a new consumption behaviour created after the water crisis was over, we created a model to understand the influence of some factors on water consumption levels by the inhabitants of São Paulo. We used a panel model, also considering information about the consumption of water per household (in cubic metres) provided by Sabesp (as the dependent variable), but for only 18 districts, since for three districts, Jardins, Americanópolis, and Pirajussara, there was no reliable information regarding all the variables.

The set of explanatory variables includes demographics such as average household income (deflated by the inflation rate from the period, using the Broad Consumer Price Index) and the percentage of women living in each district. These two demographic variables were included since the average income was shown to be significant in determining water consumption reduction during the São Paulo 2013–2015 water crises (Sousa & Fouto, 2019) and since the literature points out that women tend to act more environmentally consciously (Meinzen-Dick *et al*., 2014) and, therefore, may consume water more rationally. Both explanatory variables were provided by the State Statistical Department ('Fundação Seade', in Portuguese).

We also included dummy variables to analyse the influence of the financial burden and bonus programme and a dummy variable to determine if the population was supplied by the Cantareira system, the reservoir that was more strongly impacted by the drought. Finally, dummy variables for time were used as controls; month variables prevented distortions due to seasonality throughout the year (since water consumption depends on weather, for instance), and year variables helped control various factors that occur only in one specific year and may affect water consumption by citizens.

The model used is represented below, and Table 3 summarizes the variables used in the panel model.

$$\text{Consumption} = \alpha + \beta_1\text{income} + \beta_2\ \text{gender} + \beta_3\ \text{bonus} + \beta_4\ \text{tariff} + \beta_5\ \text{reservoir} + \beta_6\ \text{year} + \beta_7\ \text{month}$$

where α is the constant, and β_i is the coefficient of each variable considered.

RESULTS AND DISCUSSION

From the average household consumption information in each district analysed, as plotted in Figure 2, we can preliminarily infer that although the programme was over, the population in all districts did not return to its consumption threshold before the implementation of the bonus and financial burden. We can also infer that, from the moment the bonus programme started for users of the Cantareira reservoir system, in February 2014, all districts

Table 2. | Periods of analysis.

	t_0 Before the programme was implemented	t_1 During the programme	t_2 After the programme ended
Cantareira reservoir system	14 months (Jan 2013–Feb 2014)	25 months (Mar 2014–Mar 2016)	42 months (Apr 2016–Sept 2019)
Guarapiranga and Alto Tietê reservoirs	16 months (Jan 2013–Apr 2014)	23 months (May 2014–Mar 2016)	42 months (Apr 2016–Sept 2019)

Table 3. | Summary – variables used.

Classification	Variable	Form of measurement	Source
Demographic variables	Average annual income ('income')	Brazilian real (R$ – Dec 2019)	Seade
	Gender ('gender')	% of women (values of 2017)	Seade
Sabesp's programme variables	Bonus ('bonus')	Dummy (1 for present; 0 for absent)	Sabesp
	Contingence tariff ('tariff')	Dummy (1 for present; 0 for absent)	Sabesp
Scarcity intensity	Cantareira ('reservoir')	Dummy (1 for 'supplied by Cantareira'; 0 for 'supplied by other reservoir')	Sabesp
Control variables	Year ('year')	Year of the consumption measurement	–
	Month ('month')	Month of the consumption measurement	–

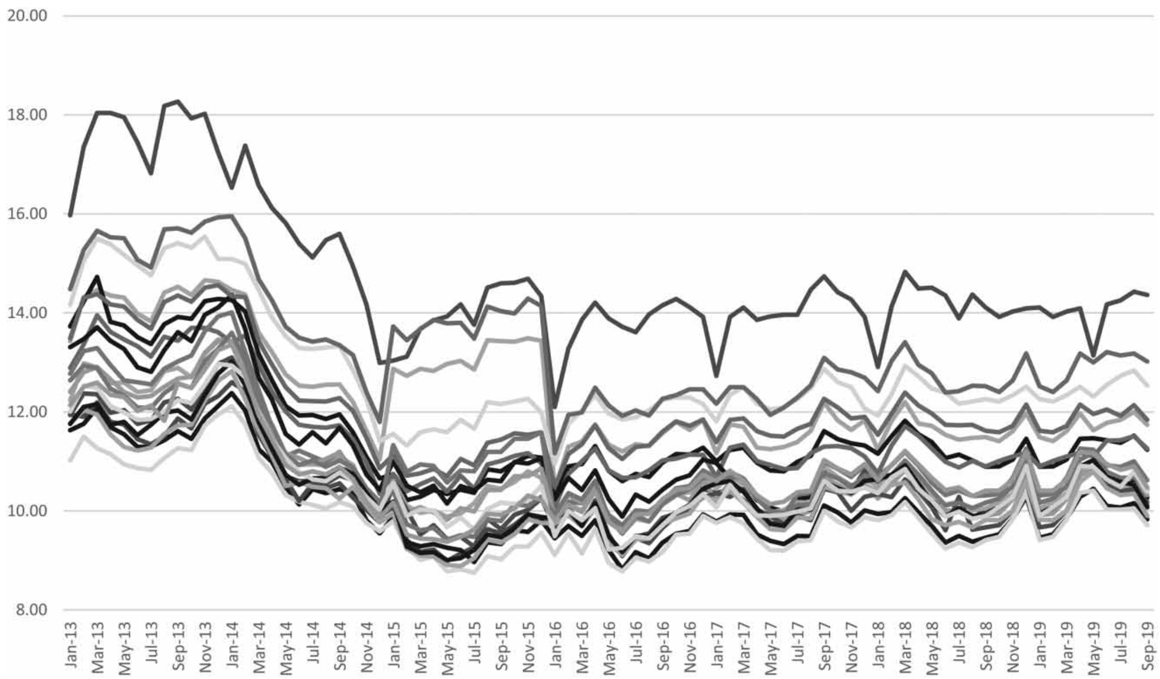


Fig. 2. | Average household consumption information per district (m^3).

showed consumption reduction, regardless of the origin of the water supply. Additionally, until September 2019, the consumption levels did not return to the threshold from before the water scarcity period. We highlight that consumption averages sometimes may not be representative, hiding affordability situations, nevertheless, it does not impact the overall information and our analysis.

The database used for the HLM3 analysis has 1,701 observations. Our dependent variable varied from 8.75 to 18.27 m^3/household/month. The mean water consumption was 13.166 m^3 for the period before the drought, 10.978 m^3 during the drought, and 10.853 m^3 after the drought (Figure 3).

First, by the HLM3 model (results shown in Table 4), one may infer that the variable corresponding to the period (linear trend) with fixed effects is statistically significant at the significance level of 5% (Sig. $z = 0.000 < 0.05$),

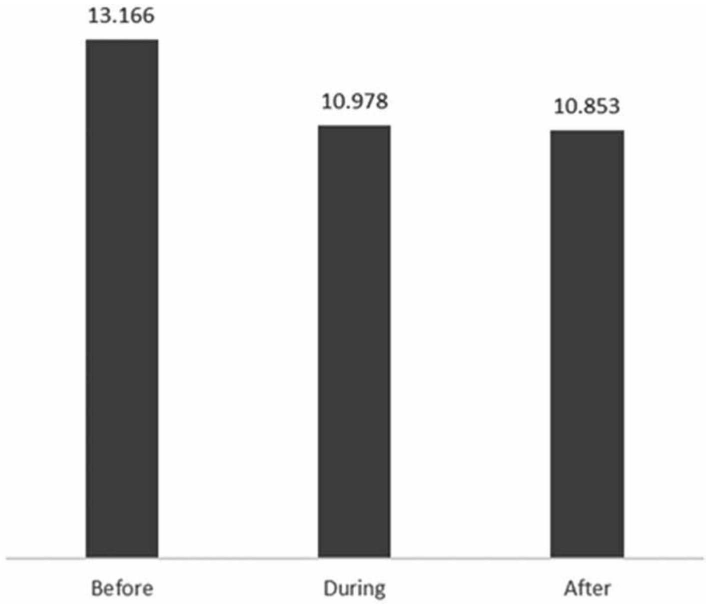


Fig. 3. | Average household consumption information per period (before, during, and after the drought; m^3).

which demonstrates that water consumption differs depending on the water scarcity context. Such findings indicate that the scarcity situation is a factor that may have affected consumption behaviour, both in the reduction and use of innovative alternative solutions. Regarding the random effects, from the results (estimates column), we estimate that reservoir and district random effects represent approximately 85% of the total variance of the residuals, with the variance among districts being stronger than the variance among reservoirs.

Table 4. | HLM3 model.

				Wald χ^2 (1) = 69.77		
Log-restricted likelihood = −1,855.741				**Prob.>χ^2 = 0.0000**		
Consumption	**Coef.**	**SE**	***z***	***P*>|*z*|**	**95% CI**	
Period	−0.97603	0.1168479	−8.35	0.000	−1.205048	0.7470125
_cons	13.5107	0.687623	19.65	0.000	12.16298	14.85841
Random-effect parameters	**Estimate**	**SE**			**95% CI**	
dspring: independent						
var(period)	0.0368189	0.0405703			0.0042476	0.3191533
var(_cons)	1.174906	1.395802			0.1144895	12.05704
iddistrict: independent						
var(period)	0.0183054	0.0094246			0.0066733	0.0502137
var(_cons)	1.59454	0.5518833			0.8091472	3.142268
var(Residual)	0.4746057	0.0165152			0.4433155	0.5081043
LR test vs. linear model: χ^2 (4) = 2,184.86			Prob. > χ^2 = 0.0000			

SE, standard error; CI, confidence interval.

These results show that even after the programme was over, the population did not return to the water consumption level from before the crisis, remaining on the threshold achieved. Such evidence indicates that the population, during the crisis, may have adopted new water consumption practices, reduced water demand for daily activities, and/or identified innovative solutions to fulfil their needs. One of these adaptations is the use of rainwater to clean floors, flush toilets, and water flowers (Wang *et al.*, 2019). Such adaptation was used in households in São Paulo, as well as the installation of water flow regulators on taps and showerheads, adjustments on toilet flows, recycling of rainwater, reusing water from washing machines, and storing water (Souza, 2015) actions voluntarily made by residents of the municipality.

Williams & Shepherd (2016) identified two types of approaches on how emergent organizations respond to suffering and build resilience to disasters: sustaining and transforming. Even though both approaches were able to address solutions for the situation studied by these authors (earthquake in Haiti in 2010), the latter was associated with greater self-reliance, while the former led to greater dependence. It is feasible to relate their findings to the Sabesp bonus and financial burden programme, and in this context, one may infer that the overall impact of the programme was changing people's behaviour and creating resilience for future possible drought periods, even though its first purpose was to overcome one specific environmental event.

For the analysis of the factors that influence water consumption in the MRSP using panel data, we first performed Wooldridge and Pesaran tests to verify the existence of a first-order serial correlation in terms of error and the correlation between cross-sections (Fávero & Belfiore, 2017). From the results (shown in Table 5), we confirmed the lack of first-order serial correlation in terms of error and the existence of heteroscedastic error terms (both at the significance level of 5%), indicating that the best model to conduct the panel analysis is the generalized least squares estimation with autoregressive effects of first-order AR (1) and heteroscedastic error terms.

The database has 1,458 observations for 18 districts of São Paulo, analysed for 81 months. Our dependent variable varied on the database from 8.75 to 15.95 m^3/household/month. The income variable varied from R$1,918.50 to R$8,581.57 (values of December 2019), and the percentage of women living in the districts varied from 35.82 to 58.53% (values of 2017).

Table 6 presents the results of the regression panel. From the results, we can infer that the implementation of the bonus by Sabesp was significant and that it negatively influenced water consumption (coefficient −0.195), while the financial burden was not statistically significant in shaping the water consumption of the inhabitants of the city of São Paulo.

Economic incentives impact intrinsic motivations, bringing engagement with the conservation of biodiversity and the ecosystem (Rode *et al.*, 2015). Such economic incentives are clearly important when developing new policies and strategies that seek to influence the behaviour of the population (Kollmuss & Agyeman, 2002). Even so, those authors point out that predicting people's behaviour based only on economic parameters does not allow the

Table 5. | Results for Wooldridge and Pesaran tests.

Wooldridge test	
$F(1, 17)$	235.726
Prob. $> F$	0.000
Pesaran test	
Pesaran test of cross-sectional independence	63.345, Pr 0.000
Average absolute value of the off-diagonal elements	0.596

Table 6. | Results from panel data.

Explanatory variables	Coef. (*p*-value)
Bonus	−0.195 (0.020)
Contingency tariff	−0.274 (0.248)
Cantareira reservoir system	−0.114 (0.000)
Income	0.0003 (0.000)
Women (%)	1.003 (0.000)
2014	−0.282 (0.150)
2015	0.165 (0.568)
2016	−0.754 (0.007)
2017	−0.931 (0.001)
2018	−1.061 (0.000)
2019	−1.400 (0.000)
February	0.134 (0.087)
March	0.140 (0.181)
April	−0.004 (0.975)
May	−0.303 (0.025)
June	−0.372 (0.009)
July	−0.333 (0.021)
August	−0.188 (0.190)
September	−0.188 (0.180)
October	−0.129 (0.339)
November	−0.081 (0.514)
December	−0.049 (0.639)
Constant	10.851 (0.000)
No. of observations	1,458

understanding of reality, since such factors are linked to social, infrastructure, and even psychological factors. Additionally, the same authors emphasize that the question of what shapes pro-environmental behaviour is such a complex one that it cannot be visualized through a single framework or diagram. Therefore, the combination of economic signalling with other noneconomic mechanisms is essential to create long-term changes in behaviour patterns (Magnusson, 2004), and the place, time, and other aspects must be also considered.

In other words, although these economic incentives were shown to be efficient in reducing consumption by households, there are other aspects that may be able to explain water consumption behaviour. As Liu *et al.* (2014) evidenced in their study in 47 cities in China, determinants of urban water use can be divided into two main classes: natural variables, e.g., rainfall, and socioeconomic variables, such as total population and water price. Specifically, the latter item has a complex impact on consumer behaviour, being positive or negative, depending on different scenarios, such as water scarcity. A considerable volume of knowledge about the price and income elasticities of residential water demand is available through a substantial number of empirical studies, but these estimated elasticities vary, and as Dalhuisen *et al.* (2003) note, such variation may result from differences in spatial and temporal dynamics, among other factors.

In the field of conservation psychology, efforts have been made to study the determinants of pro-ecological activities. For example, while punishment (i.e., fines) for excessive consumption also induces water conservation, in general, the more motives a person has for saving water, the more one conserves this resource, as Corral-Verdugo *et al.* (2003) determined after interviewing 510 inhabitants of two Mexican cities.

In addition to the importance of economic incentives in the MRSP, as well as the arguments brought from the literature, the use of such instruments may have an adverse effect. In São Paulo, the adoption of the bonus/onus programme, along with investments in infrastructure to reduce the number of people supplied by Cantareira, increased the unitary cost of water, while the unitary price (respective tariff) did not follow up in a timely manner (Pinto *et al.*, 2021). Additionally, the reward-based instrument implemented in São Paulo was expensive, as the instrument cost water utility, in payments to households, more than the added value resulting from the penalty-based instrument (Grover & Lucinda, 2020).

Measures regarding supply and demand must be taken simultaneously. For instance, governors could simultaneously apply tax stimuli for industries to produce and sell household appliances that consume less water and communicate this information to consumers, indicating the advantages of buying such products and creating labels to differentiate more efficient household appliances. At the same time, infrastructural investments are needed to diminish leak incidence and reduce the misuse of resources. Moreover, surveillance and the application of fines to anyone caught using potable water to wash sidewalks or cars (São Paulo is already an example within Brazil of this type of action to contain individual wastage behaviour, but it can be expanded even further, and this surveillance also should be extended to large rural and urban consumers), in extreme cases, may be needed. The success of these measures depends on political will, planning, and coordination in execution. In short, a series of continuous and integrated actions must be adopted to produce enduring results.

Regarding the reservoir used for supply, inhabitants supplied by the Cantareira system, the reservoir that was most dramatically affected in the dry season, showed a tendency to consume less water (coefficient −0.114), indicating that there may be an influence of the intensity of the water scarcity condition. On average, the consumption of inhabitants supplied by the Cantareira reservoir after the programme ended was 20% lower than before the programme, a greater drop compared to the average consumption of inhabitants supplied by other reservoirs, such as Guarapiranga (an average drop of 17%) or Alto Tietê (an average drop of 16%). These findings are compatible with the literature; in São Paulo, the consumption reduction was more meaningful in districts that used water originating from reservoirs under more critical conditions (Sousa & Fouto, 2019), and in Mallee, Australia, substantially more people from water scarcity locations were supportive of most water conservation behaviours (Gilbertson *et al.*, 2011).

In that sense, a construal level theory (CLT) can provide important inputs to understand this attitudinal process. Basically, the CLT links distance and abstraction; the more psychologically distant a given event is, the higher the levels of abstraction will be (Trope *et al.*, 2007). Thus, an event is somehow psychologically distant whenever it is not part of the direct experience of the here and now (Trope & Liberman, 2010). The authors call this psychological distance a phenomenon related to four dimensions: probability, social distance, time-lapse, and spatial distance. For this research, it is important to highlight these last two dimensions, because events in the distant past or future are more abstract and out of context, as well as those of greater spatial distance, and thus make the experience more abstract and out of context.

The relationship between psychological distance and construal levels is bidirectional; that is, individuals use mental constructions with a low level of abstraction to represent nearby events and mental constructions with a high level of abstraction to represent events that are distant and less concrete (Trope *et al.*, 2007). For instance, water use may decrease during droughts but then return again, and in periods with higher rain levels, people do not tend to save water (Magnusson, 2004). Similarly, Arbués *et al.* (2016) evaluated the attitudes of households towards water conservation in Spain and concluded that (i) there is a lower tendency to save water in wet areas, especially in small cities, (ii) dry areas tend to consume water more rationally, except for those with lower education levels, and (iii) the probability of saving water is lower in households with low-income levels.

Despite those findings in the literature, it is important to highlight that decision makers in a given country should not rely only on the findings of studies conducted in other countries in formulating their policies (Sebri, 2014). Similarly, most prior research on drought response effectiveness has focused on developed country contexts (Grover & Lucinda, 2020), which do not meet São Paulo contexts in many ways, such as the heterogeneity of population affordability, educational levels, and previous drought experience.

Finally, demographic variables can influence the pro-environmental behaviour of individuals. For example, in the literature, one may find evidence of different demographic factors that can influence attitudes and behaviours towards environment conservation, such as income, gender, and years of education (Kollmuss & Agyeman, 2002; Kideghesho *et al.*, 2007; Dolnicar *et al.*, 2012). Regarding the demographic variables, the results of our analysis indicate that women tend to consume more water than men (coefficient 1.003). In the present study, the estimated model showed that population income has also proven to be a significant factor in shaping water consumption, in line with Sousa & Fouto (2019) findings for the particular case of São Paulo; however, it has a lower impact than economic incentives, the reservoir used for the water supply, and gender. Despite the results from our model, it is important to highlight that in the MRSP, regions with higher income are those that have higher water consumption, which means there is a greater margin in reducing consumption since the inhabitants may use water for less essential activities (Sousa & Fouto, 2019), and that the characteristics of the tariff structure in the MRSP, where there is a block with a guaranteed volume of 10 m^3 which may promote over-consumption (Pinto *et al.*, 2021), may have influenced the results.

In the literature, 'information' is considered an important factor influencing consumption behaviour (Magnusson, 2004; Trumbo & O'Keefe, 2005). Even though 'information' was not a variable considered in the model, since there were no sufficient data to create such a variable, one may say that the population of São Paulo was continuously informed about both the status of the reservoir levels and pluviometry (Sabesp, 2019). Additionally, the regional media and other governmental organizations presented, during the programme period, information on this issue (Alesp, 2015). These facts may have helped in shaping water conservation behaviour; knowledge about water scarcity, acquired through public information, is important in shaping attitudes to reduce water consumption (Magnusson, 2004), heightened public awareness can result in behavioural changes, and both traditional news and social media are important for relaying information to the public (Quesnel & Ajami, 2017). Trumbo & O'Keefe (2005) outline their findings, pointing out that conservation promoters should recognize the power of information.

The overall findings presented in this study are in line with the literature. Not so recent studies have already pointed out the importance of environmental conditions on behaviour shaping. For instance, Hines *et al.* (1986), in a meta-analysis of 128 pro-environmental behaviour research studies, concluded that the following variables are usually associated with responsible pro-environmental behaviour: direct experience (direct experiences have a stronger influence on people's behaviour than indirect experiences), knowledge of issues (familiarity with the environmental problem and its causes, which can be understood as 'information' availability), and knowledge of action strategies (knowledge on how to act to lower the impact of the environmental problem).

Regarding water specifically, several studies have shown that there are other diverse factors influencing water conservation behaviour. The literature synthesizes three situations in which people engage in water conservation practices: (i) for saving that resource, (ii) for cooperating with a conservation campaign, or (iii) for paying less for the consumed resource (Corral-Verdugo, 2002; Corral-Verdugo *et al.*, 2003). Of course, this conclusion derives from the specific context studied by these authors and must not be generalized throughout the world, since particularities from each country or region may influence and shape the population's behaviour.

CONCLUSION

The increase in the number and duration of water shortage periods due to the consequences of global warming is a trend to be considered for any water system planning in Brazil over the upcoming decades. In this sense, examining the public policies adopted during the 2013–2015 water crisis and their midterm effects on water consumption behaviour, nevertheless having in mind its particularities, can provide policy instruments for more assertive and sustainable decision-making in the inevitable future droughts.

As shown throughout this paper, there was a significant reduction in water consumption in the MRSP, Brazil, subsequent to the 2013–2015 drought; almost 5 years after the worst moment of scarcity, the population did not return to its consumption threshold before the implementation of the bonus and financial burden. Evidence indicates that there was resilience built during the crisis in response to the water scarcity, which led to the adoption of new water consumption practices.

Although the economic incentives used were a successful instrument for shaping water consumption during the scarcity period, there were other factors that helped in building up new behaviour and, on average, in consuming less water than before the crisis. For example, income also behaved as a significant variable to discriminate means of water consumption after the water shortage period, since evidence showed that districts in higher income were more willing to reduce consumption.

Further research could be developed considering the consumption behaviour of large consumers in the MRSP to measure the effect of the implemented actions in reducing consumption or seeking alternative sources of water supply. Another possibility lies in the study of other geographies, non-Brazilian consumers, and cross-cultural particularities. In addition, future studies may be developed exploring the combination of economic signalling with other governmental noneconomic mechanisms to investigate long-term changes in behaviour patterns. For example, whether traditional news and social media to inform and increase public awareness can result in behavioural changes.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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