Water Policy 23 (2021) 327–342

Concentration of water use permit and volume-based fees in Ceará, Brazil

Francisco Wellington Ribeiro[a], Jackeline Lucas Souza[b], Raimundo Eduardo Silveira Fontenele[c] and Francisco Adelmo Medeiros Damasceno[d]

[a]Corresponding author. Graduate Program in Management and Controllership, Federal University of Ceará, Av. da Universidade, 2431, CEP 60020-180, Fortaleza, Ceará, Brazil. E-mail: fwribeiro@hotmail.com

[b]Department of Accounting, Federal University of Ceará, Av. da Universidade, 2431, CEP 60020-180, Fortaleza, Ceará, Brazil

[c]Department of Applied Economics and Graduate Program in Management and Controllership, Federal University of Ceará, Av. da Universidade, 2431, CEP 60020-180, Fortaleza, Ceará, Brazil

[d]Department of Hydraulic and Environmental Engineering, Federal University of Ceará, Rua Campus do Pici, s/n, Bl. 713, CEP 60440-900, Fortaleza, Ceará, Brazil

Abstract

This research aims to identify the level of concentration of the volume granted (the so-called permit) by grantee sectors in the State of Ceará, Brazil, as well as to simulate both the impact of the permit fees, and to conjecture about the permit concentration trend due to fee increase. The Gini index is calculated for all users with granted volume; next, fees are applied to the volume granted, observing the impact of charging to users; and lastly, the migration of irrigation users are conjectured based on the volume granted. The results indicate high Gini index for the supply, industry and irrigation; high impact on irrigation charge and low impacts on supply and industry; and concentration trend in irrigation due to elevated charges when the permit fee is applied. The authors conclude that the joint charging (consumption and permit) is relevant, as long as an effort is made by the basin committee to increase acceptance of a substantial fee increase.

Keywords: Charging; Gini index; Permit concentration; Permit fees; Permit granted; Volume granted

doi: 10.2166/wp.2021.169

Highlights

- Permit fees application.
- Gini index of volume-based permit to users.
- Conjecture about the permit concentration trend.

Introduction

The management of water resources implies a persistent search for equalization of demands by the various segments of society, considering its scarce character. Such a challenge is the responsibility not only of governmental authorities but also of a set of actors who participate in the water management process, such as users and of civil society, according to the proposal of the Water Law of 1997 in Brazil and several studies (Veiga & Magrini, 2013; Sousa Júnior *et al*., 2016; Libanio, 2018; Rey *et al*., 2019).

At the heart of water resources management, two instruments are among the main water policies, precisely because they are applied directly to users: the water use permitting and the elevated charges. The first one aims to ensure access to the different users, since water is considered a public domain property, and the second one intends to indicate a monetary value to the user, since water is also endowed with economic value (Braga *et al*., 2009; Hartmann, 2010; Fracalanza *et al*., 2013).

While the classification of water bodies represents a quality standard established to the whole society, the water plan is a diagnostic and forecasting document for scenarios, and the water information system serves as a subsidy to the water system. However, the relevance of these three instruments to an adequate management is also highlighted, noting, however, that they establish an indirect relationship with the users, compared to the relationship placed in the scope of permit grant and fee collection.

Considering the importance of permit for water management, it is recognized as pertinent to verify its distribution among users. In addition, given the greater application of this instrument, it is considered relevant to incorporate it as a variable, together with consumption, in the water fee charging policy, which is another important management tool that gains strength year after year. Since the objective is to regulate water access and use, the permit grant and fee collection assume greater importance in semi-arid regions, such as that in the State of Ceará, in northeastern Brazil. This state has rainfall that is low and poorly distributed in time and space, resulting in constant drought periods, in addition to the predominance of crystalline soils, resulting in low groundwater potential, making the state dependent on large reservoirs, which in turn, suffer from high evaporation. According to Kazemi *et al*. (2020), in these regions, scarcity affects economic, social, and environmental conditions, restricting the possibilities of allocating water and increasing conflicts. In view of the above, this research seeks to answer the following problems: What is the concentration degree of permit by users of water resources in Ceará? And what is the effect of applying the permit fee on the charging of users and, specifically in irrigation, on the level of the granted volume concentration?

Thus, the objective is to evaluate the concentration of the distribution of volumes granted and the effect of permit fees for water resources to users by sectors in the State of Ceará, starting from (i) the calculation of the Gini index for issuance of volume-based permit to users in each use sector, (ii) the simulation of the impact of permit fee for use sectors, and (iii) the conjecture of possible irrigating users clustering by granted volumes after charging a permit fee.

To support the proposed questions, some hypotheses are used. First, that different use sectors must have different levels of concentration of access (permitting) to water (Cullis & van Koppen, 2007; Liu *et al.*, 2019). Second, that increases in charging due to the incorporation of a new fee (in the case of this research, the permit fee) have different economic impacts to users (Aquino *et al.*, 2013; Oliveira *et al.*, 2017). Third, that more vulnerable sectors, such as irrigation, are more sensitive to increases in the cost of water (Frija *et al.*, 2011). Hence, it is reasonable to assume that sectors that have a higher concentration of permits and are more impacted by higher cost show a tendency towards a concentration of access to water.

Methodologically, the Gini index is calculated for all users with participation in the conceded volume (i.e., authorized or granted) in Ceará, considering permits in force in the year 2015 according to Water Resources State Company (COGERH, 2018) registration data. Next, fees (exogenous variable) are applied to the volume granted to the users (except in the fraction of the volume with fee exemption), verifying the impact of charging to users (as a consequence, also to COGERH revenue). Finally, the migration of irrigated agriculture users is conjectured based on the demand for volume granted, given that this sector combines two conditions, based on the research findings: high Gini index of granted volume and the great impact to users after the implementation of permit fee.

Permit and charging in water policy

Among the five instruments – basin plan, classification of water bodies, permitting, charging, and information system – foreseen in the National Water Resources Policy (PNRH), permitting consists of a mechanism of regulation, from the perspective of command and control instruments, useful for the disciplining of actors, both users and government, through the establishment of responsibilities and rights. According to Braga *et al.* (2009), permitting is an allocation instrument that aims to ensure the qualitative and quantitative control of water use, as well as the effective exercise of access rights. Permitting is conceived as an instrument of public regulation, compatible with the objectives socially established in the water plans, serving as a basis for the charging of fees (Braga *et al.*, 2009), as well as the implementation of mechanisms based on the water market, which depends on a rigorous concession control system (Jansouz *et al.*, 2017). However, the instrumental framework is a necessary condition for the development of good and adequate management of water resources but it is not a sufficient condition. The integration of such instruments constitutes one of the major challenges to the actors responsible in the management process (Braga *et al.*, 2009).

All these aspects make permitting a relevant and necessary instrument to the State, as a manager, as well as to the various user groups, making it quite frequently used in Brazil. Up until the year 2015 permitting was applied in 24 of the 27 Brazilian states, except in Amapá, Amazonas, and Mato Grosso do Sul (ANA, 2016).

With regard to water use charge, this is less common, occurring until 2015 in a few basins in Brazil, where, even after more than two decades as an established management instrument, there is little effective application, especially in the case of waters under state control, as shown in Table 1. Charging of a fee for water use, this management economic tool intends to mitigate the social cost, in an attempt to impute to the users an internalization of negative externalities, due to the use of common good. However, the promotion of more rational use of water is not the only object of the charging; other instruments should be considered, according to Berbel *et al.* (2019) and Rey *et al.* (2019).

In charging, two objectives may be expressed, one more noble, which consists in the induction to the more rational use, less spendthrift, and the other one consists in obtaining resources for management and investment (Aquino *et al.*, 2013), especially in the regions more in need like the semi-arid northeast.

Table 1. Beginning of the application of charges for the use of waters in state and interstate basins of Brazil.

State basins	Start year	Interstate basins (federative units)	Start year
Ceará	1996	Paraíba do Sul River (MG, RJ and SP)	2003
Rio de Janeiro	2004	Piracicaba, Capivari e Jundiaí Rivers (MG and SP)	2006
São Paulo	2007	São Francisco River (DF, GO, MG, BA, PE,AL and SE)	2010
Minas Gerais	2010	Doce River (MG e ES)	2011
Paraná	2013		
Paraíba	2015		

Source: ANA (2016).

Notes: Minas Gerais (MG), Rio de Janeiro (RJ), São Paulo (SP), Distrito Federal (DF), Goiás (GO), Bahia (BA), Pernambuco (PE), Alagoas (AL), Sergipe (SE) and Espírito Santo (ES).

Schuerhoff *et al*. (2013) point out the complexity of defining a policy that equalizes revenue realization and behavioral change, while revenue does not express a Ramseyian meaning. In this sense, in the case of Ceará, the charging model constitutes, above all, a financial instrument to recover management costs (operation and maintenance) of the water infrastructure necessary for the availability and distribution of water resources, which is compatible with the characteristics of the state, which can realize its water potential only through investment in storage and water transfer (Aquino *et al*., 2013). When considering only management costs in the charging practiced in Ceará, the resulting situation is a position that admits the cost of investment as a natural obligation of the government (Aquino *et al*., 2013), especially because it is a sector characterized by the existence of sunk costs.

In Brazil, the system of water fee charging, restricted to a few states and basins, is basically limited to cover management costs, neglecting the potential for rationalization of the system as well as the use of water conservation tools. The low fees currently charged generate, as a consequence, an inability to change user behavior in the Brazilian case (Libanio, 2018) and in other countries around the world (Frija *et al*., 2011; Berbel *et al*., 2019; Rey *et al*., 2019).

This complexity, associated with the permit and charging in water policy, inevitably involves an attempt to form a decentralized, participatory, and integrated management system with a significant number of participants, levels, and sectors in the processes of discussion and decision on water, in order to reduce the gap between policy concept and practice of management (Veiga & Magrini, 2013; Barbosa *et al*., 2016; Berbel *et al*., 2019). In this sense, basin committees come into play as legitimate institutions involving government, users, and civil society (Braga *et al*., 2009), while such institutions are responsible for the management of hydrographic basins, defined as planning units. Having laid out those more general aspects related to permitting and charging, a discussion on the water resources access, distribution, and conflicts is undertaken.

Water concentration and conflict

The conflict over the use of water becomes evident when demand is greater than availability, making explicit the water issue. In order to solve or mitigate this issue, proposals based on several management principles and mechanisms have emerged. With the Brazilian redemocratization in the 1980s, together with the pressure of popular movements for more transparency, responsibility, and participation, the construction of legal and institutional reform of water resources began, consolidated in the 1990s with the creation of state water councils and basin committees, giving deliberative powers to users and civil society in decision-making, from allocation to charging (Libanio, 2018). The main principles of the new national water policy, strongly influenced by the French legislation, are integration, decentralization, and participation (Veiga & Magrini, 2013), which aim to collectivize management and mitigate existing and potential conflicts.

This policy seeks to effect the decentralization of power and decisions, promote integration between different levels and sectors, and encourage the participation of different interest groups (Veiga & Magrini, 2013; Barbosa *et al.*, 2016; Berbel *et al.*, 2019). However, as Barbosa *et al.* (2016), Libanio (2018), Sousa Júnior *et al.* (2016), and Veiga & Magrini (2013) point out, despite the benefits of the Brazilian democratic water policy, there is evidence of gaps in the application of principles of integration, decentralization, and participation in the system. Despite the democratic directives of the water management system, in many cases the necessary demand management is verified and the type of water allocation can be characterized by increased conflicts and concentration of access.

As Cullis & van Koppen (2007) and Hartmann (2010) reason, efficient allocation often results in changes either in how the water is used or in the reallocation expressed at intra- or inter-sectoral levels, for example, from low- to high-value crops or agriculture for industry, respectively. However, as shown by Kazemi *et al.* (2020), the negotiated allocation (under the hydropolitical context) is a feasible practice in the conflict resolution process, with effective participation of users and civil society.

The guarantee of access to multiple uses, consolidated in the Water Law of 1997, aims to mitigate the conflict of access to water. Sousa Júnior *et al.* (2016) show that the market logic was preponderant in the country, with strong influence of the hydroelectric sector through the hydraulic operation of the reservoirs, losing hegemony with the effective adoption of multiple uses starting from the Water Law.

It is important to emphasize that in addition, to ensure multiple uses, it is fundamental, in this new scenario of democratic planning and management, to adopt a new strategy for integrated and participatory management, considering the conflicts of use and, mainly, the priorities for the use of water resources (Fracalanza *et al.*, 2013). These researchers also highlight the conflicts that arise between the multiple uses and the good results of applying the existing management tools to manage them, such as permit and charging. As an example of macro action, the policy of water transfer between basins is presented as a solution to the supply problem and is also identified as a source of conflict in the donor basin (Ioris, 2001; Rodrigues *et al.*, 2015), as well as causing an impact on water supply costs (Braga *et al.*, 2009; Sjöstrand *et al.*, 2019). Given the scarcity situation, the imbalance between supply and demand, multiple uses and users, and inadequate management practices, it is not difficult to predict the appearance of conflicts (Kazemi *et al.*, 2020).

Methodology

In the State of Ceará, located in the northeastern region of Brazil, the water resources charges have been billed monthly since 1996. The charging is defined by use sector and conceived as a binomial model (considering permit and consumption) by COGERH (according to State Decree n. 32,032, September 2, 2016). This model could already have the effect to avoid the speculation of water availability, that is, request of volume-based permit that will not be used. However, in COGERH's Fee Schedule, only the consumed volume is considered for charging purposes, and the authorized one is not considered, unlike the other charging cases in the country. This practice may compromise the proper use of water, allowing the adoption of speculative behavior in the request of permit by users.

It is true that there is a basic structure that is common to all charging models proposed and/or practiced in Brazil, considering the multiple uses of water and based on the volume used, on unit price (fee) and on specific coefficients (Vera *et al.*, 2017), while in Ceará the charging structure is different, since it considers only the consumed volume. However, in Ceará's charging, explicit fee charging discrimination occurs both in different use sectors, as well as in an intra-sectoral manner. This practice is important due to the notorious asymmetry in the ability to pay for water resources that exists in different sectors – the case of industry and sanitation – as well as among users of the same sector – the case of small and large irrigators, as suggested by Frija *et al*. (2011).

Ceará, with 1,117 concessions from August 2014 to July 2015, is the fifth in the country in terms of the number of water permits (ANA, 2016). This indicator, although absolute, may suggest that Ceará has an effective practice of water allocation management, through the granting of water use rights to users, and is among the states with the most frequent use of this management tool. This argument is reinforced in view of the fact that the other eight states of the northeast region have 2,505 permits for the same period (ANA, 2016).

Analysis procedures

To achieve the first specific objective, the Gini index of volume-based permit to users of water resources in the State of Ceará is calculated. The index is calculated among users of the same sector, making it possible to observe the level of concentration in each of the sectors with permit granted (irrigation, industry, human consumption, spring and potable water, aquaculture, animal water consumption, effluent dilution, tourism and leisure, and other uses). Various measures of concentration are developed in the literature in order to describe how the data of a variable are distributed within a set of individuals or elements, the Gini index being one of the most famous and frequently used, including by official institutions in Brazil and the world in order to measure inequality, for example, of income and land. Cullis & van Koppen (2007), Cole *et al*. (2018), Liu *et al*. (2019), and Kazemi *et al*. (2020) applied this index in studies of water access/use concentration in many places around the world, and these kinds of studies have not been found in any Brazilian context.

As Atkinson & Brandolini (2015) point out, the Gini index has at least two advantages: (i) to be affected by changes along the Lorenz curve due to the concavity of this in relation to the equidistribution line; (ii) to obey the Pigou–Dalton transfer principle, where the measure of concentration or inequality in a given variable increases when regression of that variable occurs, that is, transfer of an amount of the variable X from A to B, with B already having a greater amount of variable X compared to A (e.g., transfer of water from a small irrigator to a large irrigator). Mathematically, the Gini index calculation proposal, as applied to the issuance of raw water permits by use sectors in the State of Ceará is (Equation (1)):

$$G = 1 - \sum_{i=1}^{n} [(U_{i+1} - U_i).(Q_{i+1} + Q_i)] \tag{1}$$

where $G =$ Gini index of a use sector, $U_i = i$-th sector user, $Q_i =$ volume granted of i-th sector user, and $n =$ number of users. Remembering that the closest G is to 0, the more uniform the distribution of volume granted among users of a given sector is; whereas, the closest to 1, the highest the concentration.

The database comprises the registry of permits available on the COGERH's website (COGERH, 2018) (database obtained from the link http://outorgasvigentes.cogerh.com.br/paginaSemValidacao/outorgaVigente/outorgas_fh.xhtml or from the spreadsheets accessed from the COGERH website on 01/27/2018), taking the permits in force only in the year 2015. The registry contains data on each request of permit granted, concession period, user (which may have several permit requests), type of use sector, among other information. When necessary, said registry allows checking the sum of the various authorized volumes in the period to a single user, in order to associate the percentage distributions of users and volumes granted (Cullis & van Koppen, 2007).

Then, to evaluate the impact of the permit fee to users in Ceará and to COGERH's revenue, the fee of Paraíba is used. The reason is because Paraíba is the only northeastern state to charge a permit fee, and due to the lack of definition of this type of fee in Ceará and considering similarities between the two states, which are neighbors and part of the same region (Ceará implemented charging on consumption and Paraíba implemented charging on permit), as well as having similar socioeconomic and water infrastructure characteristics. The permit fee amount will be calculated based on the water volume granted to each sector in Ceará, and it is therefore possible to observe both the impact of charging to users and the impact to the granting agency's revenue. It is also worth noting that this evaluation is carried out only in sectors that are subject to charging (i.e., irrigation, industry, human consumption, spring and potable water, aquaculture and other uses).

Finally, conjectures are made of situations involving the impact of permit fee charges as related to the concentration trend, or not, of the volume granted to users. In the simulation, scenarios are included having to do with the price elasticities of water demand in irrigation ($\varepsilon = -0.50$, $\varepsilon = -0.20$, and $\varepsilon = -0.01$), based on a recent study in the northeast region (Silva *et al.*, 2015). Conjecture analysis is not undertaken in all sectors, but only in irrigation, because it combines two conditions observed in the research findings: high Gini index of the volume granted and great impact incurred by the permit fee charge.

Results and discussion

Concentration of permit between users

The number of permits issued constitutes an indicator of the better spreaded access to water done legally and under the principle of good management, at least in theory. In fact, ideally, the more different water resources management instruments (permitting, charging, classification, plan and information system) are used, the better. Also important, as Braga *et al.* (2009) point out, is the articulation between the various management instruments, providing complementarities and synergies. The high frequency of permit issuance in Ceará, in comparative terms in Brazil, justifies the charging of fees based on volume granted, considering the policy already in place of permit issuance and the already established application of fees per consumed volume. But more than the number of permits issued by the system, it is important to know how it is distributed among users in each use sector, so that there is some measure of the water use rights concentration.

From the data presented in Table 2, it can be seen that the supply, irrigation, and industry sectors represent 88% of the volume granted. These sectors are among those with the highest demand for

Table 2. Distribution and concentration level of volume granted by use sector in the State of Ceará in 2015.

Use sector	Volume of permit in force[a]		Number of users[a]		Gini index
	(m^3/year)	(%)	(count)	(%)	
Irrigation	522,593,917	33.0	1,491	43.0	0.914
Industry	195,446,211	12.3	494	14.3	0.961
Human consumption	680,904,123	42.9	629	18.1	0.988
Spring and drinking water	2,233,293	0.1	113	3.3	0.577
Aquaculture	39,766,783	2.5	87	2.5	0.690
Animal water consumption	2,207,001	0.1	219	6.3	0.886
Dilution of effluents	62,830,886	4.0	21	0.6	0.833
Tourism and leisure	3,412,694	0.2	61	1.8	0.887
Other uses	76,620,772	4.8	351	10.1	0.978
Total	1,586,015,680	100.0	3,466	100.0	–

Notes: [a]Based on COGERH (2018).

water in Ceará, as well as in the country (ANA, 2016). It should be remembered that human consumption has priority of use in a situation of scarcity.

Of the total number of permits issued, the irrigation sector is the most significant and distributed one. The great asymmetry in the distribution of water between such diverse sectors is expected, with emphasis on irrigation, given the traditional nature of the activity, and human consumption, given its essential and overriding nature. However, the inter-sectoral comparative distribution does not show the degree of intra-sectoral concentration, which is demonstrated by the calculation of the Gini index for each sector.

As far as human consumption, the Ceará Water and Sewage Company (CAGECE) is the largest user of raw water in the sector, accounting for more than 83% of the volume granted. In addition, CAGECE serves the vast majority of Ceará's municipalities, including the capital Fortaleza, thus, providing a structure that allows this agency to achieve economies of scale (Sjöstrand *et al.*, 2019). Therefore, a high concentration in this particular sector is expected, especially when there is a state supply company. It is common for supply sectors to appear as monopolists (Schuerhoff *et al.*, 2013). Without CAGECE, the Gini index would be 0.939, also high due to the large number of community associations (173) and individuals with use permits of less than 1,000 m^3/year.

In industry, on the other hand, the high level of concentration is due to the strong participation of three companies, accounting for about half of the volume granted in the sector, which operate in the steel (Pecém Steel Company (CSP)), power plant (MPX), and oil (PETROBRÁS) industries, with water permit volumes representing 24, 13, and 10%, respectively. In urban and industrial supply sectors, as Cullis & van Koppen (2007) argue, one can expect that there will be greater concentration due to the performance of some large users, such as water supply companies and large industries. This can be verified in Ceará, as demonstrated by the calculation of the Gini index, with the participation of large users such as CAGECE and the CSP, MPX, and PETROBRAS industries. In the other uses category, a single user – State Secretariat for Infrastructure (SEINFRA) – holds more than 85% of the volume granted, causing the concentration to be quite high. Removing this atypical user, the Gini would fall to 0.867, leaving three users with almost half of the use permit in this scenario, still resulting in high concentration in the sector.

In irrigation, the high concentration is mitigated by the fact that the three largest users, who hold 30% of the volume granted, comprise irrigated perimeters, i.e, a set of public or private irrigators. In this way, the large volume of permits directed to a perimeter actually serves several agricultural producers.

Without data from these three perimeters, Gini would be 0.881, showing a decrease of 4%, since the next six largest users own 23% of the water use permit.

In a study on water use concentration in South Africa, Cullis & van Koppen (2007) calculated Gini indices at 0.96 (non-urban industry), 0.89 (urban industry), 0.88 (water supply), 0.81 (irrigation), and 0.79 (aquaculture). Liu *et al*. (2019), in a region of China, calculated coefficients equivalent to 0.10 (related to domestic use and population) and 0.27 (related to industrial use and production). Cole *et al*. (2018), also in South Africa, calculated values equal to 0.36 (access to piped water at home) and 0.27 (per capita water use in the city), while Kazemi *et al*. (2020), in Iran, calculated Gini values equal to 0.10 and 0.40, in a water allocation scenario considering existing and under construction water infrastructure and in a scenario with incorporation of future infrastructure, respectively.

A greater dispersion of access to water is a characteristic of a democratic management system, which effectively guarantees multiple uses and access to various users (Braga *et al*., 2009), especially when a sector is composed of users with fairly asymmetric profiles. In this case, the permit, besides constituting an instrument that seeks to guarantee democratic access (non-concentrated), should also work, according to Fracalanza *et al*. (2013), as a mechanism for conflict mitigation. In Ceará, the permitting policy does not seem to result in a less concentrated distribution of the right of access to water, at least in what can be seen from the calculated Gini, especially in industry and irrigation, in view of the special sectors human consumption and other uses, CAGECE and SEINFRA, respectively.

The permit, in principle, should represent a close panorama of the level of actual consumption of water by users, except for the consumption portion considered insignificant by legislation and therefore exempt from permit. Based on this assumption, the largest portion is reserved to human consumption, according to the data presented. However, in general terms, irrigated agriculture is always considered as the most significant use category in terms of volume consumed (ANA, 2016). However, according to COGERH's data, billed raw water use in the human consumption sector accounted for around 62% of the total, while irrigation consumption was 27% in 2015 (SRH, 2017). It should be noted there is a possible distortion between billed and consumed volumes, due to deficiencies, such as the lack of micro-measurement, in the billing system. According to these percentages, a greater share of billed consumption (62%) is seen in the human consumption in comparison to the portion of volume granted (43%) throughout the state; the opposite occurs in irrigation, having a smaller participation in the fraction of billed volume (27%) and a larger fraction (33%) in the granted volume (see Table 2). It is noteworthy that the year 2015 represents the fourth consecutive year of drought (rains below historical average) in the State of Ceará, which probably results in rationing to productive sectors, given that human consumption has priority.

As a result, those sectors with greater participation in the volume of permits and in the number of users were also those that presented higher Gini coefficients, that is, they were shown to be more concentrated in terms of use permit rights. In those sectors, the Pigou–Dalton effect (Atkinson & Brandolini, 2015) tends to manifest itself more explicitly, as in the case of human consumption, with CAGECE assuming increasingly concessions to municipal water treatment services, and in the industry, with the inauguration of the CSP steel and the MPX power plant in Pecém. This regressive effect has great potential also in the irrigation sector, especially as suggested by Hartmann (2010) and Jansouz *et al*. (2017), when facing multi-annual periods of drought, where scarcity justifies, in the name of efficient use, the reallocation of water from small to large producers, in theory, more efficient in the use of water.

Application and impact of the permit fee

In Ceará, there only exists charging of the fee and the consumption volume; there is no permit fee, despite charging for both components (consumption and permit) being in the state's plans. Thus, here the application of the permit fee is simulated based on what is done in the state of Paraíba (see justification in subsection Analysis procedures), as well as the impact of this charge to use sectors in Ceará, as shown in Table 3. As a consequence, from the charges on permit and billed consumption, the impact of applying the permit fee in each user sector can be measured, obtaining a greater impact in the irrigating sector (195.3%). The impact on COGERH's revenues is equivalent to 16.4%. Adding or changing of components in existing or proposed charging models can certainly increase the amount to be charged to use sectors. Oliveira *et al.* (2017) simulated an impact of 64% to almost 500% on the sanitation sector in the Rio Doce Basin (Minas Gerais and Espírito Santo), by increasing the charging model in force with effluent release parameters. Aquino *et al.* (2013) simulated the application of fees for investment recovering in water infrastructure in water charge in Ceará, with impacts varying from 6% to 17% (industry), from 86% to 226% (supply), and from 770% to 2,465% (irrigation). These studies demonstrate that the application of the permit component on the charging of use sectors in the State of Ceará is plausible, with impact on cost to users with water varying from 8% to 195%.

However, the impact is not only to use sectors, but also to COGERH's revenue, in which case the simulation expresses an increase of 16%. This percentage can be considered low, since the significant impact rests upon irrigation, other uses, and aquaculture; however, these sectors have a reduced participation in the total company charge (less than 6%). On the contrary, the impact on COGERH's revenues can be perceived as significant since the company receives higher revenues without incurring costs. In 2015, the company's operation and maintenance (O&M) cost was R$ 95,313,000 (US$ 28,622,523) higher than the company's R$ 90,502,000 (US$ 27,177,778) revenue (SRH, 2017). In the case of charging on consumption and permit, for the same year, the amount billed becomes R$ 105,369,000

Table 3. Consumption charge and impact of the permit fee in the State of Ceará in 2015.

User sector	Consumption charge[a]		Permit fee[b]		Impact[c]
	R$ (US$)	(%)	R$ (US$)	(%)	(%)
Irrigation	1,337,744 (401,725)	1.5	2,612,970 (784,676)	17.6	195.3
Industry	36,683,369 (11,016,027)	40.5	2,931,693 (880,388)	19.7	8.0
Human consumption	51,457,831 (15,452,802)	56.9	8,170,849 (2,453,708)	55.0	15.9
Spring and drinking water	159,873 (48,010)	0.2	33,499 (10,060)	0.2	21.0
Aquaculture	282,801 (84,925)	0.3	198,834 (59,710)	1.3	70.3
Other uses[d]	580,394 (174,292)	0.6	919,449 (276,111)	6.2	158.4
Total	90,502,013 (27,177,782)	100.0	14,867,295 (4,464,653)	100.0	16.4

Notes: R$ = Real; US$ = American Dollar. Average dollar price in 2015: US$ 1,00 = R$ 3,33.
[a]Based on SRH (2017). [b]Figures are obtained from the volume of permit in force (Table 2) and the permit fee values from Paraíba. According to the Decree 33,613 of December 14, 2012, from the State Government of Paraíba (values of permit fees per 1,000 m^3): irrigation, other agricultural uses, intensive fish farming, shrimp farming and agroindustry = R$ 5.00 (US$ 1.50); public supply, trade and discharge of sewage and other effluents = R$ 12.00 (US$ 3.60); industry = R$ 15.00 (US$ 4.50).
[c]Impact is permit fee divided by consumption charge.
[d]The trade permit fee applies.

(US$ 31,642,342), now being higher than the cost of O&M by more than ten million (10%). Obviously this result occurs in the condition *ceteris paribus* or demand perfectly inelastic. However, with evidence of inelastic behavior in relation to the demand for water (Féres *et al*., 2012; Silva *et al*., 2015; Sun *et al*., 2018), an increase in the company's revenue is expected, even if there is an increase in user charges.

Hence, the existence of the political cost in the charging model reformulation is not negligible, since it incorporates the permit fee, especially for the most affected sectors (Hartmann, 2010). Even if the charging is reasonably accepted, this issue should be discussed with users. On the acceptance of the charging, Féres *et al*. (2012) verified an acceptance of only 49% in the industry and Vera *et al*. (2017) find an acceptance of more than 91% for all use sectors, even with the perception that the resources raised are not adequately invested in actions in the basin. Thus, it should be emphasized that the implementation of the permit component, already established in Ceará's conception model, but not yet implemented, should be preceded by the wide acceptance in the basin committees and, especially, of water users who will pay higher fees. It is essential to legitimize and accept the review process of the current charging model in the state.

Moreover, the permit fee charging, together with the consumption fee, can contribute to a better match between the granted volume application and their actual needs, avoiding the accumulation without effectiveness of the use right, i.e., what can be called speculation of the water availability. This speculation problem can be found in other countries, such as the USA, according to Rodrigues *et al*. (2015). From this perspective, it is necessary to consider the permit component in the charging, without which the water resources system may have its availability conditioned by virtual scarcity due to water speculation. Due to water scarcity, as Hartmann (2010) suggests, the formulation that considers both consumption and permit have positive effects precisely because it does not encourage waste in consumption and encourages appropriateness in the permits' request by the users. In this way, a more rational use of water is sought in order to avoid the shortage of supply, both real scarcity, through wasteful consumption, and virtual scarcity, through speculation by permit.

Hence, charging in this format can provide at least three benefits to the water resources system:

1. penalize water speculation through an indiscriminate permit application, which generates virtual shortage of water;
2. to induce, to some extent, the less wasteful use of water, due to the higher cost incurred with the permit;
3. generate more revenue for the water management company, without causing a cost increase in supply.

Conjectures on movements of demand for permit

In the research findings, the irrigation and other uses are those that present a combination of high Gini index of the volume granted and greater impact on the charging due to the charging of permit fee. Considering only irrigation, since it is a better defined sector, and considering a certain increase in the value of water use charge, it is possible to conjecture two situations: a decrease in the number of users, especially the group with less capacity of payment (more sensitive to the elevation of water costs), or even a reduction of the volumes consumed and granted by this segment of users.

In the first situation, the Gini index may decline, as it decreases the user base with the lowest volumes granted, if they leave the sector, or may increase if they only reduce the volume granted to the level close to or equal to the exemption level (the water resources policy in Ceará allows for fee exemption for users with a demand lower than 17,280 m^3/year). In any case, there is the effect of generating non-voluntary unemployment in the irrigated agriculture activity, that is, these users abandon the sector or reduce production because they cannot absorb the impact of charging. Frija *et al.* (2011) identify the possibility of a negative effect of increased charging on the sector's economy, with a reduction in the occupation and performance of the agricultural activity. These researchers also suggest that this effect may even result in the switch from irrigated crops to dry crops. Berbel *et al.* (2019) suggest that the increased charging may lead to a concentration on water reallocation, while Rey *et al.* (2019) point out that one of the unintended consequences of water charges is an income decrease in agriculture. In the second situation, the Gini index in irrigation increases, due to the concentration of greater granted volumes to users of greater capacity to pay for water use, that is, less sensitive to the increase in water costs. Frija *et al.* (2011) identify that smaller irrigators are more sensitive to water cost increases, as compared to large producers of the sector.

Irrigated agriculture has a high opportunity cost of water, not having alternative sources, still suffering from high systemic risks inherent in the activity (dry spells, flood). Due to the peculiarities regarding the opportunity cost and the associated risks, an increase in the charging can entail a greater concentration of access to the waters. The case of irrigation is notorious, as Frija *et al.* (2011), Berbel *et al.* (2019), and Rey *et al.* (2019) point out, being one of the most vulnerable sectors, benefiting from public subsidies that result in reduced water fees. According to Schuerhoff *et al.* (2013), irrigators also enjoy political influence among decision-makers, often even resulting in exemption.

The behavior of water demand is often described as a function of elasticity. The price elasticity of water demand is intrinsically related to the ability to pay for water use. In general, in the face of increased water cost, it is expected that the user with the greater (or lower) payment capacity will be less (or more) sensitive to rising costs, presenting an inelastic (or elastic) behavior.

Taking irrigated agriculture as an example, studies on the theme also point to inelastic behavior. Silva *et al.* (2015) estimate coefficients between −0.552 and −0.017, covering 11 irrigated perimeters in the São Francisco basin (states of Pernambuco and Bahia) and Sun *et al.* (2018) calculate values between −0.58 and −0.48 for Chinese irrigators. Generally, the demand for water is inelastic, particularly due to the reduced price of water in proportional terms when it comes to cost to users (Frija *et al.*, 2011; Féres *et al.*, 2012; Sun *et al.*, 2018). There is evidence that only by exceeding a moderate level of charging is it that user behavior becomes less inelastic, i.e., with more significant reductions in consumption (Frija *et al.*, 2011). In fact, there is evidence that use sectors present inelastic behavior regarding water charges, both those with high payment capacity (e.g., industry) and reduced capacity (e.g., irrigators), and also occurring in the intra-sectoral level, such as between large and small irrigators, that is, less and more sensitive to the elevation of water costs, respectively.

However, it is important to conjecture about the effect on the concentration degree of permit, since the charging, as a function of two components (consumption and permit), makes the cost of water more expensive, since users who are more sensitive to changes in costs are those with less capacity to pay and, consequently, suffer greater impact due to increased charging.

By focusing the analysis on the irrigating sector, considering different values of elasticity, based on average coefficients found in the literature, and based on the practice of fee discrimination for different volume intervals established in the State of Ceará (State Decree n. 31,734, dated May 28, 2015), establishes the following consumption fees, according to the type of water collection:

1. irrigation in public perimeters or private irrigation with collection in water springs without COGERH's discharge line: R$ 1.18/1,000 m^3 (US$ 0.35/1,000 m^3), with consumption of 17,280–227,999 m^3/year, and R$ 3,54/1,000 m^3 (US$ 1.06/1,000 m^3), with consumption from 228,000 m^3/year;
2. irrigation in public perimeters or private irrigation with collection in water structure with COGERH's discharge line: R$ 9,87/1,000 m^3 (US$ 2.96/1,000 m^3), with consumption of 17,280–563,999 m^3/year, and R$ 15,79/1,000 m^3 (US$ 4.74/1,000 m^3), with consumption starting at 564,000 m^3/year.

According to these values, the following three situations can be conjectured:

1. $\varepsilon = -0.50$, if $17{,}280 \leq$ volume granted $< 228{,}000$ m^3/year;
2. $\varepsilon = -0.20$, if $228{,}000 \leq$ volume granted $< 564{,}000$ m^3/year;
3. $\varepsilon = -0.01$, if volume granted $\geq 564{,}000$ m^3/year.

In scenario (a), the first interval of the volume granted refers to the lowest fee (R$ 1.18/1,000 m^3) and the first volume interval consumed (17,280–227,999 m^3/year) considered by COGERH for charging purposes. In scenario (b), the second interval refers to non-extreme fees (R$ 3.54 and R$ 9.87/1,000 m^3) associated with the intermediate consumption interval (228,000–563,999 m^3/year). Finally, in (3) it has the highest fee (R$ 15.79/1,000 m^3) related to the higher consumption (≥564,000 m^3/year).

The different elasticities are associated with the different volume bands granted (similar to the COGERH consumption intervals), in view of the fact that irrigation users with lower consumption are characterized as the smallest producers, having lower capacity to pay, that is, these are the most sensitive to the water cost, tending to less inelastic behavior (Frija *et al.*, 2011). Thus, it is not considered an average value of elasticity in the analysis, but rather values differentiated in relation to the demanded volume and the fees practiced. By applying the different elasticities to the respective volume ranges, assuming the volume of exemption (<17,280 m^3/year) established in Ceará and obtaining the new volumes granted, a new Gini index is recalculated resulting in 0.944 (greater than 0.914 before simulating the new charging). It should be noted that the new irrigation volume, due to the permit fee, is reduced by approximately 11% (from 522,593,917 to 466,133,588 m^3/year).

Therefore, it is possible that there is a permit concentration in the irrigation sector, expressed by a higher Gini index. Considering the inelastic behaviors, a portion of the users reduces their volume of permit to the exemption level, raising the user base with low volumes. In addition, these users are more impacted, more sensitive to the increase in water cost, presenting less inelastic behavior (e.g., −0.50) in relation to those inserted in the larger consumption interval, with a more inelastic behavior (e.g., −0.01), that is, with ε closer to zero. This concentration trend is also credible for other uses, due to the high impacts with the new simulated charging (see Table 3). In the sectors with the lowest impact, it is possible to conjecture that there is no significant movement in concentration degree, due to the low impact, the reduced water cost in the total cost, to the higher payment capacity of these sectors and to the characteristic inelastic behavior (Féres *et al.*, 2012).

The industry, in general, has a low opportunity water cost, with great possibilities of alternative sources (reuse), is not characterized as water-intensive and presents low systemic risk, while the human consumption is water-intensive, being a final good, and is the priority sector in access under scarce conditions. The spring and drinking water resembles household consumption, with the advantage of operating free-market prices. Thus, based on the stated characteristics of the opportunity cost and the vulnerability of risks, a great chance of little change in behavior regarding the application of higher charging value resulting from the permit fee is expected, that is, a greater capacity of absorption of the higher cost, as it does not imply strongly increase or decrease in the volume distribution of intra-sectoral permit.

Conclusion

The management of water resources requires the use, interactive and complementary, of instruments designed within the legal landmark. Among the various instruments, the permit and charging are peculiar because they are applied directly to users. The study showed that the Gini index is high for the main users of the State of Ceará (human consumption, industry, and irrigation) and that the fee charging has a greater impact on irrigation, with a reduced impact on human consumption and industry.

The high Gini index in irrigation and the significant impact of the permit charges to the sector users suggest a favorable environment to increase the concentration of permits against an increase of the charging. This is exactly what can be verified in this study, in which the Gini index goes from 0.914 (charging on consumption) to 0.944 (charging on consumption and permit), with a reduction of 11% in volume granted. This movement is due to the volume reduction to the exemption level established in Ceará ($<$17,280 m^3/year), increasing the user base with lower volumes. In this way, the fulfillment of the objectives proposed in the research are perceived as significant (to verify the concentration degree of permit, to simulate the impact of the permit fee charge, and to conjecture about the concentration trend effect of volume granted, specifically in the irrigation sector), in particular for raising the discussion about access to water permit and volume-based fees.

The Gini index is useful as a descriptive measure of the inequality levels of water access, and can contribute to delineate the distribution form of the permit between users and subsequent establishment of water redirection policies among users of typically asymmetric sectors, such as irrigation. And, as a political mechanism, the permit fee charge (together with the consumption fee) can generate little impact on some use sectors with greater capacity to pay for water use (e.g., industry and human consumption) and relevant impact on vulnerable sectors (e.g., irrigation).

The economic and political implications are many, causing water policy managers in Ceará to have some important issues in the agenda for discussion, some of them being the high concentration of permit in key sectors, the imminent consideration of the permit component in the water charges, and the effects of access to water permitting after the fee is applied to the volume granted. Presented here, as advancement propositions to overcome the limitations of this study, are the use of comparative concentration measures, the comparison between the concentration of permits against the concentration of actual user consumption, and field surveys with a sample of users in order to construct demand functions for water use permit and to obtain the different price elasticities, intra- and inter-sectoral.

Data availability statement

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

References

ANA (2016). *Conjuntura dos Recursos Hídricos: Informe 2016 (Water Resources: 2016 Report)*. Available at: http://www3.snirh.gov.br/portal/snirh/centrais-de-conteudos/conjuntura-dos-recursos-hidricos/informe-conjuntura-2016.pdf (accessed 7 March 2018).

Aquino, T. S. A., Gomes, C. C., Souza Filho, F. A. & Silva, S. M. O. (2013). Impacto da recuperação dos investimentos na infraestrutura hídrica na cobrança pelo uso da água (Impact of recovery of investments in water infrastructure in water use billing). *Brazilian Journal of Water Resources 8*(1), 87–98.

Atkinson, A. B. & Brandolini, A. (2015). Unveiling the ethics behind inequality measurement: Dalton's contribution to economics. *The Economic Journal 125*(583), 209–234.

Barbosa, M. C., Mushtaq, S. & Alam, K. (2016). Rationalising water policy and the institutional and water governance arrangements in Sao Paulo, Brazil. *Water Policy 18*(6), 1353–1366.

Berbel, J., Borrego-Marin, M. M., Exposito, A., Giannoccaro, G., Montilla-Lopez, N. M. & Roseta-Palma, C. (2019). Analysis of irrigation water tariffs and taxes in Europe. *Water Policy 21*(4), 806–825.

Braga, B. P. F., Flecha, R., Thomas, P., Cardoso, W. & Coelho, A. C. (2009). Integrated water resources management in a federative country: the case of Brazil. *International Journal of Water Resources Development 25*(4), 611–628.

COGERH (2018). *Outorgas concedidas e vigentes (Permits Granted and in Force)*. Available at: http://outorgasvigentes.cogerh.com.br/paginaSemValidacao/outorgaVigente/outorgas_fh.xhtml (accessed 27 January 2018).

Cole, M. J., Bailey, R. M., Cullis, J. D. S. & New, M. G. (2018). Spatial inequality in water access and water use in South Africa. *Water Policy 20*(1), 37–52.

Cullis, J. & van Koppen, B. (2007). *Applying the Gini Coefficient to Measure Inequality of Water use in the Olifants River Water Management Area,* South Africa. IWMI Research Report 113. International Water Management Institute, Colombo, Sri Lanka.

Féres, J., Reynaud, A. & Thomas, A. (2012). Water reuse in Brazilian manufacturing firms. *Applied Economics 44*(11), 1417–1427.

Fracalanza, A. P., Jacob, A. M. & Eça, R. F. (2013). Environmental justice and water resources governance practices: re-introducing issues of equality to the agenda. *Ambiente & Sociedade 16*(1), 19–38.

Frija, A., Wossink, A., Buysse, J., Speelman, S. & van Huylenbroeck, G. (2011). Irrigation pricing policies and its impact on agricultural inputs demand in Tunisia: a DEA-based methodology. *Journal of Environmental Management 92*(9), 2109–2118.

Hartmann, P. (2010). *A cobrança pelo uso da água como instrumento econômico na política ambiental (The Charge for the use of Water as an Economic Instrument in Environmental Policy)*. AEBA, Porto Alegre, Brazil.

Ioris, A. A. R. (2001). Water resources development in the São Francisco River Basin (Brazil): conflicts and management perspectives. *Water International 26*(1), 24–39.

Jansouz, P., Shahraki, J. & Abdolhosseini, M. (2017). Is water trading policy an effective solution for water allocation in Voshmgir dam? *Water Policy 19*(6), 1119–1142.

Kazemi, M., Bozorg-Haddad, O., Fallah-Mehdipour, E. & Loáiciga, H. A. (2020). Inter-basin hydropolitics for optimal water resources allocation. *Environmental Monitoring and Assessment 192*(478), 1–10.

Libanio, P. A. C. (2018). Two decades of Brazil's participatory model for water resources management: from enthusiasm to frustration. *Water International 43*(4), 494–511.

Liu, Y., Zhang, Z. & Zhang, F. (2019). Challenges for water security and sustainable socio-economic development: a case study of industrial, domestic water use and pollution management in Shandong, China. *Water 11*(8), 1630.

Oliveira, A. R. M., Borges, A. C., Matos, A. T., Silva, D. D. & Pruski, F. F. (2017). Alternative mechanisms of charging for use of water resources in wastewater assimilation. *Brazilian Journal of Water Resources 22*(3), 1–10.

Rey, D., Pérez-Blanco, C. D., Escriva-Bou, A., Girard, C. & Veldkamp, T. I. E. (2019). Role of economic instruments in water allocation reform: lessons from Europe. *International Journal of Water Resources Development 35*(2), 206–239.

Rodrigues, D. B. B., Gupta, H. V., Serrat-Capdevila, A., Oliveira, P. T. S., Mendiondo, E. M., Maddock III., T. & Mahmoud, M. (2015). Contrasting American and Brazilian systems for water allocation and transfers. *Journal of Water Resources Planning and Management 141*(7), 1–11.

Schuerhoff, M., Weikard, H. -P. & Zetland, D. (2013). The life and death of Dutch groundwater tax. *Water Policy 15*(6), 1064–1077.

Silva, G. N. S., Figueiredo, L. E. N. & Moraes, M. M. G. A. (2015). Curvas de demanda pelos recursos hídricos dos principais usos consuntivos no submédio da bacia do rio São Francisco (Demand curves for water resources of the main water users in sub-middle São Francisco basin). *Revista Brasileira de Ciências Ambientais* (36), 45–59.

Sjöstrand, K., Lindhe, A., Söderqvist, T. & Rosén, L. (2019). Cost-benefit analysis for supporting intermunicipal decisions on drinking water supply. *Journal of Water Resources Planning and Management 145*(12), 1–12.

Sousa Júnior, W., Baldwin, C., Camkin, J., Fidelman, P., Silva, O., Neto, S. & Smith, T. F. (2016). Water: drought, crisis and governance in Australia and Brazil. *Water 8*(11), 493.

SRH (2017). *Consolidação da Fase I – Atualização da matriz tarifária (Consolidation of Phase I – Updating the tariff)*. Relatório 04. SRH, Fortaleza, Brazil.

Sun, T., Huang, Q. & Wang, J. (2018). Estimation of irrigation water demand and economic returns of water in Zhangye basin. *Water* *10*(1), 19.

Veiga, L. B. E. & Magrini, A. (2013). The Brazilian water resources management policy: fifteen years of success and challenges. *Water Resources Management 27*(7), 2287–2302.

Vera, L. H. A., Montenegro, S. M. G. L. & Silva, S. R. (2017). Performance of water usage charge in the Nation's domain as a water resource management tool in the São Francisco River basin. *Brazilian Journal of Water Resources 22*(7), 1–12.

Received 9 August 2020; accepted in revised form 12 January 2021. Available online 24 February 2021