



Turbulent waters in Northeast Brazil: A typology of water governance-related conflicts

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ABSTRACT

In this paper we build a water conflict typology and discuss some applications for water resources planning and management. To show how a typology was built we highlight twelve well documented water conflicts historical cases in the semiarid region of Ceará state and water conflicts collectively identified by river basin committee members in four water resources river basin plans. To show how the typology works we applied it to contemporary cases of water conflicts headlined in the national media. Conflicts are separated into component characteristics such as triggers, actors, length, coverage area, mediation arena, and other useful information. As the complexity of social-environmental issues increases new tools for organizing data into useful information increase in demand. We believe that this water conflict typology can be employed as an analytical instrument capable of providing a "bird's-eye view" of diffuse sources of conflict.

1. Introduction

How does one manage conflicts from a disperse set of data provided by impacted actors? Since we currently lack a systematic overview of water-related conflicts and since our knowledge is to a large extent sporadic and case-based, it is difficult to assess the possible causes of conflicts and their characteristics. Given that "water management, by definition, is conflict management" (Wolf, 2008) we need an analytical instrument capable of providing a "bird's-eye view" of diffuse sources of water conflict that can help us formulate policy, legislation, and other regulatory frameworks, all of which form a core part of water governance.

Conflict is as old as mankind, arising when individuals or groups hold divergent interests and values (De Waal, 2000). The study of social conflicts dates back to the sociology of the XIX Century and, since then, different approaches of analyses have been developed. The functionalist theory presents society as ordered and balanced and conflict as an element of social dysfunction. However, thinkers such as Marx, Weber, Elias and Simmel have argued against this view, rejecting the link between conflict and pathological behavior (Collins and Sanderson, 2015). Simmel explicitly discussed the concept of conflict as a form of

sociability (Birnbaum, 1995), an idea extended both by Gluckman (1964), in his concept of conflict and social cohesion, and by Van Velsen (1964) when he discusses the role of conflict as a regulating mechanism of social relationships in stateless societies. The common element between these different perspectives is the role of conflict in social regulation. Water management relies on a perspective analogous to Simmel's view on conflict, and resolving competing interests over water uses has become a hegemonic dimension of water resource management (Grigg, 1996).

Given their complex nature, the best way to study conflicts is to categorize them into types (Von Der Dunk et al., 2011). If one correctly identifies the type of conflict and organize these into a typology, then one can predict the "actors, goals, perceptions, recruitments, structures, and other key political features involved" (Frey, 1993). Another central advantages of typologies is that they bridge the breadth vs. depth dilemma exposed by Basurto and Ostrom (2009) in their critique of the "sui generis" and the "panacea" analytical traps. They build a typology to understand the socio-ecological system of inshore fisheries, forests, irrigation systems, and pastures, and what are the factors that lead communities to successful self-organization. Although they utilize four categories (users, governance system, resource system, and resource

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units) and thirteen subcategories (with “conflict” being one of them) to illustrate how the characteristics of each governance system leads to sustainability or not, they do not emphasize the centrality of conflict in socio-ecological dynamics.

There are other attempts in the literature to classify types of conflicts. Guetzkow and Gyr (1954) divide conflict into two types (substantive and affective), while Hoban (2001), on public and private domains. These works emphasize the need to classify the complex dimension of conflict, but do not offer a typology.

In other words, despite an increased interest in recent decades on the subjects of *water conflict*, *water conflict management*, and *conflict typologies*, we found little support for typologies of water-related conflicts in the academic literature. A search on the Web of Science database revealed that *water conflict* appeared in 865 article titles in the last five years. An identical search on the same aforementioned database revealed 45 papers with *conflict typology* on article titles for the same period. Repeating the search for article titles containing *water conflict typology*, zero articles were found. After removing the five-year restriction, Web of Science database returned only one specific reference.

However, we did find *water conflict typologies* focusing on warfare and terrorism, on water related crimes, and on urban water supply and sanitation in literature. Gleick and Heberger (2014), for example, built a three-category typology – (i) trigger, (ii) weapon, and (iii) causality – to sum up the nature of water conflicts at the scale geopolitical. Concerning water related crimes, Kim and Swain (2017) also use a three-category typology classifies water crimes on the basis of (i) water resources mismanagement; (ii) corruption associated with private appropriation of public water resources for paid delivery of water services; and, (iii) terrorism, associated with the deliberate targeting of water infrastructure and systems. Finally, with regards to water supply and sanitation, Vlachos (2003) argued the need to develop new conflict management approaches to complex problems of water scarcity. Although he highlights the use of typologies as a promising start for analyzing water conflicts in a number of specific dimensions (engineering, ecological, methodological, management, perceptual and cultural) he does not provide a discussion on how to build a workable typology.

Despite the lack of academic interest in building typologies, attempts have been made outside academia to build accurate typologies. To build our own typology we have researched two water conflict typologies related to governance issues – developed in the 1980’s for the semi-arid Northeast Brazil (NEB). The first is the Integrated Exploitation Plan of Northeast Water Resources (PLIRHINE) (SUDENE, 1980), developed by the Superintendence of Northeast Development (SUDENE), and the second is the Water Resource State Plan, a.k.a. the ‘Plano Zero’ (Ceará, 1983) of the State of Ceará.

PLIRHINE defined conflict as “a situation of non-compliance with requirements and/or demands of society inherent to the use and/or control of water resources.” The plan showed that conflicts have a characteristic water deficit element, classifying them in three categories: (i) conflicts in small ponds, (ii) conflicts in small and medium dams, and (iii) conflicts in large dams.

Plano Zero was a landmark in water management in Ceará State and became the basis for what was to be the Water Resource State Policy, in the same year. According to the plan, the source of conflict stemmed from the need different users have to withdraw, utilize, consume, and release from a limited water resource. The plan grouped water conflicts into two types: (i) water withdrawal conflicts; and (ii) water use conflicts. The plan highlighted the importance of disperse small reservoirs in rural zones and establishes the types of conflicts according to various types of water use during the 1979–1983 drought period. Despite the pioneering nature of these two plans, no comprehensive water conflict typology associated with governance is currently available.

The goal of this paper is to build a water conflict typology related to governance, to provide a systemic and structured view of water conflicts in Northeast Brazil. Gathering information on historical water conflicts in Ceará was a primary condition for this research and, in this case, one

of the difficulties in building a typology was working with a fragmented and diffuse conflict database. However, the creation of a database on water conflict in the state is not the ultimate goal for building a typology. It is only an intermediate element, important in generating information. The transformation of data into information is given by synthesis and by the critical analysis of the data. Typology is, therefore, the last stage of this work.

2. Material and methods

To build our typology we used an interactive method, which relied on a reciprocal information feeding process that can be divided in three stages: (1) data collection; (2) critical analysis of water conflicts database; and (3) types and subtypes categorizations. In the data collection stage, we found a number of water conflict cases formally documented in Ceará and read each document in detail. Since some of these conflicts had happened more than a century ago, we decided to include contemporary water conflicts by adding those collectively identified by river basin committees’ (RBC) members in 2010. These new conflict types were important to fill our typology. In the critical analysis stage, we identified triggers, actors, and other essential characteristics of each conflict and created the water conflict typology by classifying these dimensions into types and subtypes.

In possession of a typology grounded on historical conflicts and participatory plans, we applied it to other contemporary water conflicts. This was done as a way to test the typology’s adherence. We selected a few cases found in the media that occurred throughout the 2012–2018 drought in Northeast Brazil.

The items below describe the study area, the data collection and methods used to construct the typology, and how the *types* were determined.

2.1. Study area

The Northeast Brazil (NEB) is the most densely populated semi-arid region in the world (Marengo et al., 2017), characterized by high interannual and seasonal variability in precipitation, high evaporation rates, and shallow soils. Located in NEB, Ceará State (Fig. 1) holds more than 90% of its territory in semi-arid area. Such characteristics make the State remarkably vulnerable to droughts.

Drought has various definitions, and these are closely related to an observer’s perspective. In NEB, a ‘social drought’ means both climatic variation and economic vulnerability. For a population composed of landless sharecroppers, drought represents the collapse of agricultural production; and this collapse means hunger (Furtado, 1998).

Droughts have been reported in NEB since Portuguese colonization (Campos, 2015; Marengo et al., 2018). The 1877–1879 drought produced catastrophic economic damages and was devastating for the vulnerable population in NEB, with human deaths estimated around 500,000–1,000,000 persons (Davis, 2001). In the beginning of the 20th century, a series of drought events in 1915, 1919–20 and 1931–32 resulted on construction of ‘concentration camps’ to house famine refugees (Kenny, 2009). Since then, other significant drought events occurred in 1942, 1951–53, 1958, 1982–83, 1993–94, and, more recently a long lasting-drought 2012–2018 (Pontes Filho et al., 2020).

Since the 1877–1879 drought, the debate for solutions for recurrent water shortages gained traction in Brazil. The inflexion point was surely in October 1909 with the creation of Brazil’s federal drought work agency (IOCS/IFOCS), now called National Department for Works against Droughts (DNOCS), which started to construct hundreds of dams in NEB.

In this ‘hydraulic phase’ (1877–1958), drought relief policies mainly focused on the construction of a hydraulic infrastructure and the implantation of agricultural posts to induce irrigation in NEB. Other solutions were proposed at that time to cope with droughts such as water transfer from São Francisco River Basin and creation of work fronts to

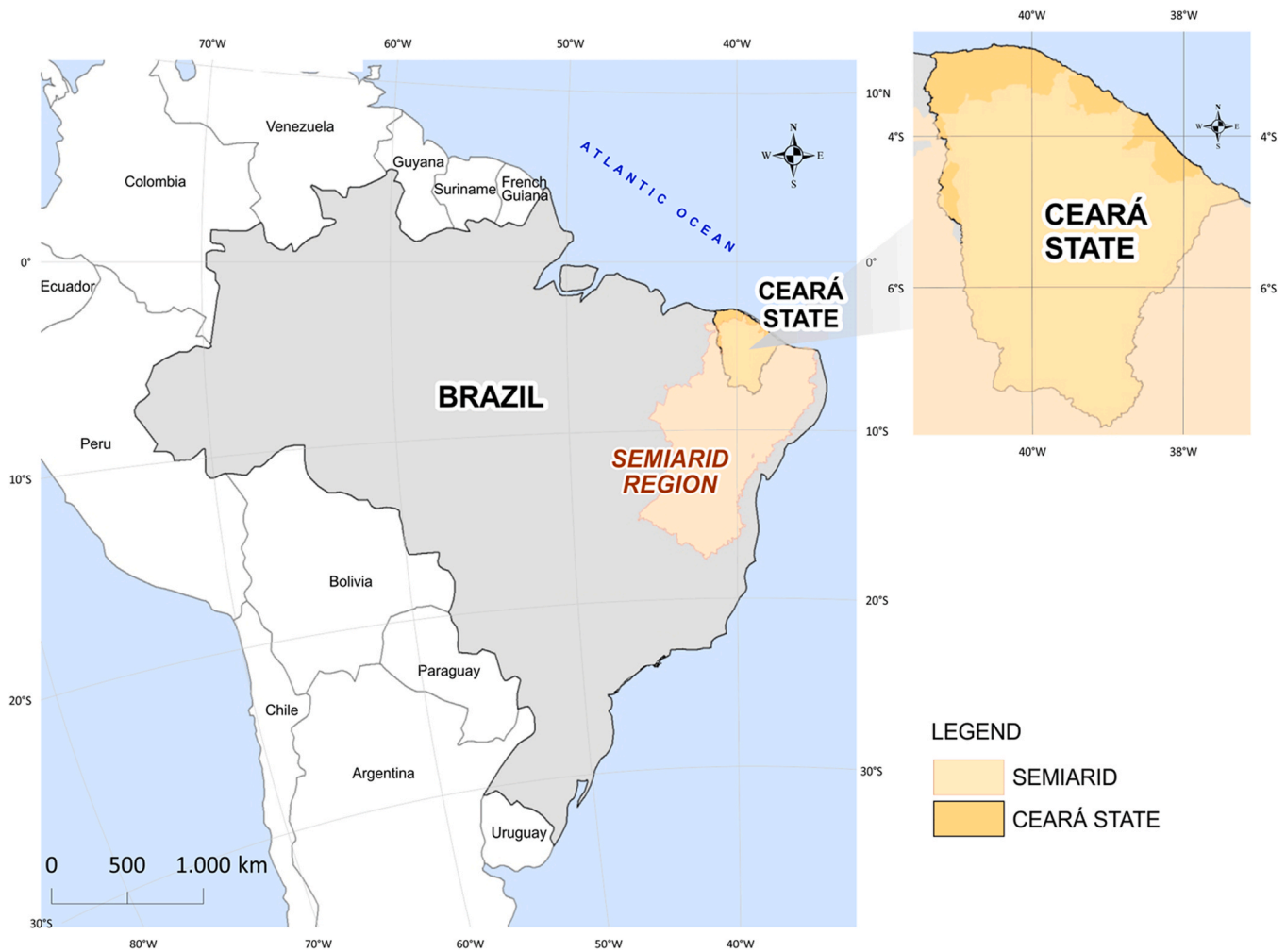


Fig. 1. Location of Ceará State and the Brazilian Semi-arid Region.

build roads and dams (Campos and Studart, 2008). Many proposals did not even have adaptive value; they were in fact primarily political, with the single objective of enjoying public funds (the so-called ‘drought industry’).

The water policy in NEB was essentially conducted by DNOCS, whose primary mission at the time was to protect the region against drought. This political-institutional context was heavily modified from 1992 onward, in the broader context of water sector reforms in Brazil, with the implementation of the Water Resources Management System at the state level. Currently, water security in Ceará State is coordinated by an integrated water resource management policy, and is grounded on three pillars: demand management, supply management, and conflict management.

2.2. Data collection

There are three sources of water conflicts: i) the historical documented conflicts; ii) the contemporary conflicts pointed by RBCs’ members; and iii) the media cases during the 2012–2018 drought.

The historical conflict ‘case studies’ were selected in consultation with local water management stakeholders, who decided which water conflicts processes (judicial and administrative) were relevant and well-documented in Ceará. Lawsuits were searched at the archives of State Water and Sanitation Company (CAGECE), National Foundation of Health Services (FNS), State Water Resources Management Agency (COGERH); State Water Resources Secretariat (SRH) and State Agency of Hydraulic Works (SOHIDRA).

The contemporary conflicts were those identified during participatory water resources basin plans, in Acaraú, Coreaú, Litoral and Metropolitan river basins in 2010 (SRH-Ce, 2010a, 2010b, 2010c, 2010d). Participatory methodologies have recently become widespread in Brazil, as well as the idea of public participation in water resources management. During the elaboration of these plans, the RBC members debated the basins’ problems in their perception, related to four thematic axes: ‘conflict’, ‘environmental issues’, ‘water balance’ and ‘institutional barrier’. The conflicts pointed out are not ‘case studies’, but existent and potential conflicts in their basin from their own perspective.

We also collected contemporary conflicts covered by national and local media in the period between 2012 and 2018. This period was one of the worst drought episodes ever recorded in Northeast Brazil and, consequently, potentialized conflict over water resources. These media conflicts were not used to construct the typology, but to evaluate its performance.

2.3. Water conflict database

The three aforementioned sources of water conflicts are presented below and are synthesized in [Supplementary Material \(Appendix A\)](#).

2.3.1. Historical cases

The historically selected case studies are well-documented and detail how water management problems evolved, how they were addressed, and how they were resolved. Fig. 2 shows the spatial distribution of the

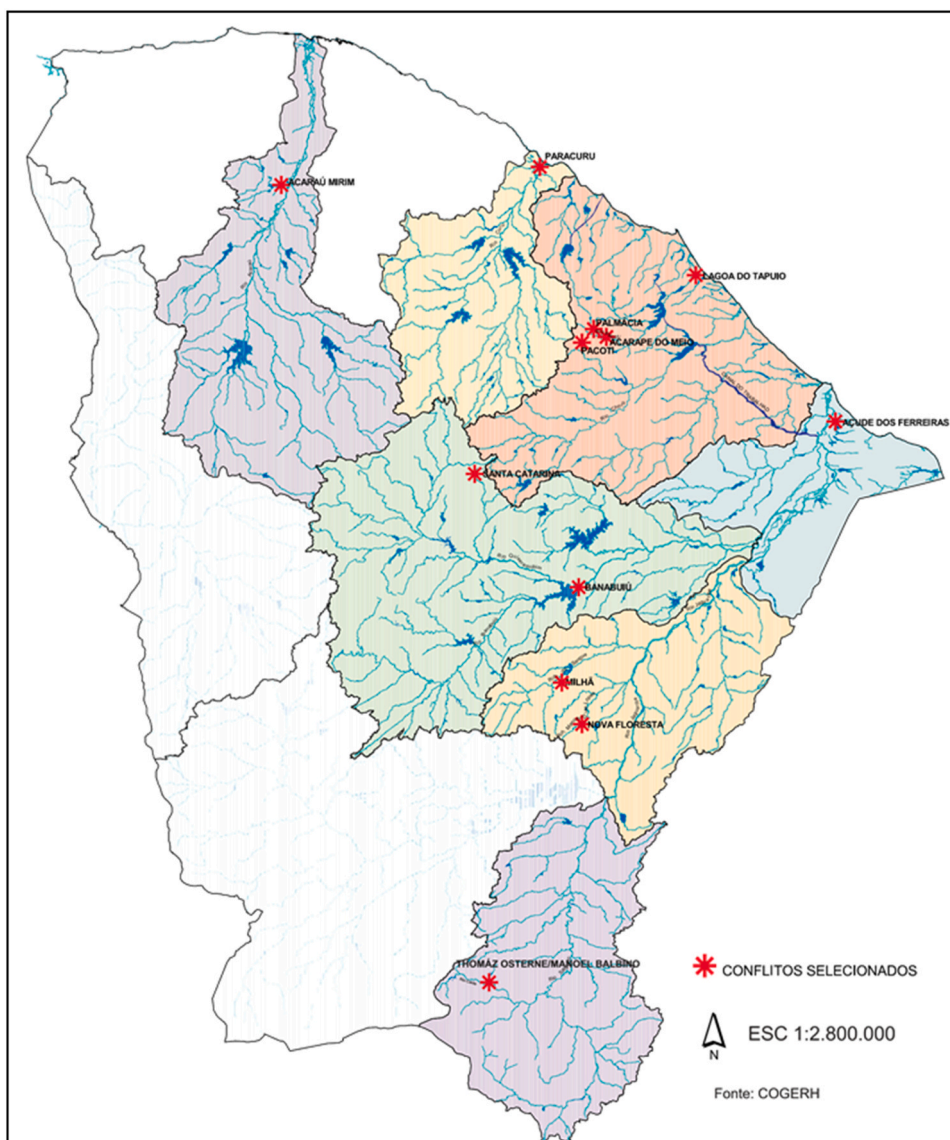


Fig. 2. Spatial distribution of selected historical water conflict in Ceará State.



Fig. 3. Participatory planning at Water Resources River Basins Plans – Acaraú, Coreaú, Litoral and Metropolitan in 2010.

selected historical water conflicts in the state of Ceará.

2.3.2. Conflicts perceived by river basin committees' members

Analyzing the four participatory water resources basin plans (SRH-Ce, 2010a, 2010b, 2010c, 2010d), we found that conflicts perceived by RBC members were of the same type, regardless of basin. These water conflicts were related to access to water, water quantity, water quality, water allocation, and governance. Fig. 3 shows RBC members debating, describing, and recording conflicts in these meetings to build consensus over which conflicts existed and which conflicts were potential in the river basin.

Conflicts related to access to water were described, all of which referred to fences that obstructed the access to bodies of water. The conflicts of water quantity were those related dams that obstruct water flow, water withdrawal without permits along the river, or water thefts in water pipelines. The water quality conflicts highlighted were those related to pollution due to fertilizer and pesticides application by reservoir riparian irrigators, irregular disposal of sanitation companies' sewage, mining of granite in springs area, presence of temporary bathrooms during Carnival and car washing in the reservoir margins, the presence of cattle and swine in reservoir hydraulic basin, irregular occupation in the reservoir area, the presence of fish cages in the reservoirs, the shrimp farming activity frequently associated with serious negative social and environmental impacts; and deforestation. The lack of water quality monitoring appears with great frequency. Conflicts of water allocation were also perceived by members of committees, when they mentioned issues related to transbasin diversion which generate conflicts among water uses and water users. Governance conflicts are common in the river basins according to the RBCs and have a great emphasis on the lacking articulation between environmental and water management institutions, between water management institutions, low level of interest of water users in participating in RBC meetings, and lack of autonomy of RBC and power struggles.

2.3.3. Water conflicts in media

Water conflicts have occupied the local and national media, mainly due to the prolonged 2012–2018 drought. We selected conflicts which were noticed in media, trying to cover different types of conflicts.

The 12 historical conflicts and media conflicts are summarized in Table 1. The trigger, actors, start date and end date of the historical ones are highlighted in text. As mentioned before these conflicts were pointed out by RBC members and are not part of the 'case studies' – they are based on the perspective assessment of committee members regarding existent and potential conflicts in their basin. These conflicts are not described in the table.

2.4. Building a water conflict typology

The first step, when building a typology, is determining the essential elements, and identifying the types as they appeared in the historical conflicts analyzed. We have detected five essential elements that will be detailed below. These are: Conflict trigger, Actors involved in conflict, Length of the conflict, Scale of conflict and Conflict arena.

2.4.1. Conflict triggers

To move beyond the strict quantitative water provision and access to water points of view we built a typology that accounts for water resource distribution by looking at other triggers of contemporary conflicts. There are other significant number of cases that trigger water conflicts related to Water Quality, Water Allocation, and Water Governance.

2.4.2. Actors involved in conflict

In our definition, the conflicting actors are the parties directly involved in the conflict – the *claimant/plaintiff* (who make a formal charge in judicial or administrative arenas) and the *defendants*, i.e., the accused of damages.

Table 1
Conflicts Cases: Sequence of Events.

Historical Conflict Cases Case (Start/End Dates)	Description
Pacoti (11/1909–12/1909)	In November 1909, the irrigator F.A.M. O filed a lawsuit against B. F. The defendant built a masonry dam which diverted water from the riverbed to his factory. F.A.M.O's sugarcane fields perished from lack of irrigation. The case was ruled in favor of B.F. on December 17, 1909.
Acarape do Meio (07/1925–12/1993)	In 1924 IFOCS concluded the Acarape do Meio Dam to supply water to Fortaleza. In 1925, IFOCS issued a delivery term obliging the state to release water from the dam to downstream irrigators. In July 1925 State Law N°2.348 was issued creating fee-based irrigation in Ceará causing these irrigators to file a lawsuit against Ceará state's water supply system. In May 1928 the Supreme Court ruled in their favor but the conflict reemerged in 1939 when the State Government decided to send water to Fortaleza by building a new pipeline in the reservoir. In 1993 a term was signed between the parties involved ratifying the irrigators' right to use the waters of the Acarape do Meio Dam free of charge.
Lagoa do Tapuio (04/1999 – 09/2002)	In April 1995, the Community Association of Lagoa do Tapuio filed an administrative proceeding to SRH against CAGECE for improper use of indigenous reserve water. A pipeline was being built to capture water from the lagoon because the Municipality of Pindoretama was supplied by contaminated subterranean water. In February 1996, the SRH evaluated that the construction of Malcozinhado Dam would be the definitive solution to supply water to Pindoretama and in May 1996 the SRH granted a temporary license to CAGECE to construct the pipeline. A temporary permit for water use was granted while the studies and construction would be carried out; the conflict ended in 2002 when Malcozinhado Dam was completed.
Palmácia (06/1980–12/1997)	In June 1980, the owners of a private property in Palmácia filed a lawsuit against CAGECE, for financial compensation. They claimed that the company has setup a hydraulic infrastructure to capture water from springs located in their property without any financial compensation. In December 1997 the parts reached a settlement that granted CAGECE the right to withdraw water, free of charge, for an indeterminate period of time from that date. The plaintiffs were strictly prohibited from disposing or selling the 0,94 ha of land where water captures were made. unless an alternative water source for customers was found.
Thomaz Osterne/ Manuel Balbino dams (09/1995–06/2007)	In September 1995, irrigators from the Thomaz Osterne and Manuel Balbino dams reported to DNOCS that private dams were being built upstream on I. B.'s, A.B.'s and F. A.'s properties. In October 1995, COGERH, SOHIDRA and DNOCS made an agreement to open gates on the masonry dams and to demolish the earth ones. However, in 1998, complaints filled to the Juazeiro do Norte Council requested a new technical inspection by COGERH; in 1999 the Judge handling the

(continued on next page)

Table 1 (continued)

	<p>case requested the same. In 2000, COGERH contacts EMATERCE to help carry out another survey with RBC representatives. In 2001 the Ceará Office of the Prosecutor General asks COGERH to ensure that the cited dams be opened. In 2007, COGERH requests the participation of the Brazilian Institute of Renewable Natural Resources (IBAMA) to enforce the order, since SRH and COGERH are not law enforcement agencies and, therefore, can only “warn” perpetrators or “request”. In June 2007, about 4 km of the Carás stream is cleared from dams.</p>
Milhã (10/1995–04/1996)	<p>In October 1995, the water company of Milhã (Water and Sewage Autonomous Services – SAAE) requested SRH’s authorization to supply water to the city of Milhã, using water from the private reservoir of Jatobá, located in G.G.M.’s private property. G.G.M. refuses to allow the use of water without receiving a cash payment in return. A settlement was achieved on the grounds of Agreement No. 67/95 SRH / SAAE where the SRH commits to a compensation of R \$20,000.00 to G.G.M.</p>
<p>Case (Start / End Dates) Santa Catarina (11/1996–05/1999)</p>	<p>Description In November 1996, irrigators signed a petition informing SRH that the waters released by the Santa Catarina public reservoir in Quixeramobim district only benefited J. A. Carneiro’s property. COGERH is sent to inspect the region and issues a technical report confirming the existence of a dam obstructing the flow of water to downstream communities. In 1998, the local public prosecutor files a class action in court against the SRH requesting the removal of dams and in May 1999 the SRH executes the injunction.</p>
Açude dos Ferreiras (06/1997–02/2000)	<p>In June 1997, the communities of Lagoa dos Porcos and Ferreira petitioned SRH to take immediate action against F. S. C. S, who fenced the Ferreira public dam, blocking the community’s free access to the water. In February 2000, the defendant refused to appear at the meeting set by Ceará’s Office of Inspector General and a Term of Agreement was signed demanding that the fenced area be removed.</p>
Paracuru (09/1997–02/2002)	<p>In 1997, J. M. R’s estate filed a lawsuit against CAGECE demanding the payment for water pumped on Lagoa Grande, in his private property. On February 2002 there was a hearing for a settlement regarding the value of compensation for the expropriation of the physical area occupied by CAGECE.</p>
Acaráú – Mirim (06/1998–11/2000)	<p>In June 1998, the irrigators of the lower Acaráú – Mirim, complained about several irregular dams on the properties of J. A. N. and R. N. T. M. impeding the natural flow of the water to downstream users. In October 1999, these dams were demolished. However, in 2000, the injunction was disobeyed by one of the dam’s owners when he began building a new dam on his property. To substantiate the necessary legal measures, a new technical inspection by representatives from COGERH, DNOCS and a Department of Justice was required. This dam was removed on November 22, 2000.</p>

Table 1 (continued)

Nova Floresta (06/1999–10/2001)	<p>In June 1999, the management commission of Nova Floresta’s reservoir informed COGERH that the local upstream community would not release water to the downstream irrigators due the low reservoir storage. The issue is taken to the Water State Council (CONERH) and a decision is made in favor of water release because it was still above the critical level. In defiance, the local upstream community decided to close the reservoir’s gate by damaging the hydromechanical structure. In October 2001, the Prosecutor’s Office was ready to enforce CONERH’s decisions, but the reservoir’s water levels reached the critical level, suddenly acquiring a legal status as a result of the 2001 dry season. In this particular case, drought resolved the issue.</p>
Banabuiú (09/2001–12/2001)	<p>In September 2001, the public water company of Morada Nova (SAAE) and the Banabuiú RBC asked the local prosecutor to prohibit irregular water withdrawal by irrigators along the Banabuiú river, upstream Morada Nova caption, jeopardizing the city’s water supply. In December 2001, the judge ruled that all equipment used for irregular withdrawals should be seized.</p>
<p>Contemporary Media Cases Headline “São Francisco River divides interests and accentuates conflicts” (Gaspar, 2016)</p>	<p>Description of the Case The São Francisco water transfer project was a contentious project in NEB, finding resistance from the São Francisco RBC. Under the Ministry of the Environment (MMA), it was approved in 2007 by the National Council of Water Resources (CNRH) and was designed to transfer a continuous flow of 26.4 m³/s over hundreds of kilometers through several states. The initial idea have emerged even before Brazil’s independence, presented in 1818 during the reign of Dom João VI. The Castanhão Dam reservoir had only 6.45% of its storage capacity during the 2012–2018 drought, leading to conflict between the water producer and water consuming basins, on the issue of transferring water to the Fortaleza Metropolitan Region (FMR). In this period SRH transferred water to the Fortaleza Metropolitan Region despite complaints of the RBC that water use would be severely impaired in the Medio Jaguaribe. The conflict ended in the State Water Resources Council.</p>
“Water transfers from Castanhão for FMR generate revolt” (Barbosa, 2018)	<p>This case exposes an inter-state conflict between the states of Ceará (CE) and Piauí (PI) regarding the construction of Fronteiras Dam in the shared Poti River Basin. The It would result in a reduction of water flow to Poti Canyon, a natural heritage of Piauí and one of the most beautiful postcards of the state. The regulatory statute for the Poti-Longá (CE/PI) hydrological system is under revision. Water allocation in the Piranhas-Açu River Basin is an inter-state conflict between Paraíba (upstream) and Rio Grande do Norte (downstream). That is a classical conflict in shared basins. ANA authorized the increase in the yield released by Coremas Mãe d’Água Dam and said that DNOCS and the water management secretariat of both states must be heard. (The regulatory statute for</p>
“The expectation of Fronteiras Dam is great” (Barbosa, 2017)	
“Water use opens dispute between RN and Pb” (Domingo, 2015)	

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Table 1 (continued)

	the Piranhas-Açu (PB/RN) hydrological system was approved in 2004 and is being revised in 2021.
“Water Theft: criminal activity targeted the water supply pipeline of Acopiara (Redação, 2019)”	This case discusses the threat to the municipality’s water security due to leaks found by the police on the water pipelines that supply the city.
The Justice of Ceará determined the interdiction of 35 water wells built by SRH to supply the Pecém Complex (CIPP)” (Castro, 2019)	Thirty-five wells were built by SRH on the west coast of the State – the Dunas/Pecém /Paracuru aquifer – to capture groundwater in the municipalities of Caucaia, São Gonçalo do Amarante, and Paracuru. The goal was to reduce FMR’s dependence on Castanhão waters and, thus, reduce conflict between the two regions. However, the Federal Prosecution Office (PO) pressed formal charges against SRH because it understood that building these wells would cause irreversible damage to the environment and leave local populations without water.
“State surveillance action bars irregular use of water in Jaguaruana” (Cogerh, 2020)	Nine shrimp farmers were diverting water upstream the municipality of Jaguaruana and had their valid water permits suspended during the negotiated water allocation meeting. However, they refused to cease their activities forcing integrated action by the SRH, COGERH, and the Military Environmental Police to seal their pumps, restoring water supply to Jaguaruana municipality. This is an example of how State Decree n° 33,559/2020 reinforces negotiated water allocation in Ceará.

2.4.3. Length and scale of the conflict

The length of the conflict is defined as a period or length of the conflict, beginning with first action up to its final resolution. The scale of conflict is given by the geographic area involved on the conflict.

2.4.4. Conflict arena

The conflict arena describes the stage where water conflicts are mediated. Basically, there are two arenas: The Administrative and the Judicial. Between these extremes there is a set of possible solutions that range from appeals within the administrative arena (River Basins Committee/State Water Resources Secretariat/State Water Resources Council) to conciliatory measures that require an external moderator.

3. Results

The five essential elements of a typology (conflict trigger, actors involved in conflict, length of the conflict, scale of conflict, and conflict arena) can be divided into types and subtypes as described below.

3.1. The five types of conflict triggers

We identified in the historical case studies and contemporary conflicts five types of triggers – Access to Water, Water Quantity, Water Quality, Water Allocation and Water Governance. The sub-types associated with each are presented below. In those cases where the type and sub-type of conflict appeared in the historical cases, its description was included to contextualize the variable.

3.1.1. Access to Water (ACCESS)

The Access to Water type incorporates two 2nd order subtypes:

- Financial Compensation for the water (FC)
- Access Obstruction (OBST)

For example, the case of Palmácia is a conflict centered on FC for water access from a well in the claimant’s property. Conversely, the Açude dos Ferreira case is a conflict centered on OBST triggers (i.e., conflict as a function of physical or infrastructural changes to water access, such as building a fence around a reservoir).

3.1.2. Water Quantity (WQT)

The Water Quantity type incorporates four 2nd order subtypes:

- Charging for Water (CHARG)
- Construction of Dams (DAM)
- Water Theft (TFT)
- Subterranean Water Exploitation (SUB)

The CHARG 2nd order subtype may trigger conflict under three circumstances: when there is no law regulating ownership rights; when the law is ambiguous or unclear regarding who has priority over the resource; or when changes in the law have not yet been assimilated culturally. Acarape do Meio, Paracuru and Milhã conflict cases illustrate those type of triggers. The Milhã case is peculiar and worth noting because in 1993 charging for water became object of intense and widely circulated discussion, often debated by the local media. The proprietor understood that it might be possible to charge the water company (SAAE) for drawing water from his reservoir. Arguing that his agriculture production would be harmed if SAAE continued getting water from his reservoir. He argued that he should be paid for his ‘ceasing profits’. The SAAE/SRH agreed to pay, although technically speaking he was not paid for the water.

The DAM 2nd order subtype may trigger conflict under three circumstances: when there is intervention altering the normal course of water (FLOW); when this intervention occurs in shared basins (within a federal state or countries) (SHARE) or when there is displacement of communities due the reservoir filling (DISPL). The FLOW 3rd order subtype appeared in Pacoti, Thomás Osterne/Manuel Balbino, Santa Catarina and Acaraú-Mirim historical conflict cases. Regarding to SHARE 3rd order subtype, conflicts may be efficiently resolved for federal basins under federal law; if the states involved fail to reach an agreement, the federal government may impose one. However, conflicts between countries are more difficult to resolve in this fashion since there is no third party with the authority to enforce agreements among national states. Regarding DISPL 3rd order subtype, the impacts that displaced communities face due to the dam’s construction can be severe and include the loss of land, income, cultural identity, community, and access to housing, health, and education (Cernea, 1997). This type of conflict occurred in Ceará in the 2000s, when an entire city – Jaguaribara – was flooded during the construction of the biggest multiple use reservoir in Brazil – the Castanhão Dam – forcing the inhabitants to relocate in the new city of Nova Jaguaribara.

The TFT 2nd order subtype triggers conflict when there is a theft along water pipelines or there is withdrawal along the river and canal without permit, harming downstream users. This last case is exemplified by Banabuiú historical conflict.

Finally, the SUB 2nd order subtype triggers conflict when user consumption is reduced by extraction of surface groundwater.

3.1.3. Water Quality (WQL)

The Water Quality type incorporates eight 2nd order subtypes:

- Release of Effluents (EFL)
- Aquaculture (AQUA)
- Agriculture (AGR)
- Livestock (LIV)
- Mining (MIN)
- Solid Residue (SOLR)
- Deforestation (DEF)
- Irregular Occupancy (IOC)

Aquaculture (AQUA) conflict subtypes are those related to the presence of fish cages in reservoirs (FISH 3rd order subtype) and to shrimp farming activity – frequently associated with serious negative social and environmental impacts (SHRIMP 3rd order subtype).

3.1.4. Water Allocation (ALLOC)

Water Allocation (ALLOC) triggers conflict when there is no consensus of users with regard to the amount of water to be released from water sources. This lack of consensus usually manifests under five circumstances (3rd order subtypes):

- among different water uses (USES)
- among different users within a certain use (USERS)
- among water producer and consumption basins in transbasin diversions (TRANSB)
- upstream vs. downstream uses and users in shared basins (within a federal state or countries) (SHARED)
- different world-views (WVIEW).

3.1.5. Water Governance (WGOV)

The water governance is associated with political, social, economic, and administrative systems to manage water and deliver water services at different societal levels. Water governance involves laws, regulations, institutions, organizations, government policies, the private sector, and civil society. It must be contextualized by the local 'institutional arrangements', seen here as the organized collective behavior which constitutes a cultural universe.

In the particular context of Ceará, the water conflict related to governance subtypes are demand for institutional power (case of RBC); lacking coordination between environmental and water management institutions to solve water pollution problems; lacking coordination between federal and state water management institutions, and personal power struggles.

3.2. Actors involved in conflict

The first type, individuals (I), encompass three 2nd order subtypes:

- Water users (WUSER) – persons or legal entities that use water. The 3rd order subtypes are: Irrigator (IRR), Industry (IND), Aquaculture Farmer (AQFARM), Public Water Supply and Sanitation companies (PWSS) and other water user (OTHER). The PWSS is formed by water users on the category of private and public water supply and sanitation concessionaries for municipal and industrial uses, such as CAGECE and SAAE.
- Displaced community from dams' construction and filling (DISPLC); and
- Land and/or Infrastructure owner (OWN).

The second type is Civil Society (CS), *formally constituted* cooperatives, foundations, associations, unions, non-governmental organizations, and business associations.

The third and final type are the institutional actors (INST), which have two 2nd order subtypes:

- Administrative (ADM) – comprises entities closely related to the Administrative functions of government such as national and state water resources management entities (e.g., SRH, COGERH, Ministry of the Environment – MMA, and National Water Agency – ANA) and the river basin committee (RBC).
- Judicial (JUD) – comprises other important type of institutional actor, such as the Federal and State Prosecution Office (PO).

3.3. Length and scale of the conflict

The length of the conflict is defined as a period or length of the

conflict, since the first action up to its final resolution. The conflict may be classified as short (equal to or less than one year), moderate (one to five years), and long (more than five years).

The scale of conflict is given by the geographic area involved and can be classified into Local – limited in space, and Systemic – which extend to river basin.

3.4. Conflict arena

The conflict mediation arena describes the setting where water conflicts are resolved. Basically, there are two arenas: the 'Administrative' and the 'Judicial'. We can think of the arenas of conflict resolution within a spectrum of formal mediation. On one end is the informal extreme, where consensus among actors in RBC is achieved by communication alone, and on the opposite end is the formal extreme, where disputes enter the judicial arena.

3.5. Water conflict typology proposed

For a better understanding, the proposed water conflict typology – with its types and sub-types – is summarized on [Table 2](#).

3.6. Applying the typology to historical and contemporary conflicts

The method used to construct the present typology was interactive, part of a reciprocal information feeding process. Thus, the twelve water conflicts formally documented in Ceará used to start building the typology are now used to feed types and subtypes in [Table 3](#). The second part of this table deals with contemporary cases, classified according to the conflict elements of the typology. Since these cases were not used to construct the typology, they increase our confidence in the robustness of the types and subtypes identified. As previously mentioned, the conflicts pointed by RBC members are not 'case studies' and therefore were not included in this table.

The historical cases clearly show that water conflicts in the state of Ceará have been mostly associated with Water Quantity, Water Allocation or Access to Water. There are two primary reasons for this. The first and most obvious reason is that people are sensitive to drought since most rural livelihoods are dependent on a continuous provision of water. The second reason is intimately linked to path dependency since most government solutions to drought are centered on infrastructure capable of providing water to users. Policies that focus on the expansion of hydraulic capacity are so popular that they have near-ubiquitous political support.

Ironically, the state's success of these recurrent 'supply-side' policies and investments have led to increased awareness that other sources of conflict over water resources are possible. Once water is secured, water quality and water governance become a source of contention.

Therefore, the RBC members pointed out several contemporary conflicts related to Water Quality. In the particular case of Ceará, water quality conflicts are intimately associated by the fact that Federal Law N° 9433/1997 defines water as a multiple use resource. For example, Aquaculture could trigger conflicts because excessive amounts of nutrients from rations given to shrimp or fish produced can compromise water for other uses. In the cases of Agriculture, Livestock, and Mining, unsustainable practices can cause eutrophication or contaminate water in the process of production. Release of Effluents and Solid Residue may solids pose a threat to freshwater ecosystems, causing eutrophication of reservoirs, affecting downstream riparian populations via erosion and loss of fishing grounds. Finally, the Deforestation and Irregular Occupancy subtypes trigger conflicts through disputes over property rights.

Water governance is crucial for water management but may also be a conflict trigger itself. The nature of local culture makes water governance non-generalizable as a conflict subtype. Water market and the participatory models, for instance, have their own types of governance conflicts. Our typology focuses on water conflict subtypes applicable to

Table 2
Water Conflict Typology.

CONFLICT TRIGGER	Subtype (2 nd order)	Subtype (3 rd order)
Type (1st order)		
Access to Water (ACCESS)	Financial Compensation (FC)	–
	Obstruction (OBST)	–
	Charging for Water (CHARG)	–
Water Quantity (WQT)	Construction of Dams (DAM)	Changes in downstream flow conditions (FLOW) Shared basins (within a federal state or countries) (SHARE) Displacement of communities (DISPL)
	Water Theft (TFT)	Water Withdrawal w/o permit (WWD) Water pipeline (PIPE)
	Subterranean Water Exploitation (SUB)	–
Water Quality (WQL)	Aquaculture (AQUA)	Intensive Fish Farming (FISH) Shrimp Farming (SHRIMP)
	Release of Effluents (EFL)	
	Agriculture (AGR)	
	Livestock (LIV)	
	Mining (MIN)	
	Solid Residue (SOLR)	
	Deforestation (DEF)	
	Irregular Occupancy – (IOC)	
Water Allocation – Quantity and Quality (ALLOC)	Transbasin Diversion (TRANSB)	
	Shared Basin (federal state or countries) (SHARED)	
	Inter Water Uses (USES)	
	Intra Water Use (USER)	
	World-view (WVIEW)	
Water Governance (WGOV)	Institutional power demand (POWER)	
	Lacking coordination environmental and WRM institutions (LC-EW)	
	Lacking coordination federal and state WRM institutions (LC-WW)	
	Power struggles (STGL)	
CONFLICT ACTORS		
Individual (I)	Water user (WUSER)	Irrigator (IRR) Industry (IND) Public Water Supply Service (PWSS) Aquaculture farmer (AQFARM) Other water user (OTHER)
	Displaced Community (DISPLC)	–
	Land/Infrastructure Owner (OWNER)	–
Civil Society (CS)	–	–
Institutional (INST)	Administrative (ADM)	National and State Water Resources Management Entity (WRME) River Basin Committee (RBC)
	Judicial (JUD)	Federal and State Prosecution Office (PO)
CONFLICT LENGHT and CONFLICT SCALE		
Short	Local	
Moderate	Systemic	
Long	–	
CONFLICT ARENA		
	National and State Water Resources Management Entity (WRME)	
Administrative (ADM)	National and State Water Resources Council (COUNC) River Basin Committee (RBC)	

Table 2 (continued)

Judicial (JUD)	Judiciary Power (JUDPW) Fed. and State Prosecution Office (PO)
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governance in Brazil.

Regarding to ‘Conflict Actors’, it is important to note that water users IRR and PWSS are the principal actors involved in *historical water conflicts*. However, with the increasing of participatory process and the strengthening of the RBC, the trend is to increase the frequency of institutional actors in contemporary conflicts.

The judicial type dominates the historical cases regarding ‘Conflict Arenas’ but, today, the trend has been to find resolution for water conflicts in the new forums. The negotiated water allocation meetings (NWAM), implemented in Ceará since 1994, have resolved most conflicts at RBC level, i.e., below the administrative or judicial. During these meetings, COGERH informs water users of the current water storage levels and presents scenarios of future levels. According to these levels, the RBC discusses how to meet demands with optimal reservoir use. State Decree n° 33.559/2020 strengthened the NWAM, recognizing its role in the state’s water management. In a period of water scarcity, NWAM can temporarily suspend a valid permit (long-term allocation) of specific water use. This has been so effective that taking a conflict to the judicial arena is seen as failure in negotiation process. Finally, we can say that the historical conflicts are evenly distributed in short, moderate, and long types regarding the ‘Conflict Length’ and that 60% of the historical cases were systemic regarding the ‘Conflict scale’.

4. Discussion

Recent focus on water governance and on conflicting interests over water resources have added a political dimension to integrated water resources management (IWRM) that must be addressed. Measures to achieve institutional security and peace in IWRM include conflict prevention and mediation which imply understanding actors’ perceptions, interests and the underlying conflict reality (Al-Saidi, 2017).

While transboundary water conflicts are quite well documented, knowledge of local water conflicts is limited and tends to be based on sporadic accounts rather than on systematic empirical evidence. However, it is becoming increasingly clear that many water-related conflicts that take place in transboundary river basins are in fact local conflicts (Ravnborg et al., 2012).

There have been some initiatives in making an inventory of conflict types such as Gleick’s classic geopolitical water conflict typology, Daoudy’s typology on the weaponization of water, and a more recent water crime and terrorism typology. However, a water conflict typology associated with governance remains a gap in the literature. A good typology can help understand how and why conflict erupts, looking at the triggers and mapping the set of actors and structures in conflict situations. In fact, we clearly saw changes from 1908 to contemporary conflicts regarding on triggers, actors, and arena when applying the typology on Ceará.

In historical cases, ‘water quantity’ type related to the irregular ‘construction of dams’ was a frequent cause of conflicts. In fact, Ravnborg (2004) demonstrated that international water events tend to take place with respect to a wide range of issues, with two of them – water quantity and infrastructure (e.g., the construction of dams and diversions) – dominating conflictive international water events. These types of conflict are also seen in contemporary media cases, such as the inter-state conflict between the states of Ceará (CE) and Piauí (PI) regarding the construction of Fronteiras Dam in the shared Poti River Basin.

‘Water allocation’ type is also evidenced in the Brazilian media both in ‘shared basins’ and in ‘transbasin diversions’. In the inter-state

Table 3
Water conflict cases. Conflict actors, trigger, length, scale and arena.

Historical cases Conflict	Conflict Actors	Conflict Trigger	Conflict length	Conflict Scale	Conflict Arena
Pacoti	I/WUSER/IRR x I/WUSER/IND	WQT/DAM	11/1909–12/1909	Systemic	Judicial
Acarape do Meio	I/WUSER/IRR x I/ WUSER/PWSS	ALLOC/USES	07/1925–12/1993	Systemic	Judicial
Lagoa do Tapuio	I/WUSER/IRR x I/WUSER/PWSS	ALLOC/USERS	04/1999–09/2002	Local	Administrative/ Judicial
Palmácia	I/OWN x I/WUSER/PWSS	ACCESS/FC	06/1980–12/1997	Local	Administrative/ Judicial
Thomaz Osterne/Manuel Balbino dams	I/WUSER/IRR x I/OWN	WQT/DAM	09/1995–06/2007	Systemic	Administrative/ Judicial
Milhã	I/WUSER/PWSS x I/OWN	WQT/CHARGE	10/1995–04/1996	Local	Administrative
Santa Catarina	I/WUSER/IRR x I/OWN	WQT/DAM	11/1996–05/1999	Systemic	Administrative/ Judicial
Açude dos Ferreiras	I/WUSER/IRR x I/OWN	ACCESS/OBST	06/1997–02/2000	Local	Administrative/ Judicial
Paracuru	I/OWN x I/WUSER/PWSS	WQT/CHARGE	09/1997–02/2002	Local	Administrative/ Judicial
Acaraú – Mirim	I/WUSER/IRR x I/OWN	WQT/DAM	06/1998–11/2000	Systemic	Administrative/ Judicial
Nova Floresta	I/WUSER/IRR x I/WUSER/IRR	ALLOC/USERS	06/1999–10/2001	Systemic	Administrative/ Judicial
Banabuiú	I/WUSER/PWSS and INST/ADM/RBC x I/WUSER/IRR	WQT/TFT	09/2001–12/2001	Systemic	Administrative/ Judicial
Contemporary Media Cases Conflict	Conflict Actors	Conflict Trigger	Conflict length	Conflict Scale	Conflict Arena
“São Francisco River divides interests and accentuates conflicts” (Gaspar, 2016)	INST/ADM x INT/ADM	ALLOC/TRANSB	1818–2007	Systemic	Administrative/ COUNC
“Water transfers from Castanhão for FMR generate revolt” (Barbosa, 2018)	INST/ ADM x INST/ADM	ALLOC/TRANSB	2012–2018	Systemic	Administrative /COUNC
“The expectation of Fronteiras Dam is great” (Barbosa, 2017)	INST/ ADM x INST/ADM	WQT/DAM/ SHARED	1998–2004 ^a	Systemic	Administrative/ WRME
“Water use opens dispute between RN and Pb” (Domingo, 2015)	INST/ADM x INST/ADM	ALLOC/ SHARED	–2004 ^a	Systemic	Administrative/ WRME
“Water Theft: criminal activity targeted the water supply pipeline of Acopiara (Redação, 2019)	–	WQT/TFT	09/2019	Local	Administrative
The Justice of Ceará determined the interdiction of 35 water wells built by SRH to supply the Pecém Complex (CIPP)” (Castro, 2019)	INST/ JUD x INST/ADM	WQT/SUB	2019–now	Local	Judicial
“State surveillance action bars irregular use of water in Jaguaruana” (Cogerh, 2020)	INST/ADM x I/WUSER/ FARM	ALLOC/USES	11/2020	Local	Administrative/ WRME

^a Regulatory Statute in review by ANA.

‘shared basins’ (e.g., media case Paraíba vs. Rio Grande do Norte) the conflicts were efficiently resolved by ‘Regulatory Statute’ mediated by ANA. The presence of treaties between two or more nations and the associated institutional capacity to deal with instances of potentially conflicting interests between nations has significantly reduced the risk of conflict (Wolf, 2008). In the ‘transbasin diversion’ – Castanhão Dam to FMR and San Francisco River media cases – the conflicts were decided by State and National Water Council. Both were viewed as being resolved peacefully, since protest of the water producer basin committees was without ‘treats’.

Looking at the ‘water allocation’ type regarding the ‘inter water uses’ and the ‘inter users’ we clearly see a reflection of general conflicts in society mirrored in this type of water conflict. Stakeholders who tend to become marginalized in society at large are also those who become marginalized in the context of water management (Ravnborg, 2004).

The ‘Negotiated Water Allocation’ initiated in Ceará State 1994, is a participative solution in which a hydrological system’s waters (perennial valley or reservoir) are allocated by RBC members based on allocation parameters previously defined by the basin committee with the assistance of COGERH. The volumes of water from the reservoirs that will be available to users throughout the year (and the associated risks) are negotiated. The decisions are endorsed by COGERH, which operates the reservoir system and verifies water uses according to the stakes

defined in the participative decision-making process. It is an innovative process of water management practice in Brazil and is considered a good strategy to cope with drought and to democratize access to water (Souza Filho et al., 2018). The importance of effective public participation for conflict mitigation and peacebuilding strategies was also pointed by Kuzdas et al. (2016), who found that violent actions in Guanacaste Province, Costa Rica only occurred when rural groups opposed government agencies in settings without mediating leadership.

Regarding ‘water governance’, the participatory model has its own types of governance conflicts. Our typology focuses on water conflict subtypes applicable to governance in Brazil but also echoes the work of Kuzdas et al. (2016), regarding to ‘latent conflicts’ associated with professional and normative differences among stakeholders.

Regarding actors and arenas, if ‘Individuals’ were the majority in historical conflicts, then ‘institutions’ are currently the predominant actors. In the past, the ‘judicial arena’ was hegemonic. Today, with negotiation forums, the judicial conflicts are seen as a failure in the negotiation process. Our data shows that present water conflicts are always resolved administratively.

5. Conclusion

In this paper we built a water conflict typology related to governance to provide a systemic and structured view of water conflicts in Northeast

Brazil. Although built from local data, the typology of water conflict is universal. However, we emphasize that the water conflict typology developed here is an evolving construct and that it is always possible to improve and build on the types presented here.

Building our typology, we compiled a database on water conflict related to governance where previously there had been none. As a result, our knowledge of the nature and the characteristics of water-related conflicts has substantially increased. As previously stated, typologies are organized systems of types and can be used as tools for categorizing, classifying, measuring, and sorting cases that are often presented in rich but diffuse empirical data. The application of a typology to water conflicts in one region clearly maps which types of conflicts are the most recurrent and help define governance strategies. The typology, however, it is not panacea and should be used as an additional tool for conflict management.

Our typology is a practical methodology for classifying water resources conflicts related to water resource governance. However, it also functions as an analytical tool of water resources management. For example, it showed that the historical conflicts were mostly related to 'Water Quantity', 'Water Allocation' and 'Access to Water' and that these were recurrent in a state that has dealt with the impacts of drought throughout its history. Currently, the State counts with a sophisticated water infrastructure (Souza Filho et al., 2018) and, since the 1990s, with technical and institutional instruments for water resources management. Other types of water conflicts, related to 'water quality' and 'governance', have arisen in this new hydraulic and institutional scenario.

Addressing water resource uses and conflicts means that one has to deal with a complex socioenvironmental reality since water involves perceptions, values, asymmetric interests, and multiple 'etna' in dispute. Future research on water conflict typologies could reveal new categories and classes of conflict. This would be a valuable contribution to water resource management.

Peter Drucker has often been quoted as saying, "you cannot manage what you cannot measure"; we would like to add that you also cannot manage what you cannot understand; and this is what the typology is for.

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CRediT authorship contribution statement

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Appendix A. Supporting information

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References

- Al-Saidi, M., 2017. Conflicts and security in integrated water resources management. *Environ. Sci. Policy* 73, 38–44. <https://doi.org/10.1016/j.envsci.2017.03.015>.
- Barbosa, H., 2018. Água do Castanhão para RMF gera revolta. *J. Diário do Nordeste*.
- Barbosa, H., 2017. A expectativa no Lago de Fronteiras é grande. *Diário do Nordeste*.
- Basurto, X., Ostrom, E., 2009. Beyond the Tragedy of the Common. *Economia delle fonti di energia e dell'ambiente*. Fascicolo 1, 2009 Fascicolo, pp. 1000–1026. doi: 10.3280/EFE2009-001004.
- Birnbaum, P., 1995. Conflitos. In: Boudon (org), R. (Ed.), *Tratado de Sociologia*. Jorge Zahar, Rio de Janeiro, pp. 247–282.
- Campos, J.N.B., 2015. Paradigms and public policies on drought in Northeast Brazil: a historical perspective. *Environ. Manag.* 55, 1052–1063. <https://doi.org/10.1007/s00267-015-0444-x>.
- Campos, J.N.B., Studart, T.M.C., 2008. Drought and water policies in Northeast Brazil: backgrounds and rationale. *Water Policy* 10, 425–438. <https://doi.org/10.2166/wp.2008.058>.
- Castro, A., 2019. Justiça determina interdição de 35 poços de água que abastecem Complexo do Pecém. *Diário do Nordeste*.
- Ceará, 1983. Plano Diretor de Recursos Hídricos, Fortaleza.
- Cernea, M., 1997. The risks and reconstruction model for resettling displaced populations. *World Dev.* 25, 1569–1587. [https://doi.org/10.1016/S0305-750X\(97\)00054-5](https://doi.org/10.1016/S0305-750X(97)00054-5).
- Cogerh, 2020. Ação de fiscalização do estado barra uso irregular de água em Jaguaruana [WWW Document]. (<https://portal.cogerh.com.br/acao-de-fiscalizacao-do-estado-o-barra-uso-irregular-de-agua-em-jaguaruana/>) (accessed 11.26.20).
- Collins, R., Sanderson, S.K., 2015. *Conflict Sociology: A Sociological Classic Updated*. Taylor and Francis. <https://doi.org/10.4324/9781315635484>.
- Davis, M., 2001. *Late Victorian Holocaust: El Niño Famines and the Making of the Third World*. Verso, London.
- De Waal, F.B.M., 2000. Primates – a natural heritage of conflict resolution. *Science* 289, 586–590. <https://doi.org/10.1126/science.289.5479.586>.
- Domingo, F., 2015. Uso da água abre disputa entre RN e PB. *J. Trib. do Norte*.
- Frey, F.W., 1993. The political context of conflict and cooperation over international river basins. *Water Int.* 18, 54–68.
- Furtado, C., 1998. *Seca e poder: entrevista com Celso Furtado, second ed. Coleção Ponto de Partida*, São Paulo.
- Gaspar, A., 2016. Rio São Francisco divide interesses e o clima acentua os conflitos. *J. O Globo*.
- Gleick, P.H., Heberger, M., 2014. Water Conflict Chronology. In: *The World's Water*. Island Press/Center for Resource Economics, Washington, DC, pp. 173–219. https://doi.org/10.5822/978-1-61091-483-3_11.
- Gluckman, M., 1964. *Custom and Conflict in Africa*. Blackwell Publishing Ltd, London.
- Grigg, N., 1996. *Water Resources Management: principles, regulations, and cases*.
- Guetzkow, H., Gyr, J., 1954. An analysis of conflict in decision-making groups. *Hum. Relat.* 7, 367–382. <https://doi.org/10.1177/001872675400700307>.
- Hoban, J.T., 2001. *Managing conflict: a guide watershed partnerships*.
- Kenny, M.L., 2009. Landscapes of memory: concentration camps and drought in Northeastern Brazil. *Lat. Am. Perspect.* 36, 21–38. <https://doi.org/10.1177/0094582x09341977>.
- Kim, K., Swain, A., 2017. *Crime, Corruption, Terrorism and Beyond: A Typology of Water Crime*. Springer, Cham, pp. 95–111. https://doi.org/10.1007/978-3-319-50161-1_5.
- Kuzdas, C., Warner, B., Wiek, A., Yglesias, M., Vignola, R., Ramírez-Cover, A., 2016. Identifying the potential of governance regimes to aggravate or mitigate local water conflicts in regions threatened by climate change. *Local Environ.* 21, 1387–1408. <https://doi.org/10.1080/13549839.2015.1129604>.
- Marengo, J.A., Alves, L.M., Alvalá, R.C., Cunha, A.P., Brito, S., Moraes, O.L.L., 2018. Climatic characteristics of the 2010–2016 drought in the semiarid Northeast Brazil region. *An. da Acad. Bras. De. Ciências* 90, 1973–1985. <https://doi.org/10.1590/0001-3765201720170206>.
- Marengo, J.A., Torres, R.R., Alves, L.M., 2017. Drought in Northeast Brazil—past, present, and future. *Theor. Appl. Climatol.* 129, 1189–1200. <https://doi.org/10.1007/s00704-016-1840-8>.

- Pontes Filho, J.D., Souza Filho, F.A., Martins, E.S.P.R., Studart, T.M., de, C., 2020. Copula-based multivariate frequency analysis of the 2012-2018 Drought in Northeast Brazil. *Water* 12. <https://doi.org/10.3390/w12030834>.
- Ravnborg, H.M., 2004. DIIS Report 2004/2. Water and Conflict. Conflict Prevention and Mitigation in Water Resources Management, Copenhagen.
- Ravnborg, H.M., Bustamante, R., Cissé, A., Cold-Ravnkilde, S.M., Cossio, V., Djiré, M., Funder, M., Gómez, L.I., Le, P., Mweemba, C., Nyambe, I., Paz, T., Pham, H., Rivas, R., Skielboe, T., Yen, N.T.B., 2012. Challenges of local water governance: the extent, nature and intensity of local water-related conflict and cooperation. *Water Policy* 14, 336–357. <https://doi.org/10.2166/wp.2011.097>.
- Redação, 2019. Furto de água: adutora que abastece Acopiara é alvo de ação criminososa. *Diário do Nordeste*.
- Souza Filho, F., Formiga Johnsson, R., de Carvalho Studart, T., Thadeu Abicalil, M., 2018. From drought to water security: Brazilian experiences and challenges, pp. 233–265. doi: 10.1007/978-981-10-7913-9_10.
- SRH-Ce, 2010a. Plano de Gerenciamento das Águas da Bacia do Acaraú. ANA/Banco Mundial/Proágua Nacional/Cogerh, Fortaleza.
- SRH-Ce, 2010b. Plano de Gerenciamento das Águas da Bacia do Coreaú. ANA/Banco Mundial/Proágua Nacional/Cogerh, Fortaleza.
- SRH-Ce, 2010c. Plano de Gerenciamento das Águas da Bacia do Litoral. ANA/Banco Mundial/Proágua Nacional/Cogerh, Fortaleza.
- SRH-Ce, 2010d. Plano de Gerenciamento das Bacias Metropolitanas. ANA/Banco Mundial/Proágua Nacional/Cogerh, Fortaleza.
- SUDENE, 1980. Plano de Aproveitamento Integrado dos Recursos Hídricos do Nordeste do Brasil – Fase I – Conflitos Inerentes aos Aproveitamentos, Recife.
- Van Velsen, J., 1964. *The Politics of Kinship: A Study in Social Manipulation Among the Lakeside Tonga of Nyasaland*. Manchester University Press.
- Vlachos, E., 2003. Towards a typology of water-related conflicts in the urban environment. *Water Sci. Technol.* 47, 205–210. <https://doi.org/10.2166/wst.2003.0399>.
- Von Der Dunk, A., Grêt-Regamey, A., Dalang, T., Hersperger, A.M., 2011. Defining a typology of peri-urban land-use conflicts – a case study from Switzerland. *Landsc. Urban Plan.* 101, 149–156. <https://doi.org/10.1016/j.landurbplan.2011.02.007>.
- Wolf, A.T., 2008. Healing the enlightenment rift: rationality, spirituality, and shared waters. *J. Int. Aff.* 61, 51–73.