Water governance in Brazil

The need to share water in the anthropocene

Costa de Barros, E.

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2.

2. METHODS

2.1. Introduction

This chapter presents the methods and the conceptual framework used in the research to address the main questions presented in the previous chapter. It explains the literature review process (see 2.2), content analysis (see 2.3), the case study approach (see 2.4), the operationalization of water-sharing (see 2.5), the phases of water governance (see 2.6), the analytical framework (see 2.7), units of analysis (see 2.8), evaluation criteria (see 2.9), the processes of data collection (see 2.10) and the ethical dimensions of this research (see 2.11). The final section summarizes how this chapter is integrated into the thesis (see 2.12).

2.2. Literature review

In order to answer the research questions, I conducted first a scoping review of water governance scholarship in general and on the paradigms of water governance and the phases of water governance (chapter 3) in particular (Arksey& O'Malley, 2005). This enabled me to identify the key gaps in knowledge (see 1.3) – which I summarize as the need for water sharing in the Anthropocene (Box 1.1).

Water Governance in the Anthropocene requires us to recognize that there are limits to our resources and sinks and that we need to share. Rockström et al. (2009) discuss the limits using the term called 'planetary boundaries'. This is defined as the environmental limits within which humanity can securely operate and it was first introduced in 2009 (Rockström et al., 2009). Steffen et al. (2015) later presented an extended analysis of this concept, and proposed a new framework focused on the regional context. Therefore, the planetary boundaries framework has been influencing the academic debate and generating policy recommendations worldwide (Biermann & Kim, 2020).

Still related with environmental limits, some scholars presented the "tipping points" concept, it means that "a particular moment in time, a small change can have large, long-term consequences for a system" (Lenton, 2011, p. 202). For example, according to Botero et al., 2015 "where even minor changes in environmental parameters can have dramatic and disproportionate consequences on population viability" (Botero et

al., 2015, p. 184). However, it is important to indicate that a "planetary boundary as originally defined is not equivalent to a global threshold or tipping point "(Steffen et al., 2015). This is because planetary boundaries have never claimed that there is a global-level tipping point for biodiversity, for instance (Rockström et al., 2018).

Over time, the literature has been also presenting some measures of water consumption. This is the case with 'water footprint' concept. It was first introduced by Hoekstra & Hung (2002) and later expanded by Chapagain & Hoekstra (2004). Water footprint is an indicator with the main goal of quantifying the virtual content of water in products and services (Lovarelli, Bacenetti & Fiala, 2016). Over years, several scholars have been also exploring this concept, for instance, Ridoutt proposed to assess the environmental impact of the consumptive use of green and blue freshwater (Ridoutt et al., 2009; Ridoutt &Pfister, 2010; Page, Ridoutt and Bellotti, 2012). Therefore, the assessment of the products and/or services related to the water footprints raised the awareness of the scale considering local businesses and consumers and the impact of the hydrological cycle worldwide (Chapagain & Hoekstra, 2008; Velasco-Muñoz et al., 2018).

The water paradigms

I also link my understanding of water sharing to the three main paradigms of water governance and how they have influenced water governance processes related with the water sharing. The review of the literature and the case studies have enabled me to assess the literature on the phases of water governance and to integrate them into three key phases, and to suggest a fourth phase based on my thesis that water sharing will become increasingly more important in the Anthropocene (see also Figure 1.1) (see the search terms used in Annex A).

The literature reveals that paradigmatic approaches in water governance for managing water have evolved from the hydraulic through integrated water resource management towards more learning and experiment based adaptive governance. Water paradigms are at different phases of evolution from government to governance, and from centralization to decentralization (Agyenim & Gupta, 2013; Gupta, Pahl-Wostl & Zondervan, 2013) (see 3.2). Therefore, it is important to understand the water paradigms because they shape water allocation.

Moreover, literature reveals also in practice, how the water allocation has been implemented in some river basins worldwide. There are a number of scholars that have described and analysed the transitions of water allocation from one phase to another. For instance, some of them distinguished different phases of river basin development (Keller, Keller & Seckler, 1996; Keller, Keller & Davids, 1998; Molden et al., 2001; Molle, 2003; Molle & Wester, 2009a). For instance, the studied examples include the Guadalquivir river basin transition in Europe (Berbel, Pedraza and Giannoccaro, 2013; Expósito & Berbel, 2019), Zayandeh Rud Basin in Iran (Molle & Mamanpoush, 2012), and Pangani River Basin in Tanzania (Komakech et al., 2011; Komakech, Condon & Van der Zaag, 2012). Therefore, I undertake an analyses of the phases in the literature and explore a possible next phase in water governance.

The instruments that explicitly deal with water-sharing

I have also conducted a literature review on the instruments that explicitly deal with water-sharing (Chapter 4). This review contributed to my understanding of current knowledge on water governance and water-sharing instruments. The review of peer-reviewed journals, academic books and the policy literature has enabled me to (a) identify water sharing instruments; (b) cluster them (i.e. sharing of responsibility between levels (centre and states); between states; between uses; between users; between humans and nature; and sharing of water-related risks) (see 2.5); and (c) analyse them.

Allocation arrangements consist of a combination of water sharing instruments. For instance, this is the case of instruments related to transboundary issues. This is not a recent phenomenon and have been often debated in the literature (Davis, 1995; Wolf, 1999; Kilgour & Dinar, 2001; Dombrowsky, 2009; Degefu et al., 2016). Discussions on transboundary water allocation arose in the 1990s amid increasing critical scarcity conditions in some regions. This is one of the causes of political tensions between Arabs and Israelis (Moore, 1994; Kliot & Shmueli, 1998; Wolf, 1999), upstream-downstream disputes regarding the operation of the Farakka Barrage on the Ganges between India and Bangladesh (Rogers & Harshadeep, 1997; Kilgour & Dinar, 2001) and the long history of disputes in the Nile River (and all 11 riparian States) (Whittington, Waterbury & McClelland, 1994; Wolf, 1999), amongst others.

Studies that examine transboundary water allocation have proliferated since the 2000s. As the literature has expanded, it is logical that scholars have begun to focus on instruments that can be generalizable to solve transboundary water allocation issues such as Water Agreements (e.g., Zhao et al., 2021; Mirumachi & Hurlbert, 2022) and the Equitable and Optimal Utilization Principle (e.g., Avarideh, Attari & Moridi, 2017; Tanzi, 2020), for example.

Case study area

Regarding the case study area, I conducted a literature review on existing scholarship on water management, water governance, multilevel governance, and environmental issues in Brazil, specifically looking at the São Francisco River Basin and the states of Bahia, Pernambuco and Alagoas. Emphasis was placed on the evolution of water governance paradigms and water-sharing instruments. I also regularly perused relevant articles in leading Portuguese newspapers, including Folha de São Paulo and Estadão. Information drawn from these sources has been integrated into the case study chapters.

2.3. Content analysis

This thesis hypotheses that water-sharing is and will become an increasingly key component of water governance in the Anthropocene (see Box 1.1). Chapter 1 showed how sharing issues were necessary as demand exceeds supply, how different sharing issues were becoming prominent in federal states, and how policy instruments including the 2030 Agenda implicitly or explicitly dealt with sharing instruments. In order to make the analysis of sharing more systematic, I have identified the laws and policies at multiple levels of governance that have to be selected for further analysis (see Table 2.1).

Based on the literature I have also identified 14 sharing instruments clustered into 6 categories of sharing in Chapter 4. The content analysis thus analyses each of the selected policies and/or laws to identify which of the sharing instruments are included in these documents (Coffey, 2014; Prior, 2008). In addition, the analysis assesses whether these documents have addressed the drivers of water quantity problems and the institutions involved in water governance. The content analysis is driven

Table 2.1. Treaties and policies at multiple levels assessed in this thesis

Level	Treaties/policies	Year
International	UNESCO Ramsar Convention	1971
	UN Framework Convention on Climate Change (UNFCCC)	1992
	ICWE Dublin Statement (ICWE)	1992
	UN Convention on Watercourses (UN CTWC)	1997
	UN Human Right to Water and Sanitation (UNGA)	2010
	UN Sustainable Development Goals	2015
National (Brazil)	Federal Constitution	1988
	National Water Law	1997
	National System of Protected Areas (Law No. 9985/2000)	2000
	National Policy on Climate Change	2008
	National Policy of Civil Protection and Defence (Law No. 12608/2012)	2012
	Irrigation Policy (Law No. 12787/2013)	2013
Basin (SFRB)	São Francisco River Basin Water Resource Plan	2004
	São Francisco River Basin Water Resource Plan (2016 till 2025)	2016
State (Bahia)	State Law (No. 6855/1995)	1995
	State Law (Law No. 10431/2006)	2006
	State Water (Law No. 11612/2009)	2009
State (Pernambuco)	State Law (No. 12984/2005)	2005
	State Law (No. 14090/2010)	2010
	State Decree (No. 47698/2019)	2019
State (Alagoas)	State Law (7776/2016)	2016
	State Water (Law No. 5965/1997)	1997

Source: Author's elaboration

by the institutional analysis method explained below in section 2.7 and the units of analysis are explained in Table 2.4.

2.4. Case study approach

According to scholars like Creswell (2007), case studies are suitable for investigating complex topics such as water-sharing. This is because the case study approach can address issues that cannot be assessed purely through the analysis of existing documents and policies, represents a broader view, and it is possible to conduct an empirical study of a current phenomenon inside its natural context using several types of evidence (Yin, 2003; Hancock, Algozzine & Lim, 2021, p. 15). A case study approach is needed when one wants to assess why something is or is not happening. Researchers from different disciplines and various paradigms have been using case studies in their research, and they normally agree that case study research: (a) addresses phenomenon such as a particular event, situation, programme, or activity; (b) space, time and context; and (c) are richly descriptive being based on deep and diverse sources of information (e.g., quotes from key participants, anecdotes, prose composed of interviews and others) (Hancock, Algozzine & Lim, 2021, p. 15).

Hence, I chose to use a multi-layered case study to explore the performance of water-sharing instruments at the national, basin and state levels of water governance in a federal system. The multi-layers of the case study comprise of three selected administrative levels (national, river basin and sub-national) within three states (Alagoas, Bahia, and Pernambuco). This allows for comparison between levels and between states while, as suggested by Yin (2013), also simultaneously retains the holistic and significant characteristics of real-life events. The nature of such a case study offers opportunity to "calibrate or adjust the measures of our abstract concepts to actual lived experiences and widely accepted standards of evidence" (Neuman, 2011, p. 42).

While there are criticisms around the generalizability and external validation of single case studies (Easton, 2010), it is nonetheless plausible and acceptable for their outcomes to prove otherwise (Woodside, 2010; Yin, 2014). I chose Brazil for my multi-layered case study (see 1.4.2).

2.5. Operationalizing Water-Sharing

In order to operationalize water-sharing in the context of federal states, I build on inclusive development and its requirement for social, ecological and relational inclusiveness (see 1.5). I then unpackage the various dimensions of water sharing.

Based on my understanding of water sharing issues in general and in federal states as also discussed in Chapter 1, I operationalize water sharing in terms of addressing water-sharing challenges between levels, states, uses, users, humans and nature, and water-related risks.

- **Sharing of responsibility between the central government and provinces/states:** This is an important sharing aspect for federal states (see 1.4.1 and 4.2.1) which explicitly allocate responsibilities, power and mandates to different levels of governance in the country. While in unitary systems, control over water is held at the central level, and this has been extensively discussed by political and legal scientists; in federal systems, water governance is shared in different ways between the central government and the different provincial governments (see 4.2.2). Sometimes, water governance is delegated to states, and in such situations federal governments only play the role of referee between states. However, in federal systems, mechanisms that focus on equitable water-sharing are often unavailable to manage inter-jurisdictional disputes over water (Garrick, Anderson & Webster, 2014). Federal systems of transboundary river basins are a major challenge for water governance as they often include complex structures involving multiple levels (Garrick et al., 2013; Schlager et al., 2011). This is exemplified in water-sharing disputes such as between Afghanistan and Pakistan over the Kabul River, as well as internal disputes among provinces in Pakistan (Hayat, 2020).

- **Water-sharing between federal units (provinces/states):** Since water is often a provincial subject, water sharing between federal states becomes important. Within the complexity of governing freshwater in federal systems is an explicitly asymmetrical water-sharing relationship between upstream and downstream users (van der Zaag, 2007; Warner & Zawahri, 2012). In India, there have been violent disputes between the upstream state of Karnataka and

the downstream state of Tamil Nadu over the Cauvery River Basin (Wolf et al., 2005); (see Box 4.1). Although disputes over water resources within countries are inevitable, there is a lack of empirical data on situations around rivers crossing more than one state within a federal country (Garrick et al., 2013, 2014, 2018; Garrick & de Stefano, 2016). Many domestic water disputes are simply not documented in scientific databases.

- **Water-sharing between uses:** Existing literature shows how water resources have been used for diverse purposes across different economies and natural ecosystems over time (Chapter 3). Water disputes between water uses, such as agriculture and domestic consumption, are increasingly addressed in recent literature (e.g. OECD, 2015a). For example, van den Brandeler (2020) draws attention to two contemporary cases involving water sharing between the river basin and cities in relation to the rivers on which the metropolitan cities of São Paulo and Mexico City depend upon, which are currently involved in water-sharing disputes between uses. In such cases, water-sharing instruments between uses are fundamental to address these disputes.

- **Water-sharing between users:** Water governance is a dynamic process involving many actors, institutions, and drivers. It influences water-sharing relations between users. While water-sharing between uses focuses on the sharing between sectors, water-sharing between users focuses on the distribution of water within the different actors in a sector. Agriculture is the largest water user throughout the world and directly influences the distribution of water between users (e.g. small holders vs large plantations) through different mechanisms, such as land ownership, prior appropriation and infrastructure development (Gleick, 2000). Research on global land and water grabbing and disputes have recently increased, but are still less discussed in global media (Zoomers, Gekker & Schäfer, 2016; Borras et al., 2019). Most of this research is carried out by civil society organizations documenting local people's experiences with losing land and water and dealing with contamination of their water, soils and animals by agrochemicals and other pollutants (GTSC, 2018; Borras et al., 2019). In Brazil, such experiences have forced

many families to relocate to the favelas in urban areas (Borras et al., 2019). This indirectly shows how water-sharing instruments adopted over the years (e.g., issuance of water use permits for allocating water to large users, water pricing, land ownership, prior appropriation, and infrastructure) have resulted in increasing food production and yet food insecurity and loss of biodiversity.

- **Water-sharing between humans and nature:** Historically, water allocation arrangements have prioritized human needs over the environment. As global production and consumption increases and as the world population increases, human use of freshwater resources is also increasing and placing enormous stress on aquatic ecosystems (Swainson, de Loë & Kreutzwiser, 2011). Without clear understanding of the relationship between humans and nature, many countries are still neglecting environmental protection, focusing instead on economic interests (Wallace, Acreman & Sullivan, 2003). It is important that allocation agreements begin to explicitly reserve water for the environment. Globally, there is recognition to maintain freshwater ecosystems and natural river flows (Swainson, de Loë & Kreutzwiser, 2011). However, the maintenance of ecosystem services require sustainable and effective freshwater resources governance, especially in the context of the Anthropocene. Currently, ecosystem services and water-sharing between nature and humans are insufficiently considered during development and planning processes of water management. The concept of buen vivir in many Latin American countries calls for a holistic relationship with nature (van Norren, 2017).

- **Sharing of water-related risks (drought, flood, and other extreme weather events):** Climate variation and change have been affecting the frequency, intensity and duration of extreme water-related weather events, such as excessive precipitation, floods and droughts. Poor economies and densely populated cities of developing regions tend to be more affected (Abeygunawardena et al., 2009; Kalantari et al., 2018; IPCC, 2022). In semi-arid regions, the sharing of benefits and risks and related governance responsibilities has caused tensions between upstream and downstream sub-national jurisdictions (Schlager et al., 2011; Garrick et al., 2013).

Table 2.2. Inclusive development, indicators and link to sharing

Inclusive development dimensions	Indicator Inclusiveness	Link to sharing
Social: contributes to material and non-material wellbeing of the poor through access to formal and public drinking water supply sanitation services	(i) Access to water and sanitation services (ii) Beneficial uses of water (e.g., access to water for growing food) (iii) Minimize the risk of water damage to humans	Sharing between users Sharing between uses Sharing of water related risks
Ecological: contributes to wellbeing of the poor through maintenance of supporting, regulating, provisioning and cultural ecosystem services	(i) Water reserve for nature/including nature considerations	Sharing with nature
Relational: contributes to addressing poverty and inequality reduction, ensuring access and empowering the marginalized and contributes to the redistribution of resources and related powers in command of these resources	(i) Positive discrimination towards the most marginalized (redistribution) (ii) Participatory approaches (e.g., access to information, decision-making, courts)	Sharing between users Sharing between users, uses, and nature

Source: Author's elaboration, building on Dos Santos, Gupta, Pouw & Schwartz (2019)

Having identified different water-sharing modes, I now identify indicators of inclusive development and link it to water-sharing (see Table 2.2). In doing so, I assume an ideal-typical approach to enable the evaluation of water-sharing instruments at various levels of governance, identifying sub-criteria for each criterion that can be used in a qualitative assessment process. The three components of ID used to test the performance of water-sharing instruments at multiple levels of governance are social, environmental and relational inclusion. Table 2.2 conceptualises inclusive development by adopting an explicit focus on resource sharing, particularly the implications that different inclusiveness indicators bear for sharing between human and non-human agents. For example, access to basic water and sanitation services is a pivotal indicator (and component) of the social inclusiveness dimension, which de facto implies sharing finite clean and freshwater resources on a regional, national and international basis across all humans. Meanwhile, maintaining adequate natural water reserves is central to ecological inclusiveness, which implies an element

of sharing available water resources with nature itself. Relational inclusiveness has been operationalized as positive discrimination towards the most marginalized and participatory approaches.

These components are discussed in Chapters 5, 6 and 7 of the thesis.

2.6. Phases of Water Governance

I have argued in Chapter 1 that as we move into the Anthropocene there is greater need for water sharing. This implies that in earlier periods including the Holocene there were other elements that were prioritized in water governance. Hence, Chapter 3 explores the three main paradigms of water governance (the hydraulic engineering paradigm, integrated water resources management, and adaptive governance) and the phases of water governance historically (where demand is less than supply, more than supply, the closing of water systems and the re-opening of water systems). As mentioned earlier, in the Anthropocene water systems are 'closing' (see also 3.3.2). Improved water governance requires a re-opening of the system. My hypothesis is that this requires water sharing and brings me to my proposal of a fourth phase of Inclusive Adaptive Water Governance.

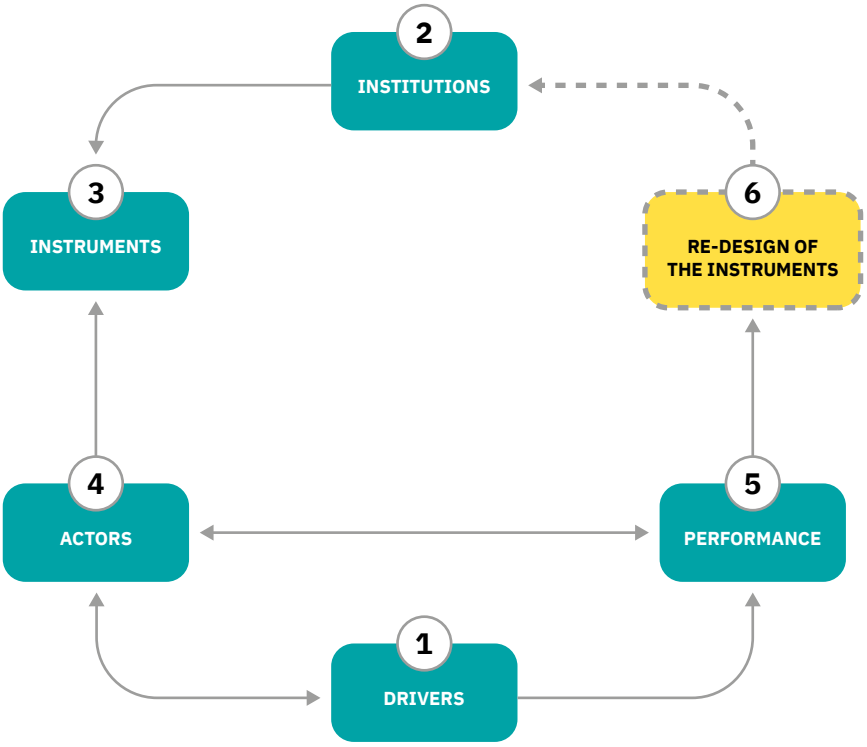
In terms of method, Chapter 3 presents the four phases and their key characteristics. The subsequent chapters assess the empirical data to conclude in which phase of water governance Brazil is currently in and to draw elements for making proposals for the following phase of water governance in Brazil.

2.7. Analytical framework

This section introduces the analytical framework used to carry out this research. This framework can be understood as a visual or written product that elucidates the key concepts to be considered and their relationships. In answering the research questions, I adopt the institutional analysis model of the Institutional Dimensions of Global Environmental Change (IDGEC) developed by the International Human Dimensions Programme (IHDP) as the basis for my analytical framework (IHDP/IDGEC, 2005). According to Young (2002) the advantage of this diagnostic tool is:

> "It is useful to treat this approach as an exercise in midrange generalization, coupled with liberal use of ceteris paribus assumptions.

Figure 2.1. Institutional analysis framework



Source: IDGEC 1999/2005; some of the terms have been adapted for better applicability to this thesis
Author's elaboration adapted from IDGEC framework

NB: The arrows represent the analytical steps undertaken in this research. Dashed lines indicate the dimension of the redesign. These indicate the proposals that may emerge from the research, but may or may not be adopted by authorities.

> Instead of attempting to identify a given problem as a generic problem type (e.g., CPR) and then applying conditions regarded as necessary to successful treatment of all instances of that type, the diagnostic approach attempts to disaggregate environmental issues, identifying elements of individual problems that are significant from a problem-solving perspective and reaching conclusions about design features necessary to address each element" (Young 2002: 176, emphasis mine).

Table 2.3. Original IDGEC framework and adapted conceptual framework

Elements	Definition in IDGEC framework	My adaptation
Drivers	Causes of human behaviours or biophysical phenomenon (e.g., economic growth, urbanization, land cover changes, climate change)	Causes of human behaviour and biophysical causes of water-related challenges (e.g., natural changes in available water quantity; climate change; economic growth; population growth)
Institutions	The set of norms (principles), rules, decision-making procedures, and programmes that define social practices	Specific laws and policies governing freshwater resource sharing at multiple levels
Instruments	Specific principles, tools, incentives, and disincentives used to change behaviour	The application of the instruments based on six categories: sharing of responsibility between levels (centre and states); between states; between uses; between users; between humans and nature; and sharing of water-related risks
Actors	The actors to whom the instruments are directed	Persons, communities, organizations, or states participating in or affected by instruments
Performance of the instruments	The effect of instruments on human behaviour given drivers/context on the biophysical condition of the resource	The effect of instruments on human behaviour given drivers/context on social inclusiveness, ecological inclusiveness and relational inclusiveness.
Redesign	Improve existing institutions and principles to address continuing actor pressure and drivers	Improve existing instruments based on their performance

Source: Based on IHDP/IDGEC (2005)

IDGEC's framework examines causality (to what extent do the institutions and instruments bear responsibility for a problem), performance (which institutions/instruments work well in a given context and which don't), and design (how can an analysis of performance enable better judgement regarding how to redesign instruments for improving the contextual effectiveness of an instrument). This framework has six parts: (1) drivers/context, (2) institutions, (3) instruments, (4) actors, (5) performance of the instruments, and (6) redesign of the instruments. I have adapted the IDGEC model to investigate water-sharing from an

institutional perspective (see Figure 2.1 and Figure 2.2). Therefore, the main goal of adopting this approach is to have the redesigned instruments ready for implementation if a political opportunity arises.

I now operationalize the above institutional analysis model through five steps to analyze the water-sharing instruments (see Figure 2.2).

(1) Major drivers of water quantity problems in the multi-level case study

The first step in the analysis was to define the context and driving forces of water problems at different levels of governance, focusing on water quantity. It is important to study the driving forces that influence human behaviour in order to assess if the instruments designed are able to address these forces. Section 1.2.1 has already explained the direct and indirect drivers at the global level. The case study chapters discuss the direct and indirect drivers at the national (Brazil), basin (São Francisco River Basin), and state (Alagoas, Bahia and Pernambuco) levels. This step was based on document analyses and the results were triangulated with semi-structured interviews.

(2) Institutions

The second step in the analysis was identifying key institutions involved in water governance. These institutions were identified by their influence on different types of water-sharing instruments. The institutions include relevant international, national, state and local level policies and laws (see Table 2.1).

(3) Instrument design analysis

The third step was to analyse the above institutions to identify the key policy instruments addressing water-sharing problems at multiple levels of governance. The criteria for including instruments include whether they address: (1) sharing of responsibility between levels; (2) sharing of water between states; (3) sharing of water between uses; (4) sharing of water between users; (5) sharing of water between humans and nature; and (6) sharing of water-related risks; as discussed in Section 2.5. Instruments were selected at the different levels of governance. Furthermore,

this process examined the design of each instrument in terms of its main characteristics, objectives, scale of implementation and consideration of inclusiveness. I then looked for empirical evidence at whether the instrument was able to change the behaviour of actors.

(4) Actors

The fourth step was to identify the key actors addressing water sharing challenges at multiple levels

(5) Impacts on inclusivity

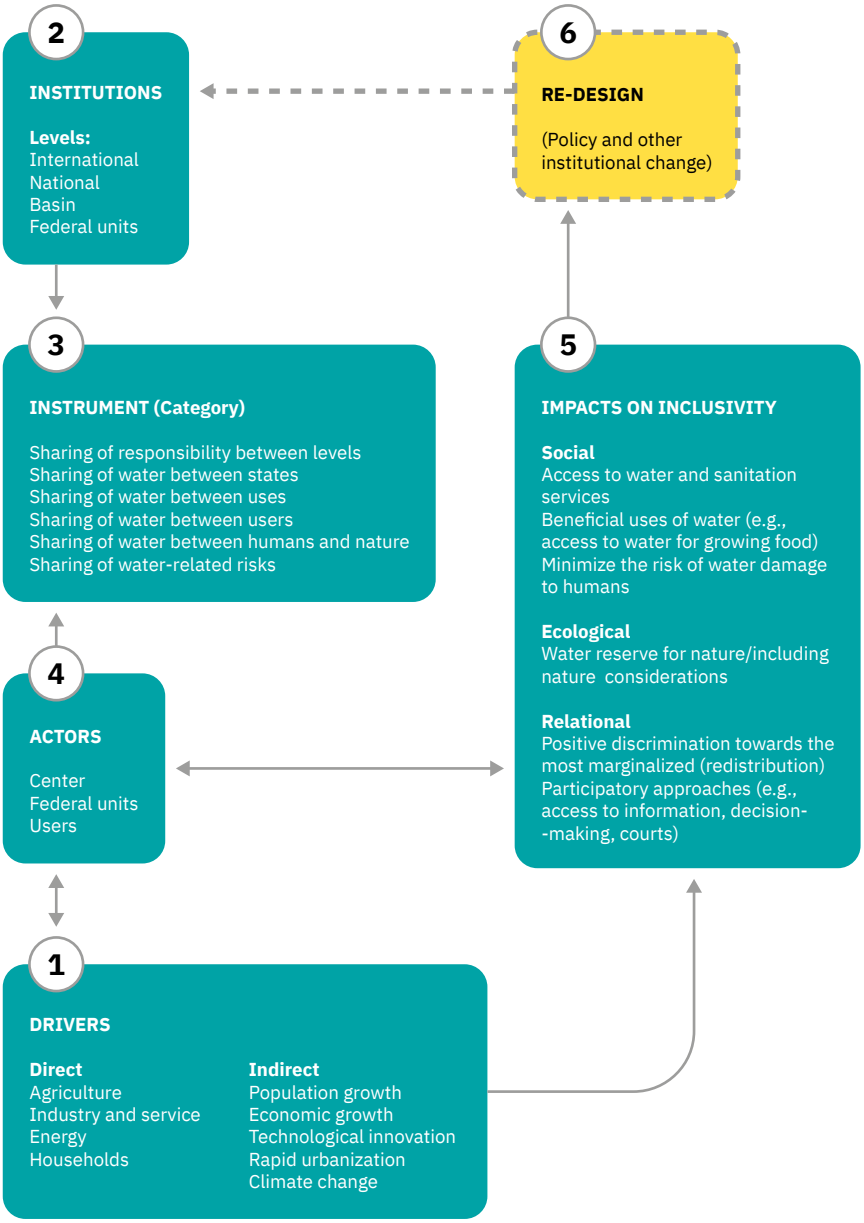
The fifth step examined the effectiveness of water policy instruments, looking at water-sharing through the specific objectives of the instruments. This process reveals whether instruments currently in place fail to, or succeed in, changing human behaviour by influencing the drivers that shape their behaviour and how they score in terms of inclusive development. It does so by highlighting the goals of the instruments, which were identified through content analysis, literature, and the perception of respondents on the extent to which these goals were met. The latter was identified through semi-structured interviews, direct observation, and other sources (e.g., informal conversations, field observations, attendance of meetings, and analysis of policy documents, maps, satellite images, databases, scientific publications, and project reports).

(6) Redesign of instruments

Based on an analysis of the impacts (see step 4 above), the research aimed to redesign the policy instruments addressing water-sharing based on the reasons for their success or failure. Where such instruments were missing, the redesign relied on literature. A mix of policy instruments will be needed to ensure that sharing objectives are met. However, such policy instruments may not be able to address all drivers. Hence, this is also where we discuss which drivers were not addressed and how such drivers can be dealt with.

The thesis deals with overall policy coherence across multiple levels. Impacts of the instruments are considered in the context of existing drivers and assessed in terms of the three dimensions of

Figure 2.2. Applied institutional analysis framework



Source: Author's elaboration adapted from IDGEC framework

NB: The arrows represent the analytical steps undertaken in this research. Dashed lines indicate the dimension of the redesign to be proposed by this thesis

inclusive development defined in Section 1.5. This process is based on semi-structured interviews, technical and scientific assessments, newspapers, and direct observation.

2.8. Units of analysis

This research was based on five units of analysis (see Table 2.4). First, water problems were looked at in terms of quantity to understand problems such as water storage, excessive groundwater abstraction, and physical and economic water scarcity. Definitions of the term 'water scarcity' vary among researchers. It is generally described as having physical and economic dimensions (Seckler, 1998). Physical water scarcity refers to availability of less than 1,000 m^3 of renewable freshwater per capita per year (UNEP GEO, 2019, p.244) (Map 1.1). Economic water scarcity refers to the lack of storage, treatment, and transport infrastructure resulting in low availability of water resources (UNEP GEO, 2019, p. 244). Water quality is closely related to water quantity and vice versa. Reduced quantity of water affects the quality thereof as, for instance, pollutants become more concentrated, rendering the water unsafe for drinking, agriculture, nature, and so on. Second, drivers of these problems were assessed to understand their direct and indirect causes and to compare them with the general drivers at global level (see Table 1.1). Third, administrative levels of governance were identified to explore institutional arrangements connecting them. Fourth, water governance paradigms were assessed to understand the attitudes and practices embedded in water management systems, taking into account that water-sharing is strongly determined by historical water availability, customs, and available techniques. Fifth, six policy-driven instruments were identified: 1) responsibility between centre and states; 2) water-sharing between states and provinces; 3) water-sharing between uses; 4) water-sharing between users; 5) water-sharing between humans and nature; and 6) water-related risks, such as droughts, floods and extreme weather events.

2.9. Evaluation based on critical instrumentalism

This thesis evaluates the instruments used by policy actors going beyond criteria like efficiency and cost recovery to critically assess the instruments from a sharing perspective. Hence I go beyond mainstream

Table 2.4. Units of analysis in the multi-level case study[a]

Units of analysis	Options
Problems	Water quantity (e.g., storage, excessive groundwater abstraction, physical water scarcity)
Drivers	Direct (agriculture, industry & services, energy, households) and Indirect (population growth, economic growth, technological innovation, rapid urbanization and climate change)
Administrative scale	National, basin, and federal units (province/state)
Water paradigms	Hydraulic engineering, IWRM, Adaptive water governance
Water-sharing categories	a. Sharing of responsibility between levels
	b. Sharing of water between federal units (province/state)
	c. Sharing of water between uses
	d. Sharing of water between users
	e. Sharing of water between humans and nature
	f. Sharing of water-related risks

Source: Author's elaboration

a. This thesis only focuses on water quantity issues, referring to quality aspects only when needed

assessment of instruments as explained below. Instruments selected for this research had to fulfil multiple criteria to ensure their relevance. First, the instruments had to address water-sharing challenges between administrative levels, states, uses, users, humans and nature, and water-related risks. Second, the focus of each instrument had to be directly related to water quantity. This meant intentionally leaving out the instruments related to water quality (see 1.3), although water quantity and quality are linked. Third, the instruments had to be implemented at national, basin and/or state levels.

Each instrument was first studied in terms of the formal text. I examined which type of sharing instrument was included. I then examined whether the text made provisions for operationalizing the instrument (see Table 2.5). I looked at whether there was a budget for actual implementation. I examined whether the instrument could, in theory, address

Table 2.5. Evaluation criteria for policy instruments[a]

(i) On paper (policy instruments enforced by law)			
(ii) Operationalization (responsible for operationalization)			
(iii) Budget (financial sources enforced by law)			
(iv) Implementation (Implementation process such as actions implemented, programs implemented, etc.)			
(v) Goal Achieved (progress towards achieving policy goals)			
(vi) Reflection on policy goals in relation to ID considering the design of the law enforced[c]	Dimension of inclusiveness	Social	(i) Access to water and sanitation services (as a human right) (ii) Beneficial uses of water (e.g., access to water for growing food) (iii) Minimize the risk of water damage
		Ecological	(i) Water reserve for nature
		Relational	(i) Positive discrimination[b] towards the most marginalized in the law/policy (ii) Participatory approaches (e.g., access to information, access to decision making, access to court)

Source: Author's elaboration

a. This thesis only focuses on water quantity issues, referring to quality aspects only when needed

b. Providing more support for these communities to participate than the rich

c. See Annex F for list of policy instruments analysed

the relevant direct and indirect drivers to achieve the goals in the law/policy. I then looked for empirical evidence at whether the instrument was able to change the behaviour of actors, given the drivers and contribute to social, ecological and relational inclusiveness. Based on this assessment, I made proposals for redesigning instruments.

2.10. Data collection

In answering the research questions (see 1.3), I used both quantitative and qualitative research methodologies. I undertook fieldwork in two phases, from September 2015 to February 2016 and between July and September 2017. In the first exploratory phase of this research, when

the major concepts had yet to be confirmed in the field, I relied more on qualitative techniques. After assessing the types of water governance activities and water-sharing instruments that were predominant in the study area, I developed new interview questions to verify development and implementation of the instruments and their drivers.

The second phase of the fieldwork focused on the policy instruments of water governance and social networks linked to inclusive development. Some data was collected through in-depth interviews with academics and state and non-state actors (see Annex D). Other data was obtained through informal conversations, field observations, attending meetings, and analysis of policy documents, maps, satellite images, databases, scientific publications, and project reports to verify water-related challenges within the context of inclusive development.

1.10.1. The qualitative techniques

I used a combination of qualitative research techniques, including semi-structured interviews with key informants at multiple levels, participatory observation, and archival analysis.

1.10.1.1. Interviews

Semi-structured interviews were used to discern perceptions of key informants on water policy instruments, their drivers, and the institutions involved in addressing related challenges at different levels of governance. The interviews were especially useful in analysing the perceived impacts of the instruments on inclusiveness.

Two techniques were used to select interviewees: purposive and snowball sampling. In purposive sampling, interviewees are selected using specific characteristics instead of a randomized representation of a specified population (Tongco, 2007). Specific characteristics considered for this research included scale factors and types of water policy instruments and their drivers. Snowball sampling is motivated by referrals from interviewees that are within the population or area of interest and identifies interviewees that would otherwise have been excluded through purposive sampling (Biernacki & Waldorf, 1981; Atkinson & Flint, 2001). Purposive and snowball sampling were used in combination to reduce individual biases in both techniques and to increase validity. This choice

Table 2.6. Participatory observation: locations and issues discussed

Location	When	Issues discussion
Recife city, Pernambuco state, Brazil	2017	Discussed the academic research about water governance projects at the University of Pernambuco
Salvador city, Bahia state, Brazil	2017	Discussed the impacts of the water governance
Delmiro Gouveia city, Alagoas state, Brazil	2017	Discussed biodiversity, seeds water storage, food diversity, capacity building of small farmers
Maceió city, Alagoas state, Brazil	2017	Current challenges and relevant episodes of the River Basin Committee of the São Francisco River Basin
Vargem Bonita city, Minas Gerais state, Brazil	2017	Upstream challenges; current challenges and relevant episodes of the region

Source: Author's elaboration

was made considering the importance of decision-making processes in multi-level water governance.

One hundred and one respondents were interviewed in Brazil (see annex D for interview list). Interviews were conducted with state and non-state actors at multiple levels of governance. Then, responses from the interviews were coded using ATLAS.ti, which helped to classify the responses and identify a set of themes.

2.10.1.2. Participatory observation

Throughout the course of my PhD programme, I attended academic and professional events related to water governance to gain direct insight into local and regional issues pertaining to water availability for performing economic activities. I recorded my observations in a fieldwork diary, which is presented in Table 2.6.

2.10.1.3. Archival analysis

In addition to fieldwork, I also incorporated a genealogical analysis of water governance practices in Brazil from its colonial origins to the present. This analysis was developed through life stories shared during interviews,

Table 2.7. Inventory of archives used in Brazil

No.	Archives	Type	City/State
1	Brazilian National Library	Public	Rio de Janeiro city at Rio de Janeiro state
2	Brazilian National Museum	Public	Rio de Janeiro city at Rio de Janeiro state
3	The São Francisco Museum	Public	Juazeiro city at Bahia state
4	Joaquin Nabuco Foundation	Public	Recife city at Pernambuco state
5	Chesf Museum	Private	Recife city at Pernambuco state
6	Alagoas Archive	Public	Maceió city at Alagoas state
7	Anguiquinhos Museum	Private	Delmiro Gouveia city at Alagoas state
8	Pedra Museum	Public	Delmiro Gouveia city at Alagoas state
9	Private archives	Private	Delmiro Gouveia city at Alagoas state

Source: Author's elaboration

as well as through collection and analysis of water policy documents retrieved from private and public archives (see Table 2.7). The data collection process was focused mainly on water management plans, planning and appraisal documents, design and infrastructure assessment reports, newspapers, and review of previous research.

2.10.2. The quantitative techniques

The research used two quantitative analysis techniques: statistical analysis and mapping and hydrological analysis.

2.10.2.1. Statistical Analysis and Mapping

Statistical analysis software and Geographical Information System (GIS), which enables the visualization of many types of data from different types of sources, were used to visualize the spatial distribution of federal countries and water availability globally. This helped to recognize and understand relevant spatial and geographic relationships and pat-

terns. Results from this analysis were translated into quantitative metrics, treated and imported into a Microsoft Excel database, and spatially visualized using ArcGIS 10.0. GIS.

2.10.2.2. Hydrological Analysis

In order to observe the temporal variation of water in the study area, I used secondary data from scientific literature and online databases of governmental agencies and regional and local civil society institutions. I specifically drew from the Brazilian Geological Service (CPRM) database of river flow measurements and historical reports from the Juazeiro fluviometric station (code 48020000) on daily flow between 1979 to 2014. I chose this period because it corresponds to the time before and after the construction of the hydroelectric plants and human impacts on the SFRB, showing changes in the flow of the basin over the years. This data contributes to the schematic representation of the SFRB in chapter 8.

2.11. Ethical dimensions

In order to meet the standards of ethical research, I obtained ethics approval before fieldwork from the Amsterdam Institute for Social Science Research (AISSR), University of Amsterdam, Ethics Review Board. The ethics statement covers ethical considerations concerning data collection during interviews, research consent and permission, the privacy of research participants, and data management.

Consent, permission and privacy

Being a Brazilian, I do not need permission to conduct research in my country. Consent from interviewees was obtained verbally and informally from actors before interviews were conducted. Before the interview, I informed the research participants about the purpose of my research, objectives, and the importance of my research. I gave them a brief overview of what the research is all about and what is required of them in terms of time. I made clear to them that they were free to not answer my questions or withdraw from the interview whenever they wanted. The information enabled them to give their consent whether or not they wanted to participate in the research processes. The key code which identifies

who said what has been encrypted to prevent abuse of this information. The topic of my thesis is neither controversial nor highly sensitive in Brazil, hence no one had to fear negative consequences from participating in this research.

Data management

The raw data collected from September 2015 to February 2016 and between July and September 2017 from the field is stored and my notes are kept under lock and key. The digital version of the data is also stored in my database and the password is protected (the author's computer is password protected). The access to the digital data would be provided only upon request from my promoter and if it is needed to respond to enquiries.

Non-personal data has been filed on my computer system and is available for broader use.

Benefit sharing

The results of my research are being made available to Brazilian scholars and policymakers as I wish to share the benefits of my research with them.

2.12. Inferences

The purpose of this thesis is to show how water governance is reaching a crises as demand is exceeding supply of water. It has therefore used a set of methods that review the literature on water paradigms and their influence on governance, identified the key water-sharing approaches and adapted an institutional analysis model to study whether existing water-sharing instruments are enabling Brazilian authorities to better govern their water and find a route out of the existing water crises.