Water governance in Brazil

The need to share water in the anthropocene

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7.

7. WATER GOVERNANCE AT THE STATE LEVEL

7.1. Introduction

Focusing on the state level, Chapter 7 presents and compares the political context that has shaped changes in water governance in Bahia, Pernambuco, and Alagoas states which are part of the SFRB. This is particularly interesting due to their commonalities and differences in water-sharing challenges, as well as asymmetrical interdependencies and upstream-downstream dynamics between the jurisdictions. The state of Bahia is the largest economy in Northeast Brazil. It is the fourth most populous state, with 15 million people (after São Paulo, Rio do Janeiro, and Minas Gerais), and the fifth-largest territory, spanning across 564,000 km² (IBGE, 2020). It was the first Brazilian capital (administrative centre) established during the colonial period in 1549 (de Oliveira and de Aguiar Arantes, 2020). The state of Pernambuco is located in the semi-arid region of Brazil and is highly dependent on the intermittent tributaries of the SFRB. It is highly politicized, with long-established oligarchies coexisting alongside with strong populist traditions and an active civil society. The Federal University of Pernambuco serves as a centre for intellectual and scientific knowledge, hosting several autonomous research institutes and some of the well-established social-development NGOs in Brazil. Alagoas is the second smallest state in Brazil. It is located in the semi-arid region, downstream of the SFRB, on which it is highly dependent.

The chapter explores the questions: What are the current drivers of water challenges in the Bahia, Pernambuco, and Alagoas? Which policy instruments address the water-sharing challenges in Bahia, Pernambuco, and Alagoas?

First, the chapter provides a general historical context of water governance in the three states (see 7.2), then presents the current policy framework (see 7.3), discusses the implications of the water-sharing instruments in the three states (see 7.4), compares the three states (see 7.5) and draws conclusions (see 7.6). As in the chapters on Brazil and the SFRB basin, this evaluation is hampered by limited monitoring of the effectiveness of the different instruments and scattered data which sometimes makes triangulation impossible.

7.2. Water governance in the different states

7.2.1. The political context and historical issues

Although I examine the political context here per state, it should be noted that I am not conducting a political analysis of the instruments. I am focusing on assessing commonalities and differences as they are also part of the same historical conjuncture as they share intervention programmes, policies, laws and culture.

Bahia

Bahia was primarily an export economy based on large single-owner land properties (latifundium) characterized by monoculture and slave labour (until 1888)(Naritomi, Soares & Assunção, 2012). The most common problems during this period identified from an Inclusive Development perspective were slavery, clientelism, high inequalities and poverty, and ecological destruction. From the 1960s onwards, the state's economy had become predominantly industrial and urbanized under the Antônio Carlos Magalhães (ACM) oligarchy (Alcoforado, 2003; Ortega, de Cerqueira & da Silva, 2016). Magalhães was appointed governor of Bahia in the early 1970s by the military government (Herrmann, 2014). He led a political machine that, except for the 1986 election, dominated politics from 1985 until 2006, when the Workers' Party took power (Herrmann, 2014). The most common problems during this period were that, despite an increase in GDP (Junior & Smith, 2004), there remained clientelism practices, violation of human rights, free speech censorship, increase in inequalities and poverty, rural to urban migration, and fragile relations between the government and people (Mera, 2016).

From 2006 to 2015, Bahia experienced considerable economic growth with increased GDP, the middle class's expansion, reduced inequalities and poverty, and increased trust between the state and people (Mera, 2016). However, since then, the state has fallen back into poverty, and ecological destruction has increased. Much like the national level, Bahia has transitioned from an agrarian and export-oriented economy to an economy increasingly influenced by neoliberal capitalist ideals.

Pernambuco

Historically, dynamics in Pernambuco differed. Although likewise controlled by oligarchies, Pernambuco also has a long history of an active civil society. Pernambuco is recognized as one of the states where the most critical rebellions and insurrections occurred during the 19th century (Andrade, 2006; Dantas, 2015). Such events include the 1817 Pernambuco Revolution led by native elites who wanted independence and the 1824 Confederation of the Equator, a separatist movement led by wealthy landowners who opposed early reforms by the central government (de Góes Jr, 2016; Costa, 2017). Both events were suppressed by the government and resulted in Pernambuco being obliged to relinquish parts of its territory to the states of Bahia and Minas Gerais (Andrade, 2006; Martins, 2010). This period is characterized by widespread inequalities and poverty in the state.

In the 1960s, during the military dictatorship, Pernambuco received financial support from the federal government through regional programmes (e.g., SUDENE) aimed at tackling recurring problems of inequalities and poverty (Furtado, 1962; Cardozo, 2018). However, political clientelism was firmly embedded in the operationalization of these programmes. This resulted in more inequalities, poverty, ecological damage, rural to urban migration, free speech censorship, and other violations of human rights, as was also the case in other states (Ames & Keck, 1998; Vasconcelos, 1999; Policarpo Lima, Benzaquem Sicsú & Fernanda G Padilha, 2007).

Between 2007 and 2014, the region experienced considerable economic growth from the expansion of the Suape Port and the development of the tourism industry (e.g., Costa Dourada) (de Arroxelas Galvão, 2015). Meanwhile, the construction of Suape Port, for instance, caused negative social and environmental impacts, including the destruction of mangrove forests, and the state still struggled to tackle increasing inequalities and poverty (Barcellos & Santos, 2019; de Oliveira Rodrigues & Soria, 2020).

Alagoas

As presented for Bahia and Pernambuco, Alagoas has also been controlled by oligarchies. From an ID perspective, there have been several

recurring problems throughout the evolution of political dynamics in the state of Alagoas. These problems include a worsening of inequalities and poverty (Nobre, 2018), ecological damage (Souza et al., 2008), rural to urban migration (Lima, da Silva & do Nascimento Feitoza, 2018), censorship of free speech, and other violations of human rights enabled by a strong presence of political clientelism (Leal, 2012). Some of these problems, also experienced in the states of Pernambuco and Bahia, are rooted in the dominance of large-scale farming activities (e.g., sugarcane monoculture) since the colonial period.

7.2.2. Similarities and differences

7.2.2.1. The physical context of water and related problems

Bahia, Pernambuco, and Alagoas are physically different in many aspects. Table 7.1 summarizes these three states' main characteristics to support this chapter's discussion. Table 7.1 emphasizes that Bahia is more than five times bigger than Pernambuco in terms of area, for example. Almost half of Bahia's territory is located in the SFRB area (48,2%). It is interesting to notice that Pernambuco is highly populated compared to Bahia, considering the size of its territory. The HDI in all the three states is not high, and Alagoas has the lowest one (0,631). The disparity in the characteristics of the three states is indirectly mirrored in water allocation, and it became more evident during recent droughts.

Moreover, Table 7.2 presents the factors that directly and indirectly shape water-related problems in Bahia, Pernambuco, and Alagoas (namely water quality, quantity, and climate variability and change).

Bahia

Bahia is the largest state in Northeast Brazil, covering 567,295 km² (IBGE, 2020) - its territorial extent is comparable to that of France. About 66% (446,021 km²) of its territory is located in the semi-arid region (IBGE, 2020). The state has 15.13 million people (7% of the Brazilian population) distributed between 417 municipalities, producing 4.2% of the country's GDP (IBGE, 2018 & 2020). It comprises plains, valleys, and mountains with altitudes reaching up to 1400 m and high spatial and seasonal variability in precipitation (Simões et al., 2018). The West, South, and Coastal

Table 7.1. Characteristics of Bahia, Pernambuco and Alagoas states

Characteristic	Bahia	Pernambuco	Alagoas
Area, km²	564,7	98,0	27,7
Area part of SFRB, km²	307,7	68,9	14,6
Area part of SFRB, %	48,2%	10,8%	2,3%
Number of municipalities	417	185	102
Population (million)	14.8	9.6	3.3
Population in urban areas (million)	10.1	7.0	2.2
Population density, population per km²	24,82	89,63	112,33
HDI[28]	0,660	0,673	0,631

Source: MMA (2006) ; Brasil (2010); IBGE (2019); AtlasBr (2021)

regions have plenty of rainfall and thus have a high water supply and fertile soils (Interview BA-7).

Many forces, directly and indirectly, drive water-related challenges in Bahia (see Table 7.2). Surface and groundwater are not distributed equally across the state. The water distribution is influenced mainly by local geographical characteristics and the variations and intensity of different meteorological conditions that operate at different times of the year (Silva et al., 2012). Water problems in Bahia include over-abstraction of groundwater for irrigation (e.g., West of Bahia) (Pousa et al., 2019; Pimenta et al., 2021; Silva et al., 2021), desertification (Santos, Machado & González, 2022), and pollution from heavy metals (Aprile & Bouvy, 2008; Souza & de Andrade Lima, 2021).

Pernambuco

Pernambuco has an area of 98.3 km² and is divided into 185 municipalities (IBGE, 2020). It has 9.6 million people, 76% of whom live in urban

28 http://www.atlasbrasil.org.br/ranking

areas (IBGE, 2020). The state contributes approximately 19.2% of the Northeast region's GDP, which is 2.7% of the national GDP (World Bank, 2009). Pernambuco is one of Brazil's driest states, with an average annual water availability of 1,320 m³ per capita, equivalent to 3.5% of the national average (World Bank, 2009). Nearly 89% of Pernambuco's territory is located in the semi-arid region, and thus most of its rivers experience intermittent conditions during dry seasons, except for the SFR (Interview PE-5)(Cirilo, Montenegro & Campos, 2017). As a result, the region has one of the lowest water availability per capita in Brazil, ranging from 400 m³ to 800 m³ per year (equivalent to 20% of water available in the state) (World Bank, 2009). The ` "low average water availability, high seasonal variability, and heterogeneous climate conditions across the state significantly" contribute to water management challenges (White et al., 2019, p.4). Saltwater intrusion is also a challenge in coastal areas of the state, especially during periods of freshwater shortages, which are frequent (Chakrabarti et al., 2017; Petelet-Giraud et al., 2018). Pernambuco is divided in five physiographic regions: Metropolitan, 'Zona da Mata', 'Agreste', 'Sertão' (arid zone), and 'Sertão de São Francisco' (arid zone of the SFRB) (Pinheiro et al., 2018).

Recife, the capital of Pernambuco, is home to nearly 1.6 million people and the larger Metropolitan Region of Recife (RMR) includes nearly 4 million people, all relying on the city's precarious water supply (White et al., 2019). Most of this supply comes from groundwater, and uncontrolled drilling has resulted in overexploitation of the aquifers (Chakrabarti et al., 2017; Marques et al., 2019). In the coastal area of Pernambuco, where the capital is located, the extensive decline in groundwater levels has caused saltwater intrusion, water quality degradation, and potentially influencing subsidence (Cary et al., 2015; Chakrabarti et al., 2017).

Alagoas

Alagoas has an area of 27,848,140 km² (0.34% of Brazilian territory) and a population of 3.3 million inhabitants, with approximately 112 people per km² (IBGE, 2020), the third-highest population density in Brazil. The state consists of 102 cities, including the capital, Maceió. Alagoas has the Lowest HDI in Brazil and is characterized by poor social indicators, including the highest illiteracy rate in Brazil (17.2%) and the second-lowest monthly income *per capita* (IBGE, 2019 & 2020).

Table 7.2. Water problems in Bahia, Pernambuco and Alagoas

Issues		BA	PE	A
Water quantity	Excessive groundwater abstraction	✓	✓	
	Decreasing water availability for nature in some parts of the basin (e.g., upstream)		✓	✓
	Desertification	✓	✓	✓
	Decreasing water quantity (hydroelectric development resulted in the damming process along the SFRB)			✓
	Uncontrolled drilling	✓	✓	✓
	Deforestation	✓	✓	✓
Water quality	Heavy metals (industries, mining sites, agriculture)	✓		
	Silt suspended particles	✓	✓	
	Salinization of groundwater		✓	✓
	Seawater intrusion		✓	✓
Climate variability & change	An increasing number of droughts and floods	✓	✓	✓

Source: de Oliveira et al. (2017), Interview BA-1& 2, Chakrabarti et al. (2017), De Araujo & Power (1993); ANA (2018,2020)

Alagoas is located in the eastern part of the northeast Brazilian region, with altitudes lower than 850 m above sea level (Lyra, Oliveira-Júnior and Zeri, 2014). There are two main biomes in the state, the Atlantic Forest (56.21% of its territory) and Caatinga (43.79% of its territory) (Oliveira, 2019). Alagoas is divided into six physiographic regions: Zona da Mata (humid zone), Litoral (coastal zone), Sertão (arid zone), Sertão do São Francisco (arid zone of the SFRB), Lower São Francisco, and Agreste (hinterland). Some of the state's rivers experience intermittent conditions during dry seasons (ANA, 2018, p.37).

Many forces, directly and indirectly, drive water-related challenges in Alagoas (see Table 7.2). In the coastal zone, where the Metropolitan Region of Maceió is located, there are problems related to water pollu-

tion, deforestation, erosion, and siltation of rivers (De Araujo & Power, 1993; Soares et al., 2020). Saltwater intrusion is also a concern in this area, where, for instance, saline intrusion extension in the estuary was estimated at around 16 kilometres in 2018 (Soares et al., 2020). This has significantly impacted traditional fisheries and communities dependent on that livelihood.

In conclusion, Table 7.2 summarizes that all three states have water quantity problems, such as desertification in some areas of their territory. Excessive groundwater abstraction is a recurrent problem, mainly in Bahia and Pernambuco. Pernambuco and Alagoas have been suffering from high degrees of salinity and seawater intrusion. Climate change variation issues and an increasing number of droughts and floods have been common for all the states in the last decade.

7.2.2.2. Direct and indirect drivers of water-related challenges of Bahia, Pernambuco, and Alagoas

Many factors, directly and indirectly, shape water-related problems (namely water quality, quantity, and climate variability and change) in the three states part of the SFRB (see Table 7.3). The historical evolution of increasing water demand in SFRB is clearly linked to the intertwined processes of developing large infrastructures such as large hydroelectric plants and irrigation systems. Similar drivers have shaped the water-related challenges in all states: demand for commercial agriculture and livestock, urbanization, economic development, and climate change.

First, **demand for commercial agriculture and livestock:** Bahia is the major producer of grains in the Northeast and the country's second-largest producer of fresh fruit (IBGE, 2018 & 2019). The Western part of the state is considered one of the most active agricultural frontiers in the world, which uses Urucuia groundwater for irrigation purposes (Schlesinger and Noronha, 2006; Oliveira et al., 2019; Pousa et al., 2019). However, agricultural expansion throughout the state has largely contributed to deforestation, desertification, violation of environmental policy, and excessive groundwater abstraction (de Oliveira et al., 2017; de Oliveira Junior et al., 2018).

Historically, Pernambuco's economic growth has been based on large-scale sugarcane plantations, which have contributed to the deforestation and degradation of large coastal areas of the Atlantic For-

est[29] (Interview B-4)(Andrade, 2001; Lima, 2018). Commercial agriculture in these areas also causes a great deal of water pollution from the use of toxic chemicals (e.g., insecticides and pesticides) that result in a heavy concentration of metals and phosphorus in the water (Interview B-3) (Gunkel et al., 2007; Nascimento, 2013).

In Alagoas state, since the colonial period, sugarcane monoculture has also been one of the main profitable economic activities in the state (Knupfer & Assad, 2017). In the littoral zone, sugarcane production currently represents 87% of the state's exports (Freire & Natenzon, 2019, p.219). However, a study conducted by Castillo et al. (2017) focusing on bioethanol production identified negative consequences of this activity within interregional trade. For example, despite having limited water availability, Alagoas was considered the second-highest exporter of virtual scarce green water from bioethanol production. This study confirmed the increasing stress on water resources and the risk of food insecurity (Castillo et al., 2017)largely driven by national and international carbon mitigation targets. However, biofuel crops require significant amounts of water and land resources that could otherwise be used for the production of food, urban water supply, or energy generation. Given Brazil's uneven spatial distribution of water resources among regions, a potential expansion of ethanol production will need to take into account regional or local water availability, as an increased water demand for irrigation would put further pressure on already water-scarce regions and compete with other users. By applying an environmentally extended multiregional input-output (MRIO.

Second, **Rapid and disorganized urbanization:** In Bahia, rapid and disorganized urbanization is pushing low-income populations to informal settlements where they are left to their own devices when it comes to accessing drinking water, as is also the case at the national level (Interview BA-1)(Santos, 2010; Santos Oliveira and Estevam, 2019). Residents of informal settlements are the most exposed to water-related risks considering that the settlements often lack adequate infrastructure for sanitation, drainage, and solid waste collection, thereby increasing contamination risks and clogged drains (SNS, 2018). In addition, only 39% of the state population has access to sewage collection, and only 52% of the volume of Bahian sewers is treated (SNS, 2018).

In Pernambuco, since the 2000s, the high rate of urbanization and economic activities in the coastal regions have significantly increased

29 https://www.sosma.org.br/iniciativa/atlas-da-mata-atlantica/#

these problems (Magarotto *et al.*, 2016; Magarotto &Costa, 2018). According to Calvante (2020)[30], 19% of Pernambuco cities do not have a sewage collection network; 50.9% of treated water is lost on the way to consumers' homes; and the state has the highest percentage of brackish water abstraction in the country at 23%, more than the entire Northeast at 10.2% and far above the national average of 2.7%. In addition, only 83 cities in the state monitor the quality of water that reaches their populations (Calvante 2020). In rural areas, the sanitation deficiency is even worse, with 56 municipalities lacking a water distribution network and 111 lacking a sewage collection system (Calvante 2020).

Moreover, between 1980 and 2006, urban populations in Alagoas cities rose from around 600,000 to two million (Freire & Natenzon, 2019, p.219). Consequently, between 1991 and 2000, most regional municipalities transformed from eminently rural to dominantly urban (Freire & Natenzon, 2019, p.219). However, most migrants from rural areas could not find work in the urban areas due to a lack of qualifications (Freire & Natenzon, 2019, p.219). The population variation created intense pressures on urban infrastructures and services, which local authorities could not provide (Freire & Natenzon, 2019, p. 219). Therefore, informal settlements increased, which increased the risks of contamination and clogged drains due to the lack of adequate infrastructure for sanitation, drainage, and solid waste collection. In 2000, only 50% of Alagoas households (650,000) had individual wells for wastewater, and only 15% were connected to the general sewage system (Freire & Natenzon, 2019, p.219).

As already noted, climate variability and change are crucial underlying drivers of water issues in the three states. Extreme weather events and rainfall are increasingly more common in all three states. A large area of Bahia is susceptible to natural disasters (e.g., droughts and floods) (Rios, Silva & Carvalho-Santos, 2020; da Silva *et al.*, 2021). These disasters have been increasing in the last decades and have had adverse and prolonged effects on the state's economy and society (CEPED/UFSC, 2013; Novais, 2020). Between 1991 and 2016, 3,605 disasters were recorded, with 79% related to droughts and the rest to floods (CEPED/UFSC, 2013; Novais, 2020). Meanwhile, some areas of the state are already in the desertification process due to increasing droughts in the last decade (Spinoni *et al.*, 2015; Dourado, 2017)

30 https://www.diariodepernambuco.com.br/noticia/vidaurbana/2020/07/50-9-da-agua-tratada-em-pernambuco-se-perde-na-distribuicao-diz-ibge.html

Table 7.3. Drivers of water problems in Bahia, Pernambuco and Alagoas

Direct Drivers	BA	PE	A
Demand for commercial agriculture	✓	✓	✓
Demand for energy	✓	✓	
Demand for households	✓	✓	✓
Demand for industry and service	✓	✓	✓
Natural changes and variability in weather (e.g., droughts and floods)	✓	✓	✓
Indirect Drivers			
Rapid and disorganized urbanization	✓	✓	✓
Economic policy (the pursuit of economic growth)	✓		
Agriculture policy	✓		
Climate change (e.g., increase in desertification)	✓	✓	
Upstream pollution			✓
Poverty	✓	✓	✓

Source: ANA (2017), Cerqueira (2017); Chakrabarti et al. (2017), IBRAM (2018), Freire Natenzon (2019), Ferreira et al. (2021), de Alcantara et al.(2020), Nicollier, Cordeiro Bernardes, Kiperstok (2022), Interview AL -10, Fieldwork

In specific, projections of possible effects of climate change in Pernambuco from 2040 through 2100 show increasing vulnerabilities in agricultural production, including loss of crops in the medium to long term, a series of adverse socioeconomic effects, and a decrease in reservoir water levels, which will affect water supply for human and animal consumption, and power generation (Assad et al., 2019). While in Alagoas, projections of possible effects of climate change indicate the rising sea levels in Maceió city (the capital), some coastal cities and disappearance of some cities in Alagoas[31], sinking of some areas because of excessive groundwater pumping that creates a change in pressure and volume that causes the land to sink (Interview AL – 7/ AL – 10) (CPRM, 2019; Euillades et al., 2020).

31 https://tribunahoje.com/noticias/cidades/2021/07/17/avanco-do-mar-ameaca-orla-de-maceio/

Poverty is also a critical driver significantly affected by income distribution in all states. However, poverty is severest in Alagoas. According to Nóbrega Barbosa et al. (2021, 2), "the concentration of wealth along the coast contrasts strongly against the extreme poverty and socioeconomic deprivation of Alagoas". The Human Development Report from 2010 also pointed out how Alagoas has been transformed into the most unequal state in Brazil, with a Gini Index for household income at 0.63, demonstrating a high degree of polarity between rich and poor (Freire & Natenzon, 2019, p.219). Half of Alagoas' population is dependent on social services like conditional cash transfer programmes (e.g., Bolsa Família[32]) (de Carvalho, 2008) (Interview AL - 10). Around 64.5 thousand homes are situated in favelas (slums), and 55.1 thousand are located in the capital (Maceió)(Gonçalves, 2020). Moreover, looking at the newspapers, upstream pollution is a big issue in the state[33].

7.2.2.3. Sharing challenges in Bahia, Pernambuco and Alagoas states

Bahia

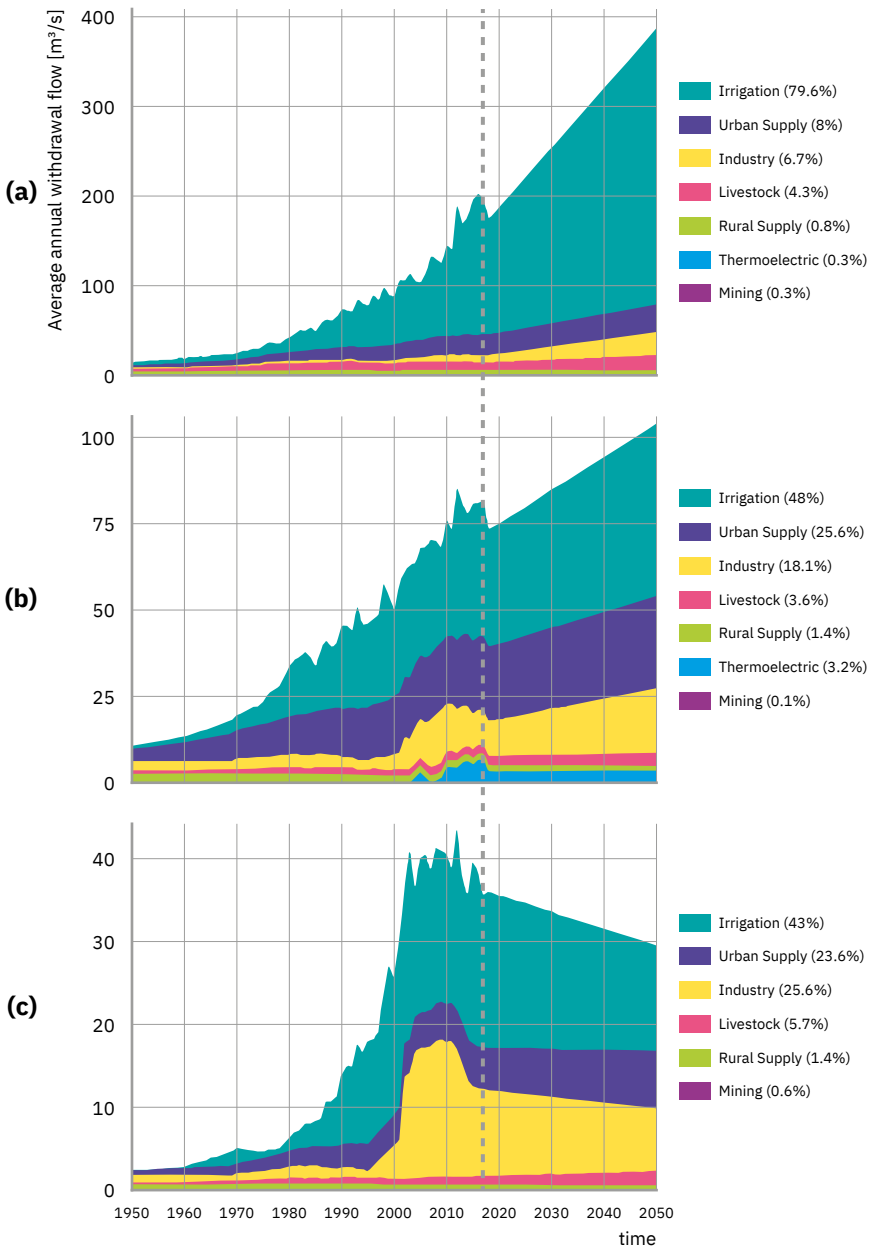
In 2017, the main consumptive uses of water in Bahia were agricultural irrigation (79.6%), urban supply (8%), and industries (6.7%)(ANA, 2019d). Figure 7.1 (a) presents the evolution of water withdrawal per use in Bahia, considering historical data between 1950 and 2017 and projections towards 2050. This table is based on data of water licensed, the best available proxy for water use. In 2017, water withdrawal for irrigation use in Bahia was almost 30% higher than the national average. The steep increase from the mid-1980s occurred due to high investment in the expansion of irrigated areas through irrigation programmes implemented in the Brazilian Northeast (Interview BA-17) (see 6.3). Projections of future withdrawal in the state are high compared to other states in the basin because Bahia is located in the Middle São Francisco, where water availability is most in the basin.

Moreover, hydroelectric production is also concentrated in this state, indicating one more challenge for water-sharing as they are highly

32 https://ipcig.org/pub/IPCWorkingPaper21.pdf

33 https://www.noticiaquente.com.br/site/post/mar-avanca-sobre-rio-sao-francisco-e-afeta-populacao-ribeirinha-em-alagoas/2115

Figure 7.1. Evolution and projected water withdrawal by use in Bahia (a), Pernambuco (b), and Alagoas (c) (1950 - 2050)



Source: Author's elaboration based on raw data from ANA (2019)

The dashed line delimits the year 2017 (historical data and future projected data)

dependent on water. Even though hydroelectricity is not a direct water consumptive user, it affects water-sharing because hydroelectric power is derived from flowing water. It means that it is necessary to have a specific level of water on the dam to move the turbines and produce energy (Interview N - 2). For instance, Bahia has the biggest hydroelectric dam Sobradinho with 1,050 MW power output, and other important ones such as Paulo Afonso I, II, III, and IV (3,986 MW) and Itaparica (1,500 MW) (Brazil 2004; ANA 2015). Therefore, often there is a conflict of interest between the energy and agriculture sectors.

The balance of water sharing between humans and nature in Bahia has been directly affected by uncoordinated growth in commercial agriculture, specifically the increased pumping from the Urucuia Aquifer System for agribusiness in the Western region (Oliveira et al., 2019; Pousa et al., 2019). Around 6% of the base flow of this area's main rivers has been reduced due to intense use of surface and groundwater storage (Oliveira et al. 2019).

Commercial agriculture, through supply to farms, villages, and irrigation projects, has also caused direct and indirect damage to nature in the Western region (de Oliveira et al., 2017; Oliveira et al, 2019). These damages include deforestation and land degradation from losses of topsoil, vegetation, and biodiversity and increases in soil salinity and desertification processes (Siqueira Filho, 2012) (Interview B-2). Moreover the intense water withdrawal for irrigation purposes has been causing several conflicts in Bahia, for instance the well-known case of Salitre River basin (see Box 7.1).

Pernambuco

In 2017, water-sharing in Pernambuco occurred between irrigation (48%), urban supply (25.6%), industries (18.1%), livestock (3.6%), and thermal electricity generation[34] (3.2%) (ANA, 2019d). Figure 7.1 (b) illustrates the evolution of water demand per use in Pernambuco between 1950 and 2017, including projections through 2050, according to ANA (2019). This table is based on data of water licensed, the best available proxy for water use. In 2017, water withdrawal for water supply use in Pernambuco was 25.6%, considered higher when compared with the national amount and the other states such as Bahia and Alagoas.

34 Thermal power station uses a lot of water because thermoelectric power generation because it needs water during the cooling of the electrical generating equipment (Interview N - 2).

Box 7.1. Demand for commercial agriculture and Salitre disputes

The intense water withdrawal for irrigation purposes in the Salitre River basin is a well-known example of the pursuit of economic growth in Bahia. The Salitre River basin is in the north of Bahia (13,467.93 km²) in the semi-arid region. The main river is 333 km long and is one of the São Francisco River tributaries. It crosses nine municipalities (Boca da Madeira, Várzea Nova, Miguel Calmon, Ourolândia, Umburanas, Jacobina, Mirangaba, Campo Formoso and Juazeiro).

In the 1970s, the federal government intensified agricultural activities through the Development Company of the São Francisco Valley (CODEVASF) (see 6.3.3). Several irrigation systems (approximately 30,000 ha) were developed through partnerships with private companies. The developed perimeters focused on sugarcane crops and were driven by non-water policy intervention. Since the implementation of the irrigation systems, there have been constant tensions between commercial irrigators and smallholder farmers (Rossi &Santos, 2018). In the mid-1980s, a violent conflict scaled up between the two users, resulting in several deaths.

The intense use of the Salitre's water by commercial users has also caused the drying up of the low Salitre river (Nascimento &Becker, 2009). The river, which used to be permanent, has become semi-perennial, directly impacting a nearby community that depended on its resources (Rossi & Santos, 2018).

Note: This text is based on the Interview with BA-17

The state's Water and Sanitation Company (Compesa) provides water supply services to around 2.3 million households and sewage services to 600,000 households (World Bank, 2020,p. 5). In doing so, the company faces many challenges, including high water losses, exacerbating the existing water scarcity problems. While there have been some improvements in the last ten years, non-revenue water (NRW) remains very high, with an average of 57.3% (World Bank, 2020). In volumetric terms, current water losses stand at 678 litres per connection per day, and this is the highest among Brazilian metropolitan cities. Another challenge faced by Compesa is water supply intermittency, given an average supply time of around 20 h/day. In some areas the rationing is much more strict than in others (Interview B-3). This holds in particular for the Northern part of the RMR, and also in the higher areas of the hills (World Bank, 2020). Sanitation is consider low and it covers about 42 percent, and this number is even lower in the poor areas (World Bank, 2020). In the RMR,

only “an estimated 20% of total sewage is treated, and the four existing treatment facilities present have severe operational problems” (World Bank, 2020, p. 4). Therefore, the “heavily contaminated river system affects the quality of the water along the coast, especially the northern coast, from Olinda onwards” (Interview B-3; World Bank, 2020,p. 4).

Alagoas

According to 2017 water allocation statistics, the major classes of consumptive water use in Alagoas were irrigation (43%), urban supply (23.6%), industries (25.6%), and livestock (5.7%)(ANA, 2019d). Figure 7.1 (c) illustrates the evolution of water demand per use in Alagoas between 1950 and 2017, including projections through 2050. This table is based on data of water licensed, the best available proxy for water use. The figure reveals a tendency towards a gradual decrease in water withdrawals for irrigation after 2017, and one of the main reasons is water availability. The SFRB water availability has significantly decreased over the years, and the state is highly dependent on the SFRB.

Uncoordinated growth in commercial agriculture has also directly impacted the balance of water sharing among uses, users, humans, and nature: for example, sugarcane, which requires large volumes of water (an average of 20 mega litres/ha), is a primary crop in the state. However, its production has also declined due to the low availability of water (Interview AL-3). Another area highly impacted by the high fluctuation of water levels in the SFRB is rice cultivation downstream (Soares et al., 2020).

Salt mining has been extensively explored by the private company BRASKEM S.A (part of the Odebrecht Group) in Maceió City, the largest city and capital of Alagoas, with nearly 932,078 people. This extensive exploration has deformed the underground caverns of the densely populated neighbourhoods of Pinheiro, Bebedouro, Mutange, and Bom Parto (Euillades et al., 2020). In 2018, after heavy rains and a significant earthquake, these neighbourhoods were further affected by cracks and sinking events in buildings and city infrastructure[35] (Euillades et al., 2020). Around 13,641 houses were evacuated, and 57,000 people were directly affected. A total of

35 https://www.brasildefato.com.br/2020/01/14/quatro-bairros-de-maceio-podem-desaparecer-por-conta-da-acao-de-mineradora; “Afundamento em Maceió já atinge 4.500 comerciantes e realoca até hospital” - Folha de S. Paulo, 01/08/2021 and https://bit.ly/3izmYh6; “A Braskem passou por aqui: A catástrofe de Maceio” | Carlos Pronzato: https://youtu.be/zBOJbOGcBwo

Figure 7.2. Sedimentation process at the lower part of the river at Piaçabuçu City in Alagoas state

Source: Jonathan Lins/G1 (2017)[36]

more than 5,000 business stores, schools, gas stations, and a hospital were in imminent danger.25 Most of them are still waiting for compensation from the private company. This salt mining exploration is a classic example of conflicting interests between users, humans, and nature.

The combination of the damning upstream, increased agriculture, and climate variation has resulted in a lower flow of the SFRB and sea-water intrusion. In 2015, the sedimentation and salinity of the river increased downstream and contaminated drinking water (Figure 7.2). In Piaçabuçu City, 25 thousand people were directly affected by the contamination[37] (Interview B- 8). There is unequal water-sharing from upstream to downstream, humans and nature, users, and uses (Sax, 2020) (Interview B- 8).

36 https://www.noticiaquente.com.br/site/post/mar-avanca-sobre-rio-sao-francisco-e-afeta-populacao-ribeirinha-em-alagoas/2115

37 High consumption of substantial amounts of sodium through drinking water can affect human health causing high blood pressure, for example.

Finally, based on the main consumptive uses of water and the sharing challenges between the three states, it is possible to notice some differences among them. In Bahia, the main struggle is based on disputes between irrigator users, as almost 80% of the water supply is directed to the agriculture sector. However, in Pernambuco, the dispute is focused on uses: between agriculture and urban water. In Alagoas, the problem is between humans and nature, as the state already suffers from sedimentation and seawater intrusion (Oliveira et al., 2018).

7.3. Current policy frameworks

This section examines the current water policy framework and instruments dealing with water-sharing in the states of Bahia, Pernambuco, and Alagoas. As the national discourse on water in Brazil shifted from a centralized to a decentralized approach, as presented in section 5.2.4, the national policy is now mirrored at the state level.

7.3.1. Current policy framework in Bahia

This section examines the current water policy framework and instruments dealing with water-sharing in Bahia. The state discourse on water in Bahia has shifted from a centralized to a more decentralized approach with the adoption of the Water State Law in 1995 (State Law No. 6855/1995), prior to the Federal Law (Federal Law No. 9433/1997, see 5.3). The state law intended to develop the state's water resources and strengthen rational use thereof considering the following principles:

> "(I) it is the right of everyone to have access to state resources (human rights principle); (II) the distribution of water within Bahia must always obey economic, social, and environmental dynamics; (III) the planning and management of the use of water resources in the state should be compatible with the requirements of sustainable development; and (IV) the charge for the use of the state's water resources must always take into account the economic and social situations of the consumer" (State Law No. 6855/1995).

The Law also established three key instruments: (i) the State River Basin Plan; (ii) water permits; and (iii) water use charges (Art. 4, State Law No.

6855 of 1995). In other ways, however, this new framework conflicted with the 1997 National Water Law as it did not actually elaborate on participatory management, nor clarify the legal conditions that enable the operationalization of watershed committees (Ogata, 2001:4; Brannstrom et al., 2004). The 1995 State Law vaguely stated that Bahia could not operationalize a committee until legally permitted, yet such a law was never enacted (Interview BA-17). In this regard, the State Law reinforced the state's centralized and top-down governance system. In 1988, Bahia created the Water Resources Council (CONERH) 1998 (State Law No. 7354), marking the beginning of institutionalized participation of civil society and users in the water resources management process in Bahia (Matos and Pereira, 2012).

In 2006, the state discourse on water in Bahia became more decentralized with adopting the new water governance framework (State Law No. 10432/2006). This new framework intended to create the State Water Resources Management System considering the following principles:

> "(I) everyone has the right to access to water, a natural resource indispensable to life, social promotion, and development; (II) the priority use of water is human supply and animal drinking; (III) the management of water resources must always account for the multiple uses of water; (IV) water is a limited natural resource with economic value; (V) water use management must be decentralized, involving the participation of the government, users and civil society organizations; and (VI) the hydrographic basin is the territorial unit for the planning and management of water resources" (Art. 2, State Law No. 10432/2006).

Related instruments proposed by the new Law included six instruments: (i) the State Water Resources Plan; (ii) the Hydrographic Basin Plans; (iii) the classification of the water bodies according to their predominant uses; (iv) the granting of the right to use water resources; (v) charging for the use of water resources; and (vi) the State Water Resources Information System. (State Law No. 10432/2006). Therefore, these proposed instruments are entirely in line with the structure proposed by ANA in Figure 5.3.

Since 2011, the Institute of Environment and Water Resources (INEMA) has assumed responsibility for managing state water resources and environmental issues (Interview BA-17) (Inema, 2020). It is also respon-

sible for monitoring droughts in the Brazilian Northeast (Gutiérrez et al., 2014) and has normative and advisory duties, including implementing programmes related to the environment, water resources, protection of biodiversity, and climate change. However, even with the increasing number of weather-related disasters[38] in the last decades, Bahia still does not have a policy on climate change (Novais, 2020). Thus, water-related risks in the state remain unaddressed (Interview BA - 1).

Regarding participation, progress has been made in Bahia as the establishment of Basin Committees was adopted as part of the Water Resources Management System in 2005 (Law 9843, 2005). Table 7.4 displays the overview of the planning units (hydrographic basins) and the sub-basin committees implemented in Bahia. This table is based on data available from the literature review (Cerqueira, 2017; Cerqueira, Fadul & Spínola, 2020). Currently, Bahia has 14 sub-basin committees installed and functioning (Cerqueira, Fadul & Spínola, 2020). It is interesting to notice that 11 of the planning units are tributaries of the SFRB, which directly contribute to the water quantity and quality of the river. Besides, six of the tributary of the SFRB have a sub-basin committee settled.

Even though, it is possible to notice that there is a progress in the implementation of the committees in Bahia. It is also true that they are financially dependent on INEMA, and they have been receiving limited funding (Cerqueira, Fadul & Spínola, 2020). The main consequences are that it compromises the participation process in the elaborations of the river basin plans (Cerqueira, Fadul &Spínola, 2020). Therefore, it is not enough to create participatory spaces (Agrawal &Ribot, 2000; Abers & Jorge, 2005) such as the basin committees; it is fundamental to create conditions for decentralization to be effective (Arretche, 1996; Abrucio, 2002; Cerqueira, Fadul & Spínola, 2020).

The implementation of water resources management policies in Bahia has been marked by numerous weaknesses, including limited funding, poor coordination, and corruption (Interview BA-1) (Cerqueira, Fadul & Spínola, 2020). The monitoring and inspection of the implementation processes have offered little comprehensive data (Silva et al., 2017). Specific instruments like charges for water use have not even been implemented.

38 https://g1.globo.com/ba/bahia/noticia/2019/09/28/governo-decreta-estado-de-emergencia-em-140-cidades-da-bahia-por-causa-da-seca.ghtml

Table 7.4. Planning units and sub-basin committees implemented in the tributary of the SFRB in Bahia

Source: Cerqueira (2017) and Cerqueira, Fadul & Spínola (2020)	Sub-basin committee established	SFRB Tributary
Riacho do Tará	Not established	Yes
Rios Macururé e Curaçá	Not established	Yes
Rio Salitre	Yes, established in 2006	Yes
Rios Verde e Jacaré	Yes, established in 2006	Yes
Lago de Sobradinho	Yes, established in 2008	Yes
Rios Paramirim e Santo Onofre	Yes, established in 2009/2010	Yes
Rio Grande	Yes, established in 2008	Yes
Rio Carnaíba de Dentro	Not established	Yes
Rio Corrente e Riachos do Ramalho, Serra Dourada e Brejo Velho	Yes, established in 2008	Yes
Rio Carinhanha	Not established	Yes
Rio Verde Grande	Not established	Yes
Riacho Doce	Not established	No
Rio Mucuri Rios	Not established	No
Peruípe, Itanhém e Jucuruçu	Yes, established in 2009/2010	No
Rios dos Frades, Buranhém e Santo Antônio	Yes, established in 2009/2010	No
Rio Jequitinhonha	Not established	No
Rio Pardo	Not established	No
Leste	Yes, established in 2006	No
Rio das Contas	Yes, established in 2008	No
Recôncavo Sul	Yes, established in 2009/2010	No
Rio Paraguaçu	Yes, established in 2006	No
Recôncavo Norte e Inhambupe	Yes, established in 2006	No
Rio Itapicuru	Yes, established in 2006	No
Rio Real	Not established	No
Rio Vaza-Barris	Not established	No

Source: Cerqueira (2017) and Cerqueira, Fadul & Spínola (2020)

Compared to other states in the SFRB, Bahia actively resisted the participatory shift in water governance (Interview BA-17) Interview BA-1). The main reason behind this could be that the dominant water users in the state (commercial agriculture) had substantial political influence against the new framework and did not want their influence limited by being brought to the same level as other users (Interview BA-1/17). Hence, like the one before, this new framework was also not successful or as progressive as the one adopted in São Paulo (Interview BA-17).

7.3.2. Current policy framework in Pernambuco

The current water governance in Pernambuco can be considered more progressive than in other states because of the water scarcity and the strong participation of the university and civil society. The framework in Pernambuco was established in 1997, the same year as the federal water governance framework. Hydraulic engineering professors from Pernambuco Federal University were invited to advise the state government on its design process (Interview PE- 3/ PE- 4/ PE- 5).

Also, in 1997, Pernambuco instituted the Water Resource State Policy through State Law No. 11426/1997 and further ensured the conservation and protection of groundwater through State Law No. 11427/1997. Pernambuco is one of three Brazilian states with specific groundwater laws and where groundwater management has been intensely discussed in the last 20 years (Cabral et al., 2008). The constant discussion is because of the low average water availability, heterogeneous climate conditions across the state, and the influence of civil society (Interview PE- 3).

In 2005, the state's institutional capacity for water resources management was further strengthened through the creation of the State Water Resources Policy (SIGREH/PE) (State Law No. 12984/2005). This policy emphasized stakeholders participation, improved water quality and quantity control, and issuance of penalties for water-related violations. In addition, seven policy instruments were defined by this law to achieve integration of water resources management: (i) Master Plans; (ii) classification of water bodies according to their designated uses; (iii) water permits; (iv) water use charges; (v) Water Resources Information Systems; (vi) inspections; and (vii) monitoring (Art. 5, State Law No. 12984/2005).

In 2007, the State Department of Water Resources was established, followed by the creation of the Pernambuco Water and Climate Agency

(APAC) in 2010. Hydraulic Engineering professors from Pernambuco Federal University were also invited to advise on these two developments. Later, through APAC, the State Policy on Water Resources (State Law No. 14028) was established (White et al., 2019).

The Pernambuco water resource management model is a product of a joint effort between the Pernambuco State Environmental Agency (CPRH) and the State Department of Water Resources. CPRH is mainly responsible for environmental licenses, while the State Department of Water Resources is responsible for setting water use concession terms. Being under constant water stress from low average annual water availability in the state, Pernambuco has been much more active and progressive in the governance thereof than other states (e.g., Bahia and Alagoas). However, the integration of environmental planning in water management remains in progress and requires more commitment to performance from the state (Silva & Silva, 2014).

Regarding participation, progress has been made as Basin Committees were adopted as part of the Water Resources Management System.

Table 7.5 displays the overview of the planning units (hydrographic basins) and the sub-basin committees implemented in Pernambuco. This table is based on data available from APAC[39]. Currently, Pernambuco has five Sub-basin Committees installed and functioning in the 13 Hydrographic Basins[40]. All of them are financially dependent on APAC[41]. The members from the Basin Committees have been arguing that they have been receiving limited funding from APAC, therefore, comprising the participation process and the elaboration of the river basin plans (Interview PE- 4/ PE- 5), the same as occurred in Bahia.

When compared to other states in the SFRB, the implementation of water resources management policies in Pernambuco has marked a participatory shift in water governance and implementation of several instruments. The main reason behind this could be the presence of the hydraulic engineering professors from Pernambuco Federal University who were invited to advise in the design of the State Policy on Water Resources, APAC and training of technicians (Interview PE- 3/ PE- 4/ PE- 5), for example.

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39 https://www.apac.pe.gov.br/

40 It is important to note that the several sub-basins drain into the São Francisco River (e.g., Pajeú, Ipanema, Terra Nova)

41 https://www.apac.pe.gov.br/

Table 7.5. Planning units and sub-basin committees implemented in the tributary of the SFRB in Pernambuco

Planning Units	Sub-basin committee established	Tributary of the SFRB
Goiana	Yes, established in 2004	No
Capibaribe	Yes, established in 2007	No
Ipojuca	Yes, established in 2002	No
Sirinhaém	Not established	No
Una	Yes, established in 2002	No
Mundaú	Not established	No
Ipanema	Not established	Yes
Moxotó	Not established	Yes
Pajeú	Yes, established in 1998	Yes
Terra nova	Not established	Yes
Brígida	Not established	Yes
Garças	Not established	Yes
Pontal	Not established	Yes

Source: Based on row data from APAC(2013)[42]

7.3.3. Current policy framework in Alagoas

The current water governance framework in Alagoas was established in 1997 (State Law No. 5965/1997). The framework was established as a result of the financial-economic support received from the World Bank through the Federal Water Resources Management Project (PROÁGUA) in 1997 and Progestão in 2013 (Interview B-9). It was intended to ensure the decentralization of water governance and furtherance of the design and implementation of water policy instruments such as water permits and sub-national committees.

42 https://reporterbrasil.org.br/2007/03/pernambuco-e-as-aguas-do-rio-sao-francisco/

Table 7.6. Planning units and sub-basin committees implemented in the tributary of the SFRB in Alagoas

Planning Units	Sub-basin committee established	SFRB Tributary
Rio Piauí	Yes, established in 2005	Yes
Rio Coruripe	Yes, established in 2003	No
Rio São Miguel	Yes, established in 2006	No
Rio Pratagi	Yes, established in 2005	No
Complexo Estaurino Lagunar Mundaú-Manguaba	Yes, established in 2006	No

Source: Based on row data from the Environment and Water Resources (SEMARH)[43]

The main instruments proposed by the current framework are the State Water Resources Plans, classification of water bodies in classes, water permits, charging for the use of water resources, sharing of the costs of water resources construction, municipalities' compensation, the State Water Resources Information System, and the State Water Resources Fund (Art. 9, State Law No. 5965/1997). Most of them are only recognized on paper as the state lacks a budget to operationalize them (Interview AL-2/ AL-4).

In the case of sub-national committees, Table 7.6 displays the overview of the planning units (hydrographic basins) and the sub-basin committees implemented. This table is based on data available from SEMARH[44]. It is interesting to notice that Alagoas has only one SFRB tributary, which has fundamental importance for the socioeconomic development of the region (Interview AL-2/ AL-4). The water framework implemented was largely influenced by the IWRM paradigm (Lopes, 2005).

In 2003, the State Secretariat for the Environment and Water Resources (SEMARH) was created and tasked with managing water resources and environmental issues. The state does not have policies on climate change or drought. In terms of crisis management of droughts and floods, reactive actions have been adopted, such as tank trucks for

43 http://www.semarh.al.gov.br/comites-de-bacias

44 http://www.semarh.al.gov.br/comites-de-bacias

drinking water distribution, and sometimes lines of credit are made available to small farmers (Brito et al., 2018). However, political clientelism is still strongly embedded in these reactive actions. Often, the adoption process involves exchanges of votes for many kinds of material goods during the local elections (Interview AL-3/AL- 4).

7.4. Analyzing water sharing in Bahia, Pernambuco and Alagoas

This section assesses the functioning of the selected water-sharing instruments in Bahia, Pernambuco and Alagoas. It provides a qualitative assessment of the functioning of the instruments from design to goal achievement (see Table 2.5 for the assessment criteria) and analyses to what extent the instrument contributes to inclusive development (see 2.2 for the assessment criteria). Thus, Table 7.7 displays the five key instruments, analysed in the following section, through which water sharing is organized in the three states.

7.4.1. Priority of use

Bahia

In terms of the *design*, the 2009 State Water Law in Bahia adopted the priority of use as a principle inspired by the 1997 National Water Law. In the case of water scarcity, the priority of use instrument allocates water for drinking for humans first and animal livestock second (Art. 2, II, State Water Law No. 11612/2009). Water availability is determined based on the minimum flow of the supplying river. In a 'normal period', water is allocated based on the accountability instrument (i.e., identifying state water resources and river basin plans). Recognition of the priority of use instrument on paper (Art. 2, II State Water Law No. 11612/2009) indicates progress in accordance with Federal Law No. 9433/1997, which presents the sequence of priorities of use during periods of water scarcity. The adoption of this principle explicitly commits to supporting priority of use during water scarcity and promotes universal access to water.

In practice, however, the *implementation* of this instrument lacks specificity and strategic guidance on how water should be allocated. For instance, when prioritizing the allocation of water to livestock, it is un-

Table 7.7. Sharing instruments in Bahia, Pernambuco and Alagoas policy documents

Instruments	Water-sharing categories	Policy		
		Bahia	Pernambuco	Alagoas
Priority of use	Sharing of water between uses	State Water Law No. 11612/ 2009	State Law No. 11.426/1997	State Water Law No. 5965/1997
Water use permit for allocating water to large users	Sharing of water between users	State Water Law No. 11612/2009	State Law No. 12984/2005	Decree No. 532/2002
Protected areas	Sharing of water between humans and nature	State Law No. 10431/2006	State Law No. 13787/09; Law No. 9985/2000 and Decree (No. 3834/2001 and 4340/2002)	State Law No. 7776/2016
Minimum flow	Sharing of water between humans and nature	State Decree No. 6296/1997	Decree No. 6296/1997	Decree No. 006/2001
Climate proofing	Sharing of water-related risks		State Law No. 14090/2010	

Source: Author's elaboration

clear which animals should have priority. The instrument does not have a specific budget because it is classified as a principle.

The priority of use instrument in Bahia does not promote the preservation of ecosystem services. Nor does it consider sustainable use of water resources; hence it implies severe consequences on the health of ecosystems. According to a 2018 study conducted by Dos Santos on the lower Paraguaçu River located in the state of Bahia, the implementation of the Pedra do Cavalo dam has resulted in a decrease in the river flow. In terms of the ichthyofauna, there were changes in the species set, increased non-native species, and loss of sensitive species (Dos Santos, 2018).

Pernambuco

The *design* of the priority of use instrument was instituted as a principle in Pernambuco in 1997 by State Law No. 11.426/1997 in Art. 2, III. The instrument determines that, in the case of water scarcity, priority in water

use must be given first to humans and then to animal consumption in the livestock industry (Article 2, III), the same as in Bahia. In 'normal periods', water is allocated based on state water resources plans, which determine groundwater and tributary river water availability and the terms of water permits granted to individual users. *Operationalization* of this instrument is the responsibility of APAC, which is also responsible for elaborating and implementing the plans for the hydrographic basins. In terms of budget, the priority of use policy does not have a specific budget because it is classified as a principle. In terms of *implementation*, the state of Pernambuco promotes universal access to water, explicitly commits to the priority of use instrument, especially during periods of water scarcity, and its aim is to universalize access including low-income and marginalized groups.

Alagoas

In Alagoas, the *design* of the priority of use instrument is recognized in the State Water Law, following guidelines of the Federal Law No. 9433/1997 and showing commendable progress. During water scarcity, the priority of use is given first to humans and second to animals in the animal husbandry sector (State Water Law No. 5965/1997, Art. 1, III). In 'normal periods', the priority of use is coordinated with water availability, considering water resources plans and water permits. The priority of use instrument has been recognized on paper but not yet effectively implemented in practice. It does not have a budget.

The design of the priority of use instrument can be considered socially inclusive as it commits to minimizing the risk of water damage. The State Laws explicitly adopt priority of use as a principle, supporting priority of use during water scarcity, first to humans and second to animals (e.g., in Bahia Art. 2, II, State Water Law No. 11612/2009). This instrument considers human well-being and promotes universal access to water, thus, on paper, increasing the probability that the urban and rural poor people have access to drinking water.

In all three states, the design of the priority of use instrument is considered partially *ecologically inclusive* because it promotes integration with other instruments such as river basin plans and water permits. However, it does not reserve water for nature or promote ecosystem preservation. The instrument's design is not considered *relationally inclusive* because it does not explicitly promote participation; however, allowing participa-

tion may render the results in favour of the most influential actors, especially during drought. So, when looking at the text on paper, it is essential to consider ecological and relational inclusiveness as one of its criteria in the next round of policy making.

7.4.2. Water use permit for allocating water to large users

Bahia

In terms of *design*, Bahia implemented the water use permit instrument according to State Law No. 6855/1995 and guidelines from the National Water Law and ANA (Silva et al., 2017)(see 5.4.4), later updated by the State Law Nº 11612/2009), mirroring the National Water Law (Federal Law No. 9433/1997). The aim of the water use permit for allocating water to large users is to ensure the quantitative and qualitative control of the use of water and the right of access to water, subject to the use priorities established in the State Water Resources Plan and the Hydrographic Basin Plans (Art. 17, Chap. IV, Law Nº 11612/2009). Considering the five main components of the modern permit system (see 4.5.2.1), Bahia's permit design is almost similar to what is designed at the national level (see 5.4.4). In terms of *operationalization*, these permits are issued by the Institute of Environment and Water Resources (INEMA), which is responsible for the concession of water permits at the state level according to the guidelines proposed by ANA and the Water Resources Council of the state of Bahia (CONERH).

Water use permits authorize permit holders to use a specific amount of surface or groundwater for a particular time (validity), a certain purpose, under terms and conditions established by an administrative act (Art. 7, § 1). The granting of the right to use water resources in the State of Bahia is issued in the form of authorization (Art. 7, § 2). Art. 18 describes explicitly six types of users that should request a water permit:

> "(i) activities or undertakings that capture or derive surface or underground water; (II) the construction of dams, the aquaculture activity in net tanks, and for hydroelectricity; (III) interference in river beds and other water bodies for the extraction/exploitation of minerals or other materials, by specific legislation; (IV) the discharge of sewage and other solid, liquid or gaseous effluents, treated or not,

into water bodies, with the purpose of dilution, transport or final disposal; (V) the drilling of tubular wells; and (VI) other uses that alter the regime, quantity or quality of water existing in a water body" (Art. 18 of State Law Nº 11612/2009).

Article 18 also determines that CONERH will determine the insignificant water users (Matos and Pereira, 2012). For instance, one type of user that is considered insignificant is the dams with less than 200,000 m³ of water. Therefore, 2015 State Law No. 13457 offers more details related to the six types of water users.

Regarding the possibility of renewing the permit, permits are valid for a maximum of 35 years and can be renewed, and are subject to the ranking of water use priorities established in the water resources plan and following the guidelines from the Water Resources Council of the state of Bahia (CONERH) (Art. 7,§ 3º). Water users in Bahia can also apply for pre-emptive permits to reserve stream flows that can be licensed to support enterprise planning (Art. 21). Third, regarding the possibility of changing the permit conditions during the allotted period, Article 19 of the 2009 State Law Nº 11612/2009 presents eight conditions of partial or total suspension, or for a specified period:

"(i) modification of the assumptions that determined it; (ii) an urgent need for water to meet situations of public calamity, including those arising from adverse weather conditions; (iii) need to prevent or reverse serious environmental degradation; (iv) need to meet priority uses or uses in the collective interest, for which there are demonstrably no alternative sources; (v) need to maintain the navigability characteristics of the water body; (vi) need to reduce the granted flow, according to the hypotheses approved by CONERH, according to the provisions of item XIX of Art. 46 of this Law; (vii) exploration of groundwater, at levels that represent a risk to the aquifer; and (viii) when there is an administrative infraction subject to the application of the restrictive sanction of law provided for in item I of Art. 80 of this Law" (Art. 19 of the 2009 State Law Nº 11612/2009).

In the event of a drought or flood, for example, permits can be suspended by INEMA for a period without any compensation for the user. For instance, in 2021 this situation occurred in the Paraguaçu River, in central

and eastern Bahia. Due the water crisis[45], Inema suspended the use of the granted volume of water for commercial agriculture users by 50% (Portaria Nº 24.308) to guarantee water supply for 86 municipalities.

Moreover, water use permits for allocating water to large users can be transferred to other holders for an administrative fee but cannot be traded or leased. The Bahia water system does not compensate the permit holder in case the conditions change prematurely and lead to financial loss (Interview BA-17). Nevertheless, the permit holder can appeal the decision either judicially or administratively.

In terms of *budget*, the instrument is financed by the State Fund for Water Resources of Bahia (FERHBA) (Art. 29 and 30 of the State Law Nº 11612/2009). In terms of *implementation*, the State Environmental and Water Resources Information System (SEIA) was designed in 2011 as an informational agency. This was established to support the analysis of the water permit instrument and entailed integrating the instrument into the environmental licensing process. However, SEIA is still in its implementation phase, which has been prolonged by the complexity and lack of support for spatial and interdependent analyses of river users (Interview BA - 1). The absence of comprehensive water resources inspection and fluviometric monitoring means that data about water quantity and quality is unavailable or inconsistent at the least (Silva et al., 2017). In some instances, there have been informal internal procedures undertaken by directors, coordinators, and board technicians to analyse the water permit instrument (Silva et al., 2017)(Interview BA-1).

Mechanisms that can help minimize the risks of water damage and that are complementary to the water use permit instrument remain inoperative in Bahia. In addition, the instrument has a lack of budget, a low number of technicians, and low political will to drive the instrument. It has thus been unable to fulfil its purpose of ensuring qualitative and quantitative water control by different users. Ideally, the water permit instrument allows for control of water use by INEMA, but in practice, this is not yet reached.

Many commercial agriculture users who do not hold water permits still extensively exploit the Urucuia Aquifer System (Interview BA - 1) particularly. A study of the São Francisco River flow reveals that misuse

45 https://g1.globo.com/ba/bahia/noticia/2021/10/17/com-crise-hidrica-volume-de-agua-autorizado-para-uso-do-rio-paraguacu-e-reduzido-para-50percent-pelo-inema.ghtml; https://newsba.com.br/2021/10/15/crise-hidrica-inema-limita-em-50-o-uso-da-agua-do-rio-paraguacu/

of freshwater has had short-term and long-term environmental consequences, including reduced river flow due to depredation of the Urucuia Aquifer System (Hirata & Conicelli, 2012). Compared to 2010 values, the expected long-term impacts of climate change by 2050 will include a 70% reduction of recharge in the Northeast region aquifers (Hirata & Conicelli, 2012). With little to no enforcement control by INEMA, particularly agricultural users have taken advantage of the situation.

Pernambuco

In terms of *design*, considering the five main components of the modern permit system presented in section 4.5.2.1, Pernambuco is also almost similar to what was designed at the national level (see 5.4.4). First, regarding the right to use water, Pernambuco water use permits were established in 1997 and later reemphasized in state law in 2005. Allocation of water to the users depends on the amount of water that can be diverted from a certain waterbody and its percentage of reference flow (State Law 12.984/2005). APAC is the agency responsible for granting the water use permits in cases involving a waterbody or groundwater and the Pernambuco State Environmental Agency (CPRH) is responsible for the overall approval and regulation of surface and groundwater use (Apac, 2013). Every water user is required to obtain a water-use permit from APAC.

In Pernambuco, the permits can be renewed, subject to the ranking of water use priorities established in the water resources plan (Art. 20 State Law 12.984/2005). On the other hand, in the case of a drought, permits can be suspended for a period without any compensation (Interview N-26). Regarding the possibility of changing the permit conditions during the allotted period, Art. 19 of the 2005 State Law 12.984 presents five criteria for partial or total suspension, or for a specified period or definitively:

> "(i) non-compliance by the grantee with the terms and conditions expressed in the granting act; (ii) no use for three consecutive years; (iii) urgent need for water to meet situations of scarcity; and (iv) need to prevent or reverse serious environmental degradation" (Art. 19 of the 2005 State Law 12.984/2005).

Besides, water permits can be transferred to other holders for an administrative fee but cannot be traded or leased. The only difference between

Pernambuco and the federal unit is that the water permits are valid for a maximum of 30 years, while at the national level, they are valid for a maximum of 35 years. Pernambuco does not compensate the permit holder in case the conditions change prematurely and lead to financial loss. Nevertheless, the permit holder can appeal the decision either judicially or administratively.

In terms of *budget*, ideally, the water use permit system is supposed to allow for better control of water use by APAC and CPRH. However, in terms of implementation, both agencies are unable to enforce the system effectively. This is due to limited institutional capacity, especially to conduct inspections of the wells, and lack of control by the authorities to prevent illegal wells (Chakrabarti et al., 2017). The water permit instrument has been recognized on paper, and progress has been made in operationalizing the instrument, seeing as APAC and CPRH have shared knowledge of water permit requisitions. However, the instrument does not score high in the fourth category due to the lack of a specific budget, a low number of technicians, and low political will to further operationalize it.

Moreover, the water permit instrument has been implemented since 1998. Table 6.8 shows the number of water permits granted to large water users from 1998 to 2018. The analysis reveals that Pernambuco is highly dependent on groundwater, considering that much more permits are authorized for groundwater than for surface water. This is different from Bahia state, which is more dependent on surface water than groundwater.

The conditions for granting water use permits are based on state and water basin plans, which do not account for ecological concerns. Deep groundwater resources are threatened by overexploitation to fulfill water demand in Recife City (the capital) nowadays (Cary et al., 2015; Chakrabarti et al., 2017; Petelet-Giraud et al., 2018). There are several implications for the water resource system, such as a rapid decrease in groundwater level due to unsustainable water management strategies (e.g., deep well pumping in Cabo and Beberibe aquifers) (Petelet-Giraud et al., 2018). A very low recharge rate, which modifies the functions of the aquifer system, leads to groundwater overexploitation and quality deterioration (i.e. dramatic aquifer salinization and contamination)(Montenegro et al., 2010; Cary et al., 2015; Bertrand et al., 2016; Chatton et al., 2016 ; Petelet-Giraud et al., 2018). Often, subsistence farmers can only use groundwater, which is limited and very expensive to lift and exploit (Interview PE-3). Groundwater levels are falling because of drawdowns and slow recharge.

Table 7.8. Total number of water permits approved in Pernambuco (1998 – 2018)

Time	Groundwater	Surface	Total
1998 – 2013	2,829	1,173	4,002
2014	269	95	364
2015	415	154	569
2016	468	110	578
2017	257	96	353
2018	281	169	450
Total	**4,519**	**1,797**	**5,316**

Source: Based on Rosal (2020

Alagoas

In terms of *design*, considering the five components of permits (see 4.5.2.1), permits in Alagoas are similar to national permits (see 5.4.4).

The water use permits in Alagoas were established by the 1997 State Law (Law No. 5965/1997 and State Decree No. 06/2001 and No. 170/2001) and aim to ensure the quantitative and qualitative control of water used to guarantee the effective exercise of water rights (Art. 16, Law No. 5965/1997). First, regarding the right to use water, water use permits authorize users to use a specific amount of surface or groundwater for a particular time (validity), a certain purpose, and under terms and conditions established by an administrative act. Article 5 describes five types of users that should request a water permit:

> "(I) the derivation or abstraction of a portion of water existing in a water body, for final consumption, including public supply, or input to the production process; (II) extraction of water from underground aquifer for final consumption or input of production process; (III) discharge of sewage into a water body and other liquid or gaseous waste, treated or not, with the purpose of its dilution, transport or

final disposal; (IV) the use of hydroelectric potentials; and (V) other uses that change the regime, quantity or quality of existing water in a body of water, including the execution of works or services that configure interference and imply a change in the water regime, quantity or quality existing in a surface or underground water body" (Art. 5, State Decree No. 06/2001).

Article 6 determines that the Secretary of State for the Environment and Water Resources (SEMARH)[46] is responsible for monitoring use, control, and inspection. Article 8 classifies the four water users that are considered insignificant, but that should also register for the monitoring of use, control, and inspection:

"(I) the use of water resources to meet the needs of small population centres, distributed in rural areas, respecting item IV of this article; (II) derivations, captures and releases considered insignificant, both from the point of view of the volume and pollutant load, at the discretion of the competent body; (III) accumulations of water volumes considered insignificant, at the discretion of the competent body; and (IV) water collection whose recommended exploration flow does not exceed one thousand litres per hour. It is also considered insignificant the use of water resources to meet the basic needs, such as hygiene, food, and subsistence production, in a single-family residential unit, in a place where there is no water supply system public" (Art. 8, State Decree No. 06/2001).

Permits are valid for a maximum of 35 years and can be renewed, and subject to the ranking of water use priorities established in the water resources plan (Art. 23, III, State Decree No. 06/2001). Art. 29 State Decree No. 06/2001 presents five conditions of partial or total suspension of the water permit, or for a specified period or definitively:

"(i) need for water to meet calamity situations, including arising from adverse weather conditions; (ii) need to prevent or reverse serious environmental degradation; (iii) need to meet priority uses, of public interest, for which do not have alternative sources; (iv) need

46 http://www.semarh.al.gov.br

to maintain the navigability characteristics of the body water; and (v) in case a water resources rationing regime is instituted" (Art. 29 State Decree No. 06/2001).

Moreover, water use permits for allocating water to large users can be transferred to other holders for an administrative fee but cannot be traded or leased (Art. 27, State Decree No. 06/2001). And the water system does not compensate the permit holder in case the conditions change prematurely and lead to financial loss, but permit holders may appeal the decisions.

In terms of *operationalization*, permits are granted by SEMARH for a waterbody and groundwater under the Alagoas domain[47], following the guidelines proposed by ANA. All water users must request a permit. Regarding *budget*, the instrument is financed by the State Fund for Water Resources of Alagoas (Decree No. 532/2002).

In terms of *inclusive development* (see also 5.4.4), the design of the water permit is also considered partially *socially inclusive in all states* because it benefits some uses of water. For instance, the water permit instrument does not require small users to pay for water resources (e.g., small farmers or householders). However, agricultural users in Alagoas take unfair advantage of the lack of control of the resource by SEMARH (e.g., irrigators in "Canal do Sertão"[48] and Delmiro Gouveia City). Many have been using water resources without the legally required permit, taking a maximum amount of the resource to secure their economic activities in the short run (Interviewee AL-17/18/19). Monoculture and land concentration have significantly increased in the last decade as a result of large agriculture companies installed in the region (dos Santos, Correia & de Almeida, 2020). This has further contributed to high-income concentration, significant social vulnerability, and a high risk of water damage (dos Santos et al., 2020).

47 http://www.semarh.al.gov.br

48 This is the second biggest Brazilian water system project which started the construction in 1992, The construction has been going on for over 27 years. It has been implemented by the Federal government and Alagoas government through the Ministry of National Integration. The water system comprises a 250km long canal, located in Delmiro Gouveia city and extented to Arapiraca city. The channel enables water impounded in the São Francisco River to irrigate some 26 thousand hectares of fertile land in the semi-arid area (*Vitório, 2020*).

https://cbhsaofrancisco.org.br/noticias/novidades/um-raio-x-do-canal-do-sertao-alagoano-uma-obra-que-ja-dura-quase-tres-decadas-a-obra-avancou-115-quilometros-faltam-outros-135-ou-seja-mais-da-metade/

It is also considered partially ecologically inclusive because one of its goals is based on water quantity and quality assessment. However, this also does not guarantee adequate water to accommodate nature's needs and consequently guarantee vital ecosystem functions and freshwater biodiversity. Moreover, the design of the protected area is considered relationally inclusive because it focuses on positive discrimination towards the most marginalized. It aims to include protected areas of traditional populations, respecting and valuing their knowledge and culture and promoting them socially and economically, following the guideline from the national level.

7.4.3. Protected areas

Bahia

In terms of *design*, within Bahia, policies regarding protected areas are mainly based on the State System of Nature and Biodiversity (State Law No. 10431/2006). The aims of this instrument are to:

> "(i) improve the quality of life, considering the limitations and vulnerabilities of ecosystems; (ii) make socioeconomic development compatible with the guarantee of people's quality of life, the environment and ecological balance and the protection of the climate system; (iii) optimize the use of energy, environmental goods and inputs, aiming at saving natural resources and reducing the generation of liquid, solid and gaseous waste; (iv) promote sustainable development; (v) promote and disseminate knowledge as a guarantee of environmental quality; (vi) guarantee the perpetuity of biodiversity and its genetic heritage and the equitable sharing of benefits derived from its use and the traditional knowledge associated with them; (vii) ensure equity and fair distribution of burdens and benefits for the use of the environment and biodiversity; (viii) ensure prevention and defence against critical events of natural origin or resulting from the inappropriate use of environmental resources; and (ix) ensure the sharing of benefits from the use of biodiversity and promote social inclusion and income generation" (Art. 3, State Law No. 10431 of 2006).

Similar to the federal level, this document defines protected areas as a territorial space and its environmental resources, including jurisdiction-

al waters, with relevant natural characteristics, legally established by the Government, aiming to guarantee adequate protection with conservation objectives and defined limits, under a special administration regime (Art. 3, State Law No. 10431 of 2006). It also divides the state-protected areas into two categories: integral protection areas and sustainable use areas (State Law No. 10431 of 2006).

In terms of *operationalization*, the Secretariat of the Environment (SEMA) is the main responsible body, but it has a limited budget for the implementation of this instrument.

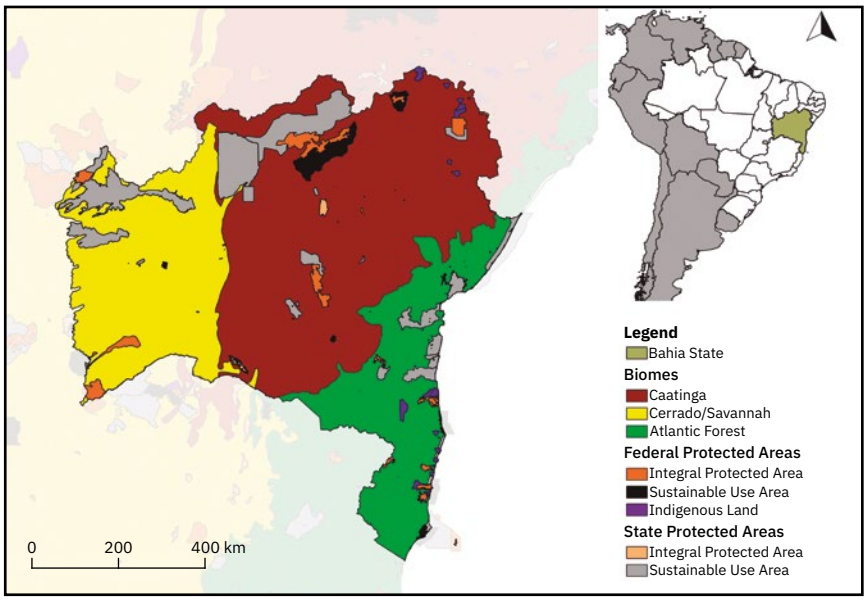
In terms of implementation, currently, Bahia has 8 integral protection areas and 70 sustainable use areas (Inema, 2020). I prepared a map based on data from the Brazilian Institute of Geography and Statistics (IBGE) and the Ministry of Environment (MMA); my map shows the location of the 78 protected areas managed by the state of Bahia, and the national protected areas managed by ICMBIO. The three predominant biomes present in the state are: Caatinga (314,499 Km²), Cerrado (138,492 Km²) and Atlantic Forest (111,941 Km²)(IBGE, 2020; Novaes and Pires, 2022). It means that Atlantic Forest comprising 19.29% of the Bahia territory, Cerrado with 26.87%, and Caatinga with 53.84% (IBGE, 2020; Novaes & Pires, 2022).

Even though there is an increasing progress in the number of environmentally protected areas, it is also true that the Secretariat of the Environment (SEMA), under INEMA, oversees the management, enforcement, and monitoring of the state-protected areas (De Oliveira, 2002) (Interview B - 2).

In terms of goals achieved, Bahia has been delimitating some protected areas for environmental conservation. However, it still has some problems such as illegal land use of protected areas, for instance, in the western part of Bahia (de Oliveira, 2017). This is also the case in the Nascentes do Rio Parnaíba National Park, the Serra Geral do Tocantins Ecological Station, the Veredas do Oeste Baiano Wildlife Refuge, the Cristópolis National Forest, and the Environmental Protection Area of Rio Preto (de Oliveira et al., 2017).

The SFRB and Bahia are highly dependent on the Cerrado biome, which covers the area where the Urucuia Groundwater System is located and thus where groundwater recharge occurs (Interview N – 9). Human occupation of the Cerrado area has intensively increased due to, for instance, the expansion of rural credit for commercial users, the introduction of new agricultural technologies, public policies, and climate

Map 7.1. Brazilian biomes and Bahia Protected Areas



Source: Author's elaboration based on raw data from the Brazilian Institute of Geography and Statistics (2020) cartographic database in shapefile format (.shp) and the Ministry of Environment (2000)

change. This has caused the deforestation of the Cerrado biome, consequently impacting the flow of the SFRB (Interview N – 9) (section 6.3). It is predicted that the river will dry up soon if effective actions against deforestation are not adopted (Siqueira Filho, 2012) (Interview N – 9).

Pernambuco

In terms of *design*, the protected areas instrument followed federal guidelines established by State Law No. 13787 of 2009. The aims of this instrument are to:

> "(i) contribute to the maintenance of biological diversity and genetic resources in the state territory and jurisdictional waters; (ii) protect endemic, rare and endangered species at the state level; (iii) protect native species of relevant economic, social or cultural value; (iv) contribute to the preservation and restoration of the diversity of state natural ecosystems; (v) promote the use of nature conservation principles and practices in the state sustainable development process; (vi) protect

> natural and little altered landscapes of remarkable scenic beauty; (vii) protect, at the state level, relevant geological, geomorphological, speleological, archaeological, paleontological and, when applicable, historical and cultural characteristics; (viii) protect and recover water and edaphic resources; (ix) recover or restore degraded ecosystems; (x) expand the representation of state ecosystems as conservation units; (xi) provide means and incentives for scientific research activities, studies and environmental monitoring; (xii) value economically and socially biological diversity; (xiii) favour conditions and promote environmental education and interpretation, recreation in contact with nature and ecotourism; (xiv) protect the natural resources necessary for the subsistence of traditional populations, respecting and valuing their knowledge and culture and promoting them socially and economically; and (xv) prioritize ecosystems that are most threatened with alteration, degradation or extinction" (Art. 4, State Law No. 13787/09).

As in Bahia, Pernambuco also has two categories of protected areas: Integral Protection and Sustainable Use Areas.

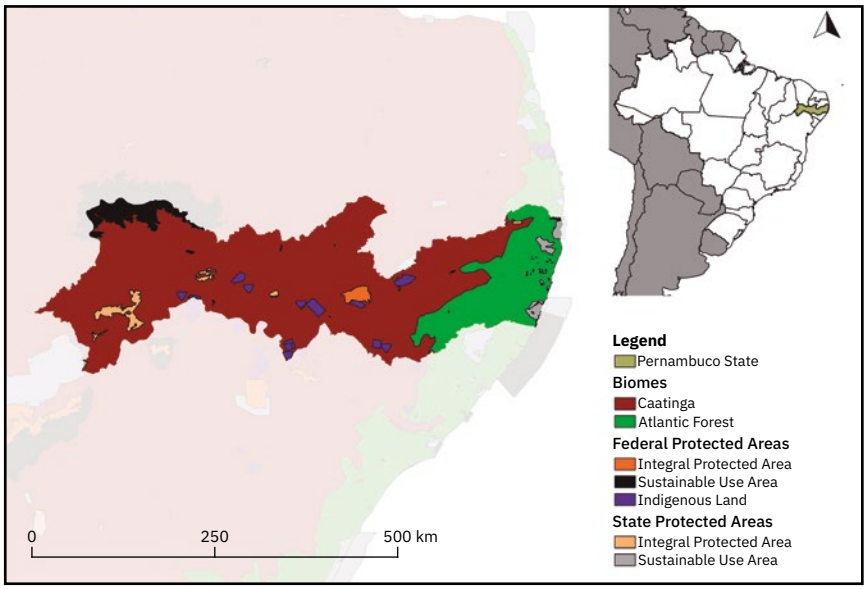
In terms of *operationalization*, the Environment Agency (CPRH) is responsible for managing the protected areas at the state level (CPRH, 2020) but it has a limited budget for the implementation of this instrument.

In terms of *implementation*, Pernambuco has implemented 86 protected areas: 42 Integral Protection Areas and 44 Sustainable Use Areas (CPRH, 2020). I prepared the Map 7.2 based on data from the Brazilian Institute of Geography and Statistics (IBGE) and the Ministry of Environment (MMA); my map shows the location of 86 protected areas managed by the state of Pernambuco (CPRH), and the national protected areas managed by ICMBIO.

Recently, CPRH has been working in partnership with Pernambuco's Water Sustainability Project (PSHPE). The group established through this partnership identified and proposed priority areas for conservation in the Capibaribe River Basin (Crispim, 2020). Based on their research, Pernambuco created three new protected areas at the end of 2020. Two are under the category of Integral Protection Areas, the Refuge of Wild Life Cabeceiras do Rio Capibaribe (6,926, 25 hectares) and the Refuge of Wild Life the Mata do Bitury (888,25 hectares). The other, a Sustainable Use Area, is the Serras e Brejos do Capibaribe (73,781, 65 hectares) (Crispim, 2020).

Moreover, the establishment of new protected areas such as the Refuge of Wild Life Cabeceiras do Rio Capibaribe, the Refuge of Wild Life the

Map 7.2. Brazilian biomes and Pernambuco Protected Areas



Source: Author's elaboration based on raw data from the Brazilian Institute of Geography and Statistics (2020) cartographic database in shapefile format (.shp) and the Ministry of Environment (2000)

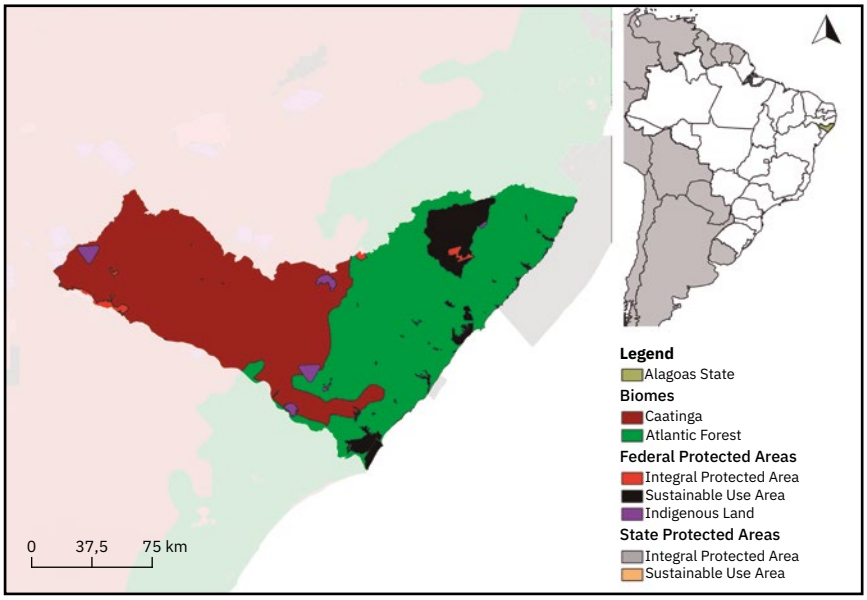
Mata do Bitury and the Serras e Brejos do Capibaribe enable support for the regulating services of the rivers. It also means connecting and improving groundwater recharge, and climate regulation through carbon sequestration in the floodplains and surrounding forests. In terms of *ecological inclusiveness*, the protected areas instrument promotes the preservation of ecosystem services and increases water reserves for nature. This is evidenced by the establishment of new protected areas around the Capibaribe Basin, a fundamental step towards increasing awareness and making conservation more effective (Crispim, 2020) (Interview PE 4/5).

Alagoas

In terms of *design*, the Alagoas government's policies on protected areas are based on the State System of Nature established in 2016 (State Law No. 7776/2016). As in the other states, Alagoas divides protected areas into two categories: Integral Protected Areas and Sustainable Use.

In terms of *operationalization*, the Institute of the Environment (IMA) coordinates the implementation of the State System of Protected Areas

Map 7.3. Brazilian biomes and Alagoas Protected Areas



Source: Author's elaboration based on raw data from the Brazilian Institute of Geography and Statistics (2020) cartographic database in shapefile format (.shp) and the Ministry of Environment (2000)

and manages the state-protected areas. This instrument has been recognized on paper, but has a limited budget.

In terms of *implementation*, Alagoas has implemented 71 protected areas. I prepared the Map 7.3 based on data from the Brazilian Institute of Geography and Statistics (IBGE) and the Ministry of Environment (MMA). My map shows the location of protected areas managed by the state of Alagoas, and the national protected areas managed by ICMBIO. Approximately 80% of Alagoas Protected Areas are located in the Atlantic Forest biome and the rest in the Caatinga biome. There are two Integral Protected Areas: the Ecological Station and the Wildlife Refuge. While the rest is classified as the Sustainable Use of Environmental Protection Areas, there are 62 Private Cultural Heritage Reserves, 2 Relevant Ecological Extractive Reserves, and 5 Sustainable Development Reserves[49].

The instrument is poorly implemented because there are too few implementation actions because of a lack of resources and technicians.

49 https://www.ima.al.gov.br/unidades-de-conservacao/

The implementation constantly faces dilemmas arising from conflicting interests between environmental conservation and economic growth. Consequently, the conservation of biodiversity in the state has been insufficient and inadequate (De Araujo & Power 1993) (Interview B-11) and there are insufficient incentives for research (De Araujo & Power 1993) (Interview AL-2). Furthermore, the most protected areas are located on private lands (i.e., Private Cultural Heritage Reserves category).

Moreover, several small farmers have indicated that they need to find a way to survive on their land or go to urban areas to find temporary jobs during severe droughts (Interview B-11/AL-1/ AL-3). If they decide to stay on their land, it is challenging to grow food for the whole family and so they resort to hunting wild animals (Interview AL-20/AL-21/AL-22). This then contributes to the many environmental crimes happening in the region, including suppression of native vegetation and hunting of wild animals (Interview N-23). Some of these crimes are related to poverty, which increases pressure on the environment (Interview B-11). In many cases, they are related to high population growth, food insecurity, droughts, and other pressures on the fragile land (Interview B-11/AL-1/ AL-3).

If considered from an ID lens, the design of the protected area instrument in all states is considered *socially*, *ecologically*, and *relationally inclusive* (see 5.4.5); this is similar to the analysis at federal level. It is *socially inclusive* because it contributes to minimizing the risk of water damage to humans (e.g., stabilising soils and reducing dust storms and desertification in arid areas by reducing grazing and trampling pressures; it can help regeneration by maintaining drought resistant plants (Amiraslani & Dragovich) and some protected areas are inhabited by indigenous peoples and used for their productive activities and is necessary for their welfare (Sneed, Nietschmann & Herlihy, 1997). The design of the protected area is considered *ecologically inclusive* because it recognizes the high value of the ecosystem services and the necessity of recharge areas of groundwater as presented in several of its aims (e.g., contribute to the preservation and restoration of the diversity of state natural ecosystems) (e.g., Art. 4, IV, State Law No. 13787 of 2009). The design of the protected area is considered *relationally inclusive* because aim XIII of Art. 4 (Law No. 9985/2000) focuses on positive discrimination towards the most marginalized. It aims to protect the natural resources necessary for the subsistence of traditional populations, respecting and valuing their knowledge and culture and promoting them socially and economically in all the states.

7.4.4. Minimum flow

Bahia

In terms of the *design*, the minimum flow instrument for rivers within the Bahia state was established in 1997 following the Federal Law (State Decree No. 6296/1997). INEMA is the main actor responsible for this instrument, and it is mainly defined as 80% of Q90. In other words, the indirect flow established is 20% of the reference flow. In cases in which the reservoir is built on a perennial river, diversion can reach 95% of the reference flow (Benetti et al., 2004). This level is also secured if the diversion is intended for public water supply systems (Benetti et al., 2004). In terms of implementation, the state still needs more studies focusing on the ecohydrological regions, given the size of the state.

Pernambuco

In terms of the *design*, the minimum flow instrument for rivers within Pernambuco was established in 1997 by Decree No. 6296/1997, following the Federal Law. Pernambuco has many temporary or intermittent rivers, which makes the determination of the river flow more complex. This means that "in the dry season, the river ceases to flow and the values of Q90% and Q95% can be zero in cases where the watercourses cease to flow in the natural regime for more than 5–10% of the time" (da Silva, Pereira and de Oliveira Vieira, 2020, p. 23). APAC is the main body responsible for this instrument, therefore, it adopted for these streams regularized flows associated with the seasonality, which is 80% (Q90reg). However, the minimum flow instrument is not yet completely implemented. Once more, technical studies considering the physical context of each river are still missing.

Alagoas

As in Pernambuco, Alagoas also has several temporary or intermittent rivers. In 2001, the design of the minimum flow instrument was established in Alagoas (Tucci, 2004). The State Secretariat for the Environment and Water Resources (SEMARH) is responsible for this instrument. It adopted regularized flows for these streams associated with the seasonality, which is 90% (Q90reg) (Art. 12 Decree 006/2001). In terms of

operationalization, as in the other states, the minimum flow instrument is not yet completely implemented and more technical studies are needed.

Regarding *inclusive development*, the design of the minimum flow instrument in all states is not considered *socially*, *ecologically*, or *relationally inclusive*. For instance, the design of the minimum flow instrument is not considered *ecologically inclusive* because its definition of reserve water for nature does not account for environmental sustainability. The design of these instruments needs to be considerably improved to make them more inclusive.

7.4.5. Climate proofing

As mentioned earlier, Pernambuco is the only one of the three states having a climate change policy in place. In terms of the *design*, this State Policy to Combat Climate Change aims to ensure the population that the state promotes efforts to increase people's resilience to climate change and variability; and to contribute to reducing greenhouse gases concentrations in the atmosphere, at levels that are not harmful to populations and ecosystems, ensuring sustainable development (Art. 2, State Law No. 14090/2010). Table 7.9 presents the aim of this policy.

In terms of *operationalization*, the State Water and Climate Agency (APAC) was established to integrate strategies to mitigate the effects of and adapt to climate change at the state level in 2010. The agency was created with the ambition to be autonomous and politically independent (Interview PE-3). In terms of the *budget*, a specific law will institute the State Fund on Climate Change, which will define the financial investments for the development of minimum activities aimed at promoting environmental maintenance, preservation, or conservation (Art. 42, State Law No. 14090/2010). However, it is not implemented yet.

In terms of *implementation*, since its inception, APAC has initiated hydrometeorological monitoring and forecasting systems, which function with online and real-time information, and a drought monitoring system that is now fully operational (Interview PE 4/5). It is also implementing an early flood warning system and has established a network of eleven water user associations around critical reservoirs to contribute to the management of water allocation from the reservoirs (Interview PE 4/5). On paper and to some extent in practice, Pernambuco has climate-proofing measures in place. However, many more actions are still

Table 7.9. Relevant legislation to climate-proofing (adaptation) instrument

	Aims of State Law No. 14090/2010
(i)	create economic, financial, and fiscal instruments to promote the objectives, guidelines, actions, and programs provided for in this Law;
(ii)	foster the creation of market instruments for the mitigation of GHG emissions;
(iii)	generate periodic information and create indicators on GHG emissions and the State's vulnerabilities to climate change;
(iv)	encourage initiatives and projects, public and private, that favour the mitigation of greenhouse gas emissions and adaptation to climate change;
(v)	support education, research, development, dissemination, and promotion of the use of technologies to combat climate change and adaptation measures and mitigation of the respective impacts;
(vi)	promote programmes and initiatives for education and awareness of the population about climate change, its causes, and consequences, in particular for populations especially vulnerable to its adverse effects;
(vii)	encourage the use and exchange of environmentally responsible technologies and practices;
(viii)	promote sustainable purchases and contracts by the government based on sustainability criteria, in particular with a view to climate balance;
(ix)	prepare action plans that contribute to mitigation or adaptation to the adverse effects of climate change at different levels of state and municipal planning;
(x)	to institute, within the scope of Ecological Economic Zoning, indicators or zones that present areas of greater vulnerability to climate change and measures compatible with this situation;
(xi)	promote energy conservation and efficiency in relevant sectors of the state economy;
(xii)	encourage the use of sustainable clean energy, promoting the gradual and rational replacement of fossil energy sources;
(xiii)	protect, recover and expand sinks and reservoirs of greenhouse gases, through the use of conservation and recovery practices and/or sustainable use of natural resources;
(xiv)	promote sustainable standards for agricultural activities in light of climate change considerations;
(xv)	encourage the adoption of policies and forums on climate change at all levels of Government;
(xvi)	promote a system of payments for environmental services;
(xvii)	promote capacity building and institutional strengthening of the State of Pernambuco in Science, Technology, and the Environment for the study of the causes and effects of climate change on the State, creating conditions for the establishment of a Pernambucana Agency or Institute for Climate Change;
(xviii)	support research on natural and anthropogenic climatic factors, in particular on the urban and regional climate system

Source: Art. 3. State Law No. 14090/2010

needed to be implemented to effectively mitigate the intensity of the natural disasters (e.g., flooding and droughts) being faced by the state as a result of climate variation. Furthermore, the policy has set so many goals that many goals are not implemented yet, and there will never be enough budget to reach these goals.

Regarding inclusive development, the design of the climate-proofing instrument is considered *ecologically inclusive* because one of its goals directly contributes to minimising the risk of water damage through the conservation and preservation of protected areas. This goal intends to protect, recover and expand sinks and reservoirs of greenhouse gases, through the use of conservation and recovery practices and/or sustainable use of natural resources (Art. 3, XIII, State Law No. 14090 of 2010).

Moreover, the design of the instrument is also considered *relationally inclusive* because it contributes to participatory approaches and positive discrimination toward the most marginalized groups. For instance, the goal that encourages the adoption of policies and forums on climate change at all levels of Government (Art. 3, XV, State Law No. 14090 of 2010) and promotes programmes and initiatives for education and awareness of the population about climate change, its causes, and consequences, especially vulnerable populations to its adverse effects (Art. 3, VI, State Law No. 14090 of 2010).

7.5. Comparative analysis of water-sharing instruments in the three the states

This section is focused on the comparison of the three states related to the water-sharing instruments presented in the last section. This is particularly interesting due to their differences in managing water.

7.5.1. Priority of use

In Bahia, Pernambuco, and Alagoas, the priority of use principle is adopted by State Laws. The three states limit themselves to repeat the priority of use principle in tune with the National Water Policy, as the priority of use is a principle a common competence of the Union, states and the federal district. Bahia, Pernambuco, and Alagoas explicitly commit to supporting the principle during water scarcity and promoting universal access to water. Therefore, they did not make different choices from each other.

In terms of inclusive development, the design of priority of use in the three States misses the ecological dimension as it does not reserve water for nature nor promote the preservation of ecosystems. This means that this instrument does not provide an objective foundation for allocating a limited resource taking nature as one of the users (as discussed in 5.4.2). The priority of use principle also misses relational inclusiveness as it does not explicitly promote participation.

7.5.2. Water use permit for allocating water to large users

Bahia, Pernambuco, and Alagoas designed the water use permit instrument according to the guidelines from the National Water Policy and ANA. The design of a water permit is almost similar in all three states, and the only difference is related to the duration of the water permit. While in Alagoas and Pernambuco, the maximum duration is 35 years, in Bahia, this duration is 30 years. They have qualitative and quantitative control of water used by different users as the primary purpose of the instrument. Moreover, each state has a different context and hence different rules. Pernambuco, for instance, is highly dependent on groundwater and most permits are for groundwater (Bertrand et al., 2016)(see Table 7.8). The capital, Recife city, has the water supply based on drilling water (Montenegro et al., 2016; Petelet-Giraud et al., 2018), for example.

In terms of implementation, Pernambuco is also more advanced when compared with Bahia and Alagoas possibly with the support of participation from some hydraulic engineering professors from the University of Pernambuco who have been directly involved in the design, training of technicians, and implementation of water permit instruments. Therefore, Pernambuco has a more progressive water governance development than the other states. Moreover, civil society participation has been strong in the past and under the current policy framework in Pernambuco (see 7.2.1).

Weak enforcement of water permits is one of the main problems in all states. The water permit instruments have been unable to fulfil their purposes of ensuring qualitative and quantitative control of the water used by different users. Ideally, the water permit instrument allows for control of water use, but in practice, this is not yet reached. Therefore, the water permit instrument has been unable to provide adequate water

management and address the drivers, especially of demand for agriculture, livestock, energy, and households.

In Bahia, for instance, the instrument is poorly enforced, creating the opportunity for agricultural users to take advantage of the situation. Agricultural users have been impacting the Urucuia Aquifer System (Hirata & Conicelli, 2012; Eger et al., 2021), decreasing the São Francisco River flow. Consequently, less water remains available to the downstream states of Pernambuco and Alagoas. Ultimately, the weak enforcement of water permits has failed to implement sustainable water use levels in the states.

7.5.3. Minimum flow

Bahia, Pernambuco and Alagoas adopted the same criterium for the Reference Streamflow (Qmr) which is Q90. Pernambuco and Alagoas adapted this criterium taking into consideration the seasonality because many of their rivers are temporary or intermittent. To ensure proper implementation, all three states need to invest in more hydrological information and studies.

As presented in 6.4.6, the minimum flow has a broad definition that does not address environmental sustainability. Hence, it does not provide enough water for nature to support riparian zones, floodplains, and other natural ecosystems (Participatory observation, 2017;WMO, 2019). Therefore, the instrument can be better designed if this instrument takes into consideration the ecological flow.

7.5.4. Climate-proofing

Only in Pernambuco the climate-proofing instrument is explicitly adopted as a policy. In Bahia and Alagoas, the climate-proofing policy has not yet been adopted. Both states could use the design of climate-proofing instruments in Pernambuco as an inspiration and learn from its experience. One of the elements that they should take into consideration is participation. In the case of Pernambuco, the state agency (APAC) has been promoting participation through daily information in the news and social media (Interview PE- 3/4/5). Therefore, APAC has been seen by society as a positive and trustful connection, and people can easily access the information, thereby reducing asymmetry in knowledge.

Table 7.10. Instruments that have the potential to address drivers at the state level

Drivers	Instruments	Bahia	Pernambuco	Alagoas
Natural changes and variability in weather	Priority of Use	✓	✓	✓
Demand for commercial agriculture Demand for energy Demand for households Demand for industry and service Agriculture policy	Water use permit for allocating water to large users	✓	✓	✓
	Minimum flow	✓	✓	✓
Climate change	Protected areas	✓	✓	✓
	Climate proofing		✓	

Source: Author's elaboration

Moreover, the climate-proofing instrument has also been addressing climate variation. And its design is also considered *socially*, *ecologically*, and *relationally inclusive*. This is because it contributes to the adoption of participatory approaches, positive discrimination towards the most marginalized groups, conservation, and preservation of protected areas.

7.5.5. Instruments addressing drivers

This section discusses how the instruments have been addressing the drivers at the state level. Table 7.9 presents an overview of the relation between the instruments and the drivers. It means the causes of human behaviour and biophysical causes of water-related challenges.

Priority of use

In terms of addressing the drivers of water problems, the priority of use principle responds to the driver of natural change and variability, as it regulates the water distribution during water scarcity by first

prioritizing humans and second the animals. It also addresses the demand for households as it firs prioritize humans (e.g., Cantareira case in São Paulo city - (de Souza Leão & De Stefano, 2019; Torres, Côrtes & Jacobi, 2020)). However, the priority of use principle could be better designed by reserving water for nature to guarantee enough water for ecosystem services. In this sense, the priority of use instruments could provide an objective foundation for allocating a limited resource taking nature as one of the users.

Water use permit for allocating water to large users

The water permit instrument has been unable to address the drivers of commercial agriculture, energy, households, industry, service, and agriculture policy. The main reason is that it is not well implemented and managed in all the states.

Protected Areas

Bahia, Pernambuco, and Alagoas legislation on Protected Areas are strongly based on the National System of Protected Areas (Law No. 9985/2000). The three states did not make different choices regarding the design of the Protected Area legal instrument. They also adopted the same definition for the categories of protected areas, such as integral protection and sustainable use areas.

On paper, the design of the state-protected areas outlines mechanisms that enforce the protection of biodiversity, traditional and local communities, as well as participatory mechanisms. However, in practice, as at the national level, the states also have a limited budget for the implementation of this instrument, resulting in poor management, monitoring, and resources for maintenance of the existing and new Protected Areas. Such limitations outline critical aspects related to institutional, managerial, and financial issues.

In general, most protected areas in Brazil struggle with the lack of land tenure regularization, which is also the case in Bahia, Pernambuco, and Alagoas. The only exception is Private Cultural Heritage Reserves under the Sustainable Use Category, which are privately owned. Therefore, the lack of land tenure regularization triggers unsustainable practices and affects the surface, groundwater sources, and biodiversity.

Considering the three states under analysis, the limitations to achieving the effective implementation of Protected Areas are closely related to the inefficient implementation of the regulations rather than the need for improvements to the instrument design.

The design of the Protected Area instrument is considered socially, ecologically, and relationally inclusive at the federal level. However, implementation has faced several problems, such as the dilemma of the states between environmental conservation and economic growth.

All the states explicitly commit to supporting the protected areas instrument. However, few resources are currently allocated to their management (Interview N- 6/ B -11). It is also true that the same situation occurred at the national level, resulting from a conflict of interest between environmental conservation and economic growth.

Climate-proofing

The climate-proofing instrument addresses climate variation and change. As presented in section 4.7.2.3, climate-proofing is explained as a response to decreasing the adverse impacts of climate change (IPCC, 2014; Islam et al., 2020).

7.5.6. The combination of the instruments for optimal effect

Policy and instrument mixes are one way to combine the strong points and weaknesses of different instruments to ensure a desired outcome. As mentioned before, some instruments can be combined for greater effectiveness of the water permit system, such as river basin plans and water information management systems. If one knows how much water is available for human use, then one can design a permit system that stays within that limit. Of course, the degree of effectiveness resulting from the combination of multiple instruments may also depend on other aspects like the operationalization of those instruments. For instance, although in 2011, Bahia designed the State Environmental and Water Resources Information System (SEIA), aiming to minimize the risks of water damage and support the water permit system, the SEIA remains inoperative. The reasons for that lie in the lack of budget, a low number of technicians, and the lack of political will.

7.6. Inferences

Overall, Bahia has three main advantages in accessing surface and groundwater when compared to the other states of the SFRB. First is its location at the higher middle area of the SFRB, which renders it less affected by upstream uses than the other two states. Second, a large area of its territory is located at the Urucuia Groundwater System, which means that Bahia has more available water for economic development. Third is the size of its territory at 567,295 km². In contrast, Pernambuco is one of the driest states in Brazil, with average water availability of 1,320 m³ *per capita* per year, equivalent to 3.5% of the national average (World Bank, 2009). A large portion of Pernambuco's population directly and indirectly depends on the SFRB and its variety of services. In all states, there are several common water-related challenges (Table 7.2), including increasing water withdrawals for irrigation purposes, organic pollutants, and deforestation. Downstream communities especially suffer the worst consequences.

Moreover, in all states, water demand is higher than there is supply (see 7.2.2.3). One of the main drivers of water-sharing challenges in all states is the demand for commercial agriculture. In Bahia, almost 80% of total water withdrawal goes for commercial agriculture (see 7.2.2.3), and a significant increase in withdrawal for agriculture occurred in the last decades (see Table 7.1). The rapid urbanization and changes in global climate are also indirectly driving water-sharing challenges in Pernambuco as they put immense pressure on existing water resources (e.g., uncontrolled drilling has resulted in overexploitation of the aquifers). Therefore, there is a clear asymmetrical relationship in water-sharing between users, humans, and nature.

Historically, water governance in all states and water resources planning processes have been based on the economic interests of powerful landowners, which tend to align with those at the national level (see 7.2.1). As the national discourse on water in Brazil shifted from a centralized to a decentralized approach (see 5.2.4), this was also reflected at the state level. This shift occurred as a result of the adoption of a new water framework in 1997 (Federal Law No. 9433/1997) and the national policy was mirrored at the state level. On paper, the states have put a coherent set of instruments in place (see 7.3). Analysing water-sharing in Bahia, Pernambuco and Alagoas, there are five key instruments (priority of use, water use permits, protected areas, minimum flow, and climate-proofing) through

which water-sharing is organized. Assessments of the instruments have shown that most of them have been unable to address the main drivers of water-sharing problems, namely commercial agriculture and climate change. The states have been focused on pursuing rapid economic growth over environmental sustainability.

Most water-sharing policy instruments have been poorly designed and operationalized in all states. As stated in Chapter 5: to be able to decide on sharing one needs to know how much there is to share. However, this chapter has shown that Bahia, Pernambuco and Alagoas have not designed adequately priority of use and minimum flow instruments. Water use permit for allocating to large users and protected areas have been not well implemented. For instance, water permit systems are not yet totally implemented and therefore impossible to know the amount of ground and surface water used.

Historically, Bahia has been controlled by old oligarchies, and now by the expansion of the manufacturing and petrochemical sectors. Similar to the national level, the state has transitioned from an agrarian and export-oriented economy into an economy increasingly influenced by neoliberal capitalist ideals. These power dynamics have been embedded in the state's water sector over time, exacerbating inequality and environmental degradation.

Alagoas is in a precarious position with very little power vis-a-vis states like Minas Gerais, Bahia, and Pernambuco, located upstream of the SFRB. Despite designing valuable policies and instruments for its water sector, the state faces challenges in economic planning due to unstable river flow and strong political resistance. Implementation of the sharing instruments in the state is particularly hindered by limited funding, lack of continuity in government policies, and poor coordination. The state water management entity also lacks the essential managerial, technological, and financial capacity to enforce instruments. Hence, the most critical drivers needed to be mitigated to achieve inclusive and sustainable development (climate change, growing inequalities, and deterioration of ecosystems) remain unaddressed.