www.water-alternatives.org Volume 16 | Issue 3

Eloy, L.; da Silva, A.L.; Coelho Filho, O. and Ghiotti, S. 2023.
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communities in the Brazilian Cerrado.
Water Alternatives 16(3): 869-891

The Water Frontier: Agribusiness vs. Smallholder Communities in the Brazilian Cerrado

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ABSTRACT: Agro-industrial expansion in the Brazilian savannas (the *Cerrado*) is associated with deforestation and land conflicts, but its relationship with water issues remains under-studied. Drawing on the basin trajectory approach, we explore the transformations in water usage and water policies over the past 20 years, as well as the divergent explanations for water scarcity in the Corrente River watershed (western Bahia). We identify a process of basin closure: Soybean farmers exploit growing volumes of surface and groundwater for centre-pivot irrigation, while, in smallholder communities located downstream from the plantations, long-established gravitational irrigation systems are declining. The volume of water licensed to agro-industrial companies grew by 431% between 2013 and 2021. During a phase of 'water abundance' and poor hydrological knowledge, water pumping relied on the deregulation of state environmental policy. Since the water scarcity phase, starting in 2015, the irrigator-farmer group has had to face growing protest from social movements and warnings from the scientific community. Its narrative, focused on climate change and the spatial dislocation of the problem (from upstream to downstream), helps to disclaim responsibility for water scarcity. This controversy over the causes of water scarcity, added to the fragility of instruments of social participation, may explain why supply augmentation is still the main response of the state for coping with basin closure.

KEYWORDS: Water licenses, water scarcity, soybean frontier, irrigated agriculture, environmental narratives, river basin trajectory, Brazilian Cerrado, Brazil

INTRODUCTION

In recent decades, the increase in global food demand has exacerbated the human pressure on global land and freshwater resources (Mehta et al., 2012; Hess et al., 2016). The total volume of water used in agriculture has more than doubled since the 1990s (Dalin et al., 2012), mainly due to the increasing demand for exports of soybean, meat, and dairy products from Latin America to Asia and Europe (Delbourg and Dinar, 2020). While there is evidence of the drivers and impacts of large-scale agricultural land acquisitions (Borras et al., 2012; Rulli and D'Odorico, 2014), the spatial and power relations that condition water appropriation by transnational agro-industrial companies (as well as their socioecological implications) have remained less studied (Dell'Angelo et al., 2018; Mehta et al., 2012).

It is essential to understand water issues on agro-industrial frontiers in order to support efficient but also equitable and sustainable water management policies (Delbourg and Dinar, 2020). Worldwide climate change is making droughts more intense and frequent in some regions, like South America, raising debates over the different causes (natural or anthropogenic) and scales (local, regional, or global) involved in the disruption of hydrological cycles (Getirana et al., 2021). The literature of political ecology shows that water scarcity is not only a natural but also a socio-political phenomenon (Mehta, 2003). The construction of water scarcity is intertwined with changing technologies, narratives, and 'solutions' for water management (Empinotti et al., 2019; Budds, 2008).

Since the 1990s, the expansion of soybean agriculture in the northern regions of Brazil has contributed to a rapid process of environmental degradation and resource dispossession for smallholders, particularly in the savannas of the Brazilian Central Plateau, called the Cerrado (Schilling-Vacaflor et al., 2021). But while the agro-industrial expansion in the Cerrado biome is well-known for resulting in intense deforestation and land appropriation (Sauer and Leite, 2012; Eloy et al., 2016; Escobar et al., 2020), its relationship with water exploitation remains less explored, despite growing concerns about water depletion (Getirana et al., 2021).

In recent years, the foremost soybean frontier in the Cerrado (and in Brazil), called MATOPIBA (an acronym formed from the names of the States of Maranhão, Tocantins, Piauí, and Bahia), has experienced a dramatic increase in irrigation areas (Favareto, 2019; Studart et al., 2021). Western Bahia is the most emblematic region for the emergence of violent water-related conflicts in MATOPIBA (Porto-Gonçalves and Chagas, 2019). A popular uprising in November 2017, known as the Water War, occurred when around 1000 smallholders revolted against the drastic lowering of the Corrente River water level. They stormed the farm headquarters of the Igarashi Company and wrecked the installations used to pump water for the irrigation systems. This action resulted in harsh police repression and triggered further urban demonstrations in Correntina and Barreiras, followed by various judicial proceedings (ibid).

Five years later, the causal links between agro-industrial expansion, the alteration of the hydrological cycle, and the emergence of conflict are still controversial. Despite evidence of growing deforestation, expanding centre-pivot irrigation (Matricardi et al., 2019), and declining river flows (Pousa et al., 2019; Gonçalves et al., 2016; da Silva et al., 2021; Maia and Genz, 2019), water pumping continues to rise (Porto-Gonçalves and Chagas, 2019). Why and how do agro-industrial companies in MATOPIBA secure access to water despite growing concerns over water scarcity and a system of water rights that is supposed to regulate water abstraction? In this paper, we examine agribusiness water exploitation strategies at the soybean frontier in western Bahia and their consequences for downstream smallholder communities' water access.

To this end, we propose using the concept of basin trajectories, i.e. the concomitant physical, social, and legal-institutional processes that have shaped a given watershed over time (Molle and Wester, 2009; Expósito and Berbel, 2019). This approach seeks to capture the diversity of actors (agro-industrial companies, associations, state representatives, and smallholders) involved in the emergence of water scarcity in a river basin, the multiscalar effects of water use, and thus, the ways in which different actors have experienced and explained water scarcity over the years.

We explore the transformations of water usage and water policies in the Corrente River Basin over the last 20 years and compare divergent environmental narratives for water scarcity. We argue that a close look at basin trajectories and environmental narratives offers a way of understanding the drivers of water scarcity – and their socioecological implications – on the agro-industrial frontiers.

BASIN TRAJECTORIES AND ENVIRONMENTAL NARRATIVES ON AGRO-INDUSTRIAL FRONTIERS

The dramatic expansion of irrigation in tropical countries during recent decades has called into question the relationship between water, politics, and development, especially in a context of more frequent droughts and climate change (Molle et al., 2008; Trottier and Perrier, 2018; Mehta et al., 2012). Irrigation projects in arid or semi-arid regions give access to an increasingly scarce and politically disputed resource, making water available to specific actors but causing water scarcity for others (Budds, 2012; Bakker, 1999; Linton and Budds, 2014).

Local strategies for water exploitation by agro-industrial companies have been studied in Latin America and sub-Saharan Africa (Woodhouse, 2012; Chaléard and Marshall, 2015). Research in the field of environmental justice focuses on the political struggles around water rights under neoliberal policies, highlighting different processes of privatisation and commodification of water resources (Boelens et al., 2018). They show how political alliances between the private sector and the state have fostered land and water policy reforms. Such reforms have enabled agro-industrial companies to accumulate water rights (Damonte and Boelens, 2019; Vos and Hinojosa, 2016).

These contributions allow us to grasp how negotiations and resistance unfold in the face of agro-industrial interests and the state, through multiscale alliances and networks (Adams et al., 2019 ; Nicolas-Artero, 2020; Boelens et al., 2016). But less attention has been paid to the spatial dimensions and temporal evolution of agribusiness strategies aimed at exploiting water resources while water scarcity and related conflicts are escalating.

Molle and Wester's (2009) framework for 'river basin trajectories' is helpful for analysing the means and consequences of irrigation development. It identifies critical water governance challenges by tracing the physical, social, and legal-institutional processes that have shaped a given watershed over time. In recent decades, the overexploitation of river basins due to large-scale irrigation has often led to overdrawing on reservoirs and aquifers and increased competition between water use(r)s (ibid). Many river basins in arid or semi-arid conditions face a trajectory of 'basin closure', whereby water resources are overcommitted and no water is left to be mobilised and used (Venot et al., 2006). Basin trajectory processes are shaped by shifts in water management strategies in the face of ongoing basin closure (Molle and Wester, 2009). Responses to water scarcity from both the state and local actors can be divided into three types: supply augmentation, conservation, and reallocation. As the basin nears closure, sectoral allocation becomes a point of tension, conflicts among competing users emerge, and new institutions evolve to address intersectoral competition (Molden et al., 2001; Randall, 1981). These responses occur concomitantly or sequentially. The particular blend of responses to water resource problems must be understood within a framework that spans not only hydrological, physical, or economic constraints, but also the distribution of agency and power among actors, their respective interests, and their strategies (Molle, 2003).

A central aspect in the study of basin trajectories is "the plurality of worldviews, ideologies, interests, and discourses related to water [that] are manifested in countless conflicts and negotiation processes" (Molle and Wester 2009: 3). According to critical political ecology, many environmental conflicts cannot be explained solely by power relationships causing social inequalities in access to resources. Competing environmental narratives (defined as knowledge for defining, explaining, and solving environmental problems) are also an aspect of power relationships (Forsyth, 2003; Goldman et al., 2011).

In the case of water, several studies have explored how political rules are coproduced with the discourses of technical expertise, calling into question both the supposed neutrality of expertise and its role in producing 'facts' to inform policy (Budds, 2009). By selecting concepts, associated methods, and hydrological data, technical expertise plays a crucial role in defining water problems and in suggesting specific solutions to water conflicts (Alatout, 2008; Trottier and Perrier, 2018). The imposition of particular perspectives on water issues, like naturalising discourse on water scarcity or water use efficiency, can be seen as constituting a politics of truth, which legitimises some water practices and forms of governance while discrediting others (Mehta, 2001; Boelens et al., 2016). These narratives may legitimise the appropriation of land and water by the private sector, especially in Latin American countries, in a context of decentralisation and liberalisation of water policies (Usón et al., 2017; Budds, 2009; Brannstrom, 2005; de Freitas, 2015).[1]

But while most of this literature is focused on the implications of dominant or hegemonic technical knowledge constructed by water experts and agencies, it is important to pay attention to how environmental narratives diverge amongst actors and along the process of water exploitation. Indeed, the unintended social and ecological consequences of large-scale irrigation projects critically shift the nature of both the problems faced by water users and managers and the skills needed to respond to these new challenges (Molle et al., 2008). Scientific discourses and methods on water issues may reinforce the interests of specific water users – those who benefit from privileged power positions in the institutions that decide water allocation in the river basin (Budds, 2008; Birkenholtz, 2008). Additionally, this discourse may change during the process of basin closure (Molle et al., 2008).

In western Bahia, the irrigator farmer association *Associacão de Agricultores e Irrigantes do Oeste da Bahia* (AIBA), an elite agribusiness group that emerged as a new social actor in the 1990s, has been extremely influential in policy reforms for more than two decades (Brannstrom, 2005; Silva Bonfim, 2019). Meanwhile, smallholder organisations have struggled to get their land rights and environmental knowledge recognised. They engage with this struggle by forming local and regional associations and connecting with national and international networks (ACCFC, 2017). As a result, unlike cases in which one expert hydrological narrative has emerged as dominant, the scientific literature about the dimensions and causes of water scarcity in this region remains controversial.

METHODS

Study area

Covering almost a quarter of Brazilian territory, the Cerrado is a mosaic of forests, savannas, and grasslands located in the central-western region of Brazil (Walter and Ribeiro, 2010). This biome hosts a remarkable – and threatened – biodiversity (Strassburg et al., 2016). It is also known as 'Brazil's water tower', because it contains the headwaters of eight of the twelve largest rivers in the country and covers three large aquifers (Bambuí, Urucuia, and Guarani) (Latrubesse et al., 2019). The Cerrado is home to indigenous and peasant populations whose livelihoods involve swidden cultivation, fruit gathering, hunting, and extensive cattle ranching (Eloy et al., 2016). The opening up of the Cerrado's frontiers by the state in the 1950s has led to the development of large-scale agriculture in the flat uplands. Since then, many communities have been dispossessed of their lands by agribusiness expansion, especially in communal uplands previously used for rangelands and fruit-gathering (ibid).

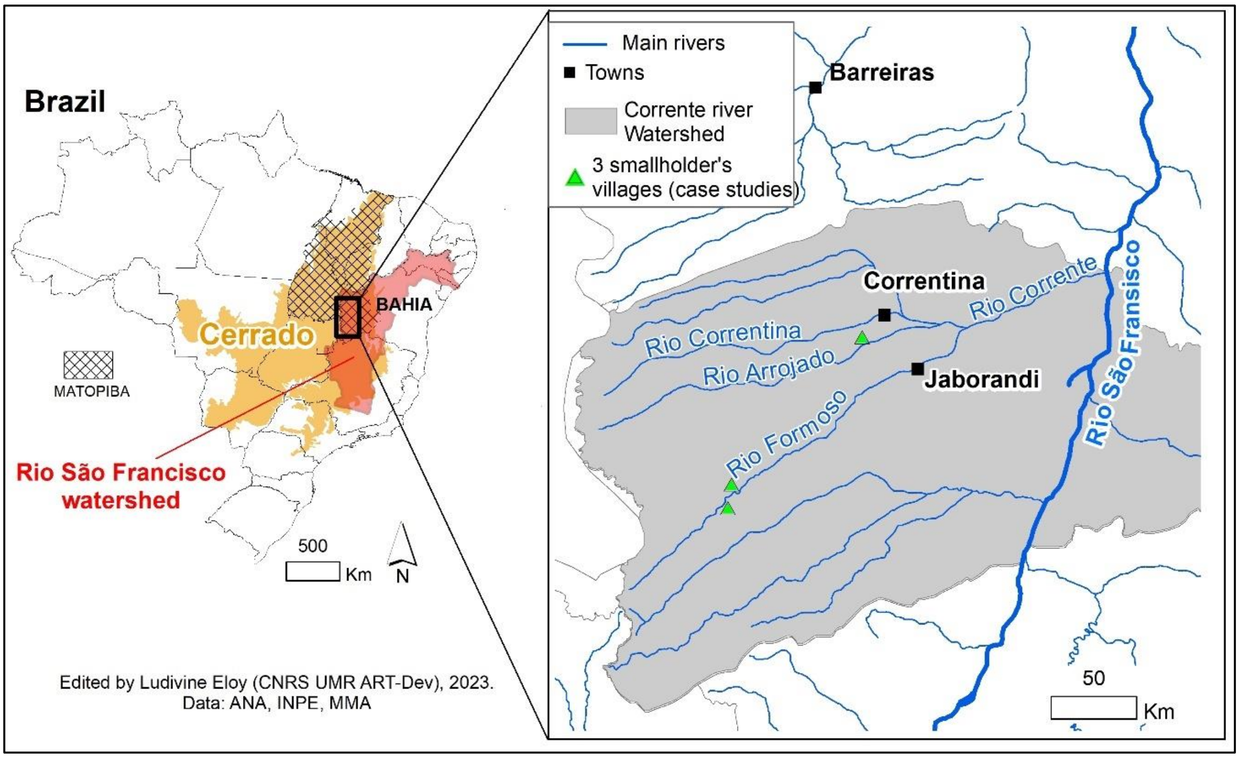
The soybean 'boom' in the Cerrado started in the 1990s and intensified after 2000 through increasing financialisation, technological modernisation, and land concentration (Oliveira and Hecht, 2016; Sauer and Leite, 2012). In the MATOPIBA, deforested areas increased by 41% between 2000 and 2016 (Matricardi et al., 2019). This region also experienced an increase in irrigated areas, going from 9 centre pivots in 1985 to 1550 centre pivots in 2016 (ANA, 2017). According to IPCC's climate models, the expansion of rainfed agriculture is reaching its (climatic) limit, especially due to recent regional warming and drying (Rattis et al., 2021).

Western Bahia is a major target for agricultural investments in MATOPIBA and accounts for 87% of the irrigated area (ANA, 2017). The region includes three river basins: the Grande River, the Corrente

[1] In Brazil, the National Water Resources Policy (Law 9433 of 8 January 1997) mandates that the management of water resources must be decentralised, with the participation of state and municipal governments, users, and communities, and that the river basin is the basic spatial unit for planning and management (Abers and Keck, 2013).

River, and the Cariranha River, all tributaries of the São Francisco River (Figure 1). The Corrente River basin has an area of 34,875 km², encompassing 11 municipalities with a total population of 196,761 inhabitants (da Silva et al., 2021) (Figure 1).

Figure 1. Study area.



This region sits on top of the Urucuia Aquifer system, a vast geological formation with an area of 82,000 km^2 that is connected to these rivers and that helps regulate their seasonality and interannual variability (Gaspar and Campos, 2007). The regional climate is tropical and humid, with two well-defined seasons: a rainy season from October to March and a dry season from April to September. The average annual precipitation is between 500 and 1200 mm. Rainfall is concentrated in the 100 km strip along the Serra Geral Mountain range (bordering the state of Goiás) and decreases sharply as one travels westwards (ibid).

In the western part of the basin, flat uplands (*chapadas*) predominate. Nowadays, agro-industrial farms are located on these flat uplands and coexist closely with smallholders settled in the valleys (Eloy et al., 2016). The natural vegetation (shrubby and open grasslands) on flat uplands mostly became converted into monocultures. These flat uplands are cut by narrow valleys that form the headwaters of the main rivers of the region (riparian forests, humid grasslands, and lagoons). In the eastern part of the river basin, the lowlands (*baixões*) are a mosaic of shrubby forests, grasslands, riparian forests, and small plots of multicrop farming and pasture (ibid). While the flat uplands function as recharge areas for the aquifer, the valleys inhabited by smallholders function as discharge areas (main rivers and their tributaries) (Porto-Gonçalves and Chagas, 2019).

Data collection and analysis

Water uses

Between 2017 and 2019, we conducted 34 semi-structured interviews with smallholders and large soybean farmers (Table 1).

Table 1. Sample characteristics for semi-structured interviews.

Type of farmers	Number of interviews	Place of interviews	Size of rural properties	Operating since	Total irrigated area (ha)	Irrigation techniques
Smallholders	26	Villages (Pratudinho, Pratudão and Praia)	0.2-6 ha	18th century	13	Gravity (trenches collecting water from the springs)
Soybean farmers	8	Jaborandi and Correntina municipality	1650 to 80,000 ha (average of 12,000 ha)	5-30 years (average: 14 years)	19175	Pumps and water reservoirs (surface and groundwater)

The interviews and observations focused on the regional agrarian history, the main characteristics of the farm (size, acquisition), agricultural productions and technologies, and their changes over the last 20 years, with a main focus on irrigation. Additionally, we compiled both projected and analysed data on land use and irrigated areas between 2000 and 2017 from two databanks: MapBiomas[2] and the Brazilian National Water Agency (ANA)[3] respectively, in order to understand changes in land use and its relationship with water usage.

Water policy

We collected, processed, and projected official data on water use licences (*outorga*) originating from the Bahia State Institute for Environment and Water Resources (INEMA) between 2013 and 2021 in the Corrente River watershed. This data set did not include the names of the corporations or individuals who benefitted from these licences, so we had to look up each licence on the SEIA databank website[4] to complete our database. We removed the water licenses awarded to public entities (the urban water supply) from this database, keeping only the data concerning private actors. Since smallholders, who abstract small volumes of water through river diversion (gravity systems), are not subject to water licensing, the database covers only the water licences allocated to agro-industrial companies.

We then analysed the evolution of environmental laws concerning water use licensing. We compared the technical documents that back these norms with official information from the federal and state governments' websites. Transcriptions of the Corrente River Watershed Committee meeting minutes were obtained from the INEMA website.

In addition, four interviews with a Corrente River Watershed Committee member and with the Bahia State Public Prosecutor helped us to interpret the evolution of these rules and to identify the technical and scientific studies on which they are based.

[2] Database: https://mapbiomas.org/en/colecoes-mapbiomas-1?cama_set_language=en

[3] Database: www.snirh.gov.br

[4] Database: http://sistema.seia.ba.gov.br/

Water knowledge

In the 34 interviews with smallholders and soybean producers, we asked questions about indicators of changes in landscape and water flows, as well as their causes and consequences. We undertook field observations with these producers and used satellite images to identify the locations of the transformations they described. We also collected indicators and explanations for the increasing water scarcity in a workshop that we organised in Correntina in May 2019. In this workshop, we brought together leaders from local smallholder associations, environmental policy managers (at municipal and federal levels), and representatives of regional NGOs (31 participants).

In addition, we analysed the evolution of AIBA publications and scientific literature on water resources in the region over the last few years and compared them to the farmers' narratives on the changes in the hydrological cycle.

PRODUCING WATER SCARCITY IN THE CORRENTE RIVER WATERSHED

A trajectory of basin closure

The history of occupation and agrarian transformation in this region before the arrival of agro-industrial farms demonstrates the importance of water control in peasant farming systems. Initially occupied by indigenous peoples, the Corrente River watershed had progressively been used for extensive cattle ranching on rangelands since the 18th century. At this time, many families migrated from the northeast, escaping slavery and drought, in order to work for large cattle ranchers and to get their own land. This led to the formation of villages along the rivers, starting in the 19th century. Today the region has hundreds of indigenous, *quilombola* (descendants of Maroon communities), and other traditional communities, with an average of less than 5 ha of land per household.

Most communities tend to practice swidden cultivation in fertile wetlands (*veredas*) through ingenious flooding and dragging practices. Such agriculture ensures production throughout the year, especially during the long dry season (4-5 months).[5] In the lower valleys, located in the eastern part of the watershed, the inhabitants also developed gravity irrigation systems to cultivate land near their homes, in use since the end of the 19th century. Today, the ditches still collect water from the springs and deliver water several kilometres away to irrigate fields and gardens during the dry season (Figure 2).

Agro-industrial development began in the 1970s on the flat uplands, initially with eucalyptus plantations, followed by soybean, corn, and cotton (Eloy et al., 2016). The first soybean producers, originating from southern Brazil, arrived in the mid-1980s. Government incentives, such as low land prices, favourable credit, and commitments to infrastructure building, gave a boost to migration processes. The agro-industrial frontier expanded from the north to the south (from Luís Eduardo Magalhães and Barreiras to Jaborandi) and from the west to the east, occupying what were once smallholders' areas (Figure 3).

Since its early years, large-scale agriculture in the Cerrado has relied on deforestation and rainfed farming (Eloy et al., 2016). But since 2000, a water-driven, agro-industrial pioneer front (what we call 'water frontier') has emerged in western Bahia. According to the spatial projection of the ANA database, irrigated areas increased from 9166 ha to 47,047 ha in the Corrente River watershed between 2000 and 2017 (+413%).

[5] Multicrop swidden fields (rice, cassava, beans, etc.) cultivated in trenched peat swamps, called *roça de esgoto* (Eloy et al., 2020).

Figure 2. Irrigation systems in the Corrente river watershed (BA). (a) Irrigation canal in smallholder community. (b) Pumping station and centre-pivot in soybean farm.

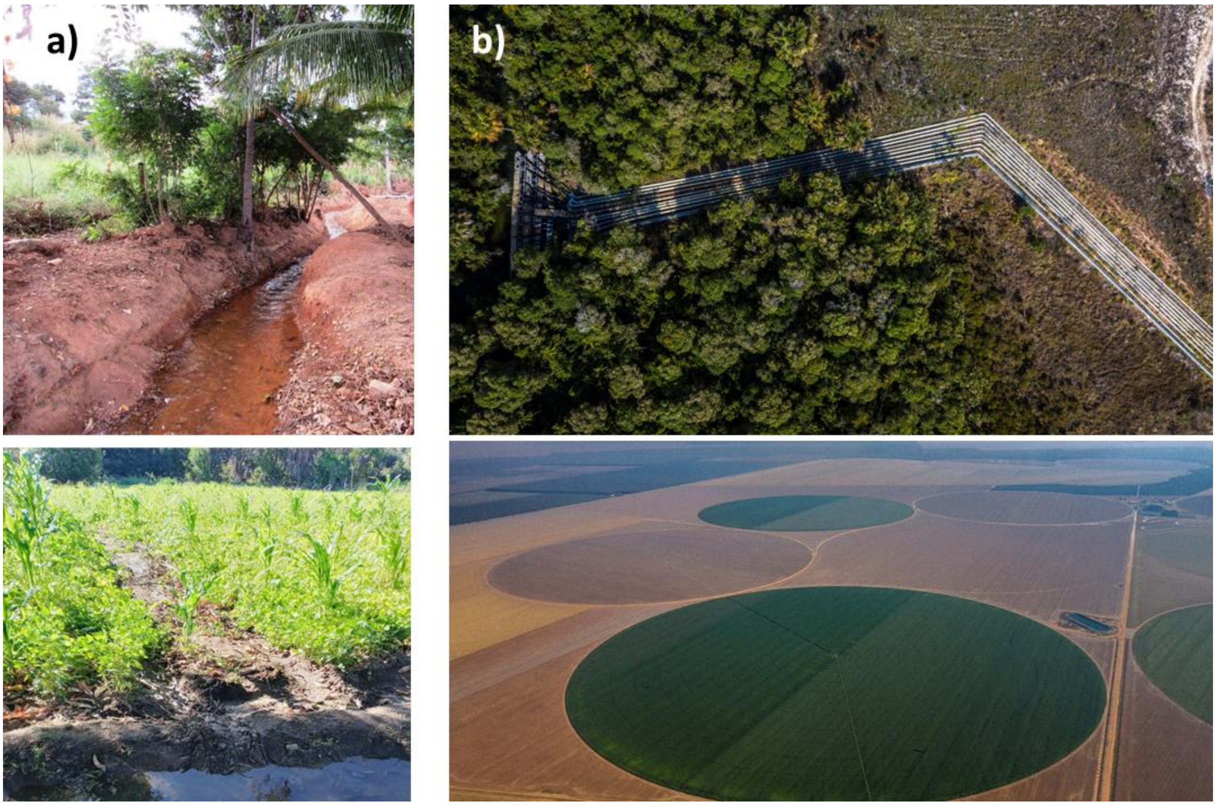
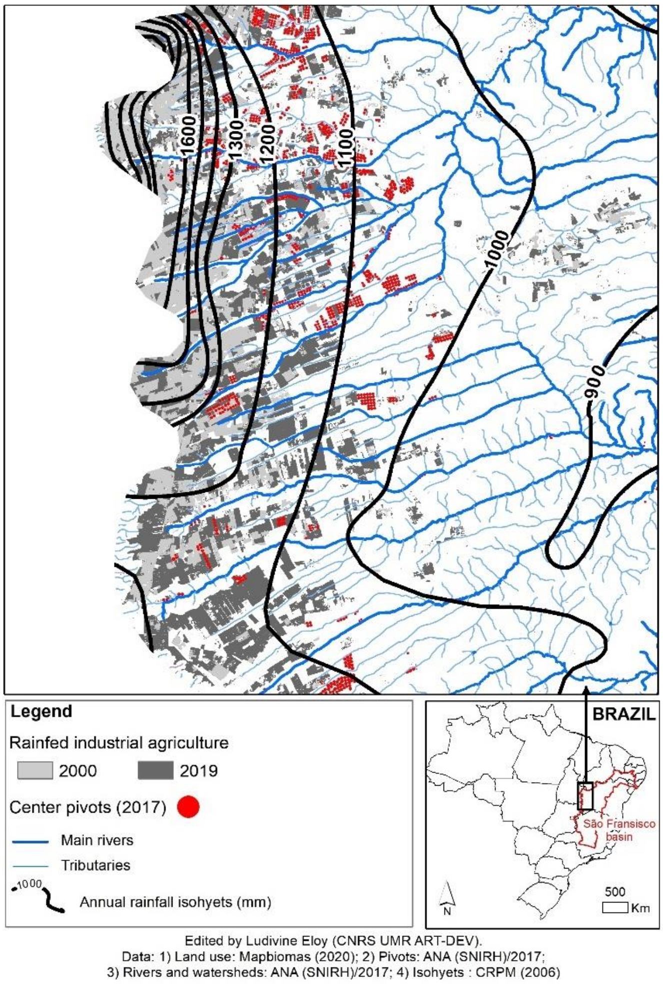


Photo credits: a) Ludivine Eloy @CNRS, b) Dado Galdieri @Hilaea Media

Large-scale irrigation in the flat uplands became possible – and necessary – in the context of new technical and financing conditions, climate variability, and territorial expansion eastwards. The uneven and rapid expansion of irrigated agriculture results from a water supply that has been increasing thanks to technological and infrastructure modernisation (roads and energy supply), a common feature of basin trajectory. In the late 1990s, some large farmers used surface water, which limited irrigation to the middle reaches of streams where surface flow was sufficient. In the 2000s, deep wells began to be sunk, thanks to better access to energy and increased investment possibilities (reservoirs, channels, and motor pumps). Such wells could draw water directly from the Urucuia Aquifer. These developments allowed the expansion of irrigation beyond riparian areas.

Indeed, this process coincided with a new phase of soybean expansion in Latin America, under new conditions of international investment, technological modernisation, and land concentration (Oliveira and Hecht, 2016). Agro-industrial firms needed to secure productive investments in a context of variable rainfall. The interviews with the soybean farmers revealed that irrigated agriculture ensures greater security for the production process and a greater return on investment. Central pivot irrigation allows the cultivation of varieties (soybean or corn) with high added value such as genetically modified seeds, obviating the rainfall constraint. Irrigation has therefore become complementary to rainfed farming. Moreover, irrigation achieved by large-scale pivot is also a means of spatial expansion (the 'water frontier'). As rainfall declines from the west to the east (Figure 3), irrigation allows for agro-industrial expansion to the east, where land is cheaper (Silva Bonfim, 2019).

Figure 3. Progression of the agricultural frontier in the west of the State of Bahia.



The uneven large-scale irrigation development put western Bahia on a trajectory of basin closure, disrupting preexisting forms of water and land use in downstream areas. Local indicators of the drying up of the agroecosystem show that water scarcity has intensified in the region since 2010. Our interlocutors in smallholder communities reported a sharp reduction in average river flows in the last 15 years. They also reported a phenomenon of 'spring migration' from the upper to the lower lands, followed by the gradual disappearance of smaller tributaries. For example, in the Arrojado River valley, residents identified eight streams that have dried up. Most swampy valleys (*veredas*), in which these communities traditionally cultivated rice in swidden fields, have begun to dry out. Moreover, since 2013, centennial irrigation ditches supplied by water from *veredas* and rivers (used in the eastern part of the watershed) have been partially drying out as well. This process has caused a decrease in agricultural output in properties that are no longer able to irrigate.

Recent hydrological studies in the region also show a sharp decrease in river flows, groundwater levels, baseflows, and superficial water storage (see below). The fact that the Urucuia Aquifer decreased its contribution to the São Francisco River flow by 49% between 1980 and 2018 (Gonçalves et al., 2017) is another indicator of the gradual closure of the basin.

But until now, responses to water scarcity from the state focus on supply augmentation: this 'supply response' is mediated by the growing allocation of water rights to agro-industrial firms in a context of water policy deregulation.

A trajectory of deregulation and disputes

The increasing pumping of water for centre-pivot irrigation has gradually become part of a legal framework since the early 2000s. The analysis of official documents reveals the timeline of these policy reforms to be divided into two periods: a first period of structuring the state's environmental policy, called 'decentralisation' (1995-2010), then a second one of deregulation (after 2011) (Figure 4).

Decentralisation

The Integrated Water Resources Management (IWRM) framework gained widespread acceptance in Latin America in the 1990s (Abers and Jorge, 2005). In Brazil, the water governance management model, based on integration, decentralisation, and participation principles[6] (Law 9.433/97), brought deep changes to Brazilian water resources management. In particular, the decentralisation in environmental policy is an offspring of the period of re-democratisation in Brazil, marked by social participation (Abers and Keck, 2013). With this law, granting water use rights became an administrative act of authorisation or concession, through which the public authority grants the right to use surface and ground water resources for a determined period of time.

The State of Bahia adopted water reforms in 1995 (Law No. 6.855/1995), two years before the National Water Resources Policy (Law No. 9.433/1997). At this time, Bahia created a state water agency (Superintendence of Water Resources – SRH) and the first state water policy. Brannstrom (2004) stresses that SRH benefitted from a loan of US$85 million from the World Bank to "strengthen the institutional structure" and "carry out integrated water resources management". When project funds expired, the water resources bureaucracy would rely on water tariffs.[7]

The SRH had the responsibility for licensing and monitoring the region's surface and groundwater, encouraging the creation of watershed committees[8] and eventually establishing tariffs for water use. But SRH provided little support for committee formation, and since the mid-2000s its institutional functions have been reduced to identifying water users and issuing licenses, shifting minor responsibilities from the state bureaucracy to regional water districts[9] (Brannstrom, 2005).

According to the author, the *Associação de Agricultores e Irrigantes do Oeste da Bahia* (AIBA) has lobbied state and federal governments for sector policy advocacy.[10] Created in 1990, AIBA represents 1300 irrigation and dryland farmers. AIBA is a regional organisation that has influenced environmental policy reforms, including water resource governance and research, overshadowing state agencies and other non-state actors (Brannstrom, 2005).

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[6] Decentralisation occurs due to the transfer of responsibility for executing decisions from central structures to local ones; in the case of the river basin, through the creation of decision-making bodies at the state and local level (e.g. councils and committees). Participation is determined by the composition of the committees, which are required to include representatives of the government, the users, and the society (Fadul et al., 2017).

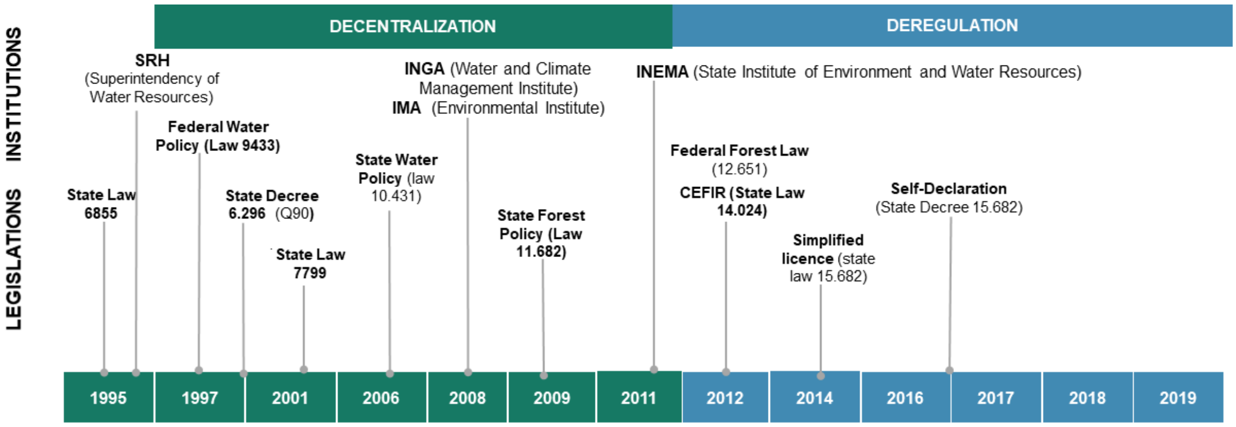
[7] Under the slogan "decentralise to optimise", the Bahian water resources bureaucracy has tried to identify, license, and charge water users such as industries (including the petrochemical sector near Salvador) and irrigated agriculture (Brannstrom, 2004).

[8] The watershed committees are collegial bodies composed of representatives of public authorities (municipal, state, and federal), civil society, and water users. They have advisory, consultative and deliberative functions to promote the participatory management of water bodies (Federal Law 9.433/2006, and State Law No. 10.432/2006, replaced by Law No. 11.612/2009).

[9] Bahia's water-management reforms, enacted by legislation passed in 1995 and implemented in 1997, shifted minor responsibilities from the state bureaucracy to 13 regional water districts. In 2005, the State Water Resources Plan redefined 17 regional water districts (known as *Regiões de Planejamento e Gestão das Águas* – RPGAs). In 2009, a new hydrographic division was published, increasing the number from 17 to 26 RPGAs (Resolution No. 43 of the State Council of Water Resources). Due to its great length, the São Francisco River was subdivided into 8 RPGAs composed of sub-basins of one or more of its tributaries.

[10] Such lobbies include improved infrastructure, increased subsidies, restructured farm debt, reductions in the value-added tax on diesel fuel, reduced environmental licensing fees, and so forth (Brannstrom 2005: 262).

Figure 4. Timeline of environmental, forest, and water legislation in the State of Bahia.



Nowadays, regional water districts still have very little power and are upwardly accountable to the water resource bureaucracy based in Salvador, the capital of the State of Bahia. In 2008, SRH was replaced by the Water and Climate Management Institute (INGA), responsible for water resource management, and the Environmental Institute (IMA), responsible for deforestation licences.

As a result, since the early 1990s, the State of Bahia has created favourable conditions for water exploitation through bureaucratic neglect, poor hydrological knowledge, and public-private partnerships that have worked to legitimise the first round of soybean expansion and helped consolidate AIBA as a powerful organisation.

Deregulation

Simplification

After 2011, the Bahia government simplified its institutions and licensing procedures. In 2011, the state government unified water and forest management systems (IMA and INGA) into a single agency, INEMA (law 12.212). INEMA became responsible for issuing water grants and deforestation authorisations. Since 2012, the State Forestry Rural Property Registry (CEFIR), equivalent to the Federal Rural Environmental Registry,[11] has become a simple tool for obtaining deforestation licences and water rights at the same time. This process of deregulation has accelerated since 2014, when the State of Bahia tried to exempt agro-industrial companies from the environmental licensing process (State Decree nº 15.682/14 and 16.963/2016).[12] At present, INEMA has adopted a simplified environmental licensing procedure, which is limited to an electronic 'self-declaration' model by CEFIR that dispenses with field checks.

Growing allocation

A dramatic increase in the volume of water licensing occurred after 2014, following the simplified licensing requirements from INEMA detailed above (Figures 4 and 6). According to our database, the extra volume of water allocated annually to agro-industrial companies grew from 772,338 m^3/day in 2013 to 1,803,956 m^3/day in 2019 (+133%). Since 2020, it has decreased to around 750,000 m^3/day. Each license is valid for four years, so the cumulative volume of water increased by 431% between 2013 and 2021 (from 772,300 to 4,106,400 m^3/day). Moreover, over the same period of time, the share of

[11]The Environmental Rural Registry (*Cadastro Ambiental Rural* – CAR) is a mandatory but self-declaratory registry of rural properties and rural landholdings that reports on compliances and non-compliances with legal and environmental requirements.

[12] https://www.jusbrasil.com.br/noticias/liminar-determina-que-inema-volte-a-realizar-o-licenciamento-de-atividades-agrossilvipastoris-na-bahia/438202350

groundwater in the total volume of water allocated to agro-industrial companies rose from 6.6% to 29.6% (Figure 5). This result means that supply augmentation has been the response to water scarcity, gradually shifting from the exploitation of surface water to groundwater tapping. And, until now, pumping water for large-scale irrigation development has been free of charge.

Figure 5. Evolution of the cumulative volume of water (1000 m³/day) allocated to agro-industrial companies in the Rio Corrente watershed between 2013 and 2021.

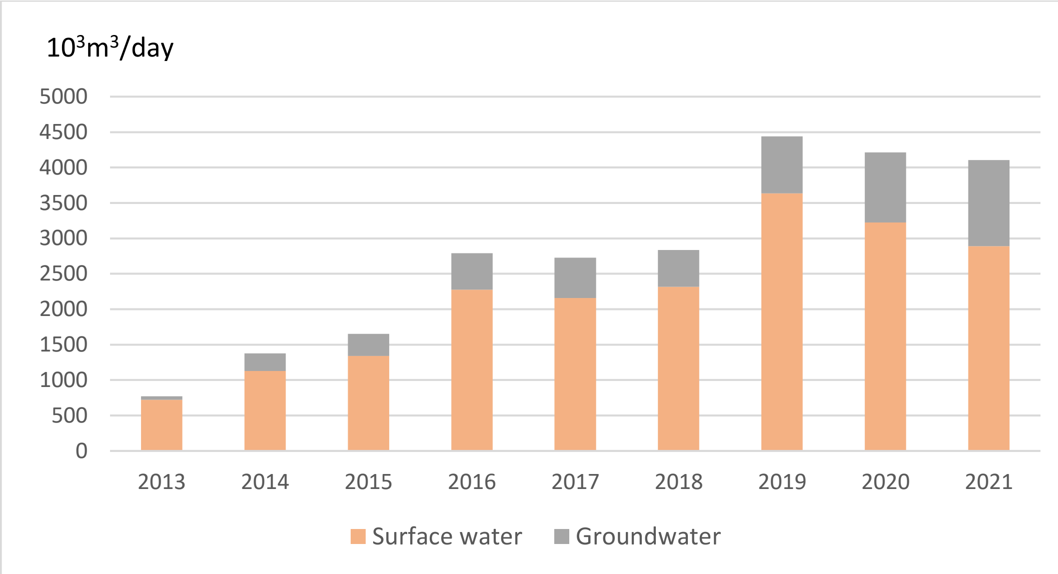


Figure 6. Spatial distribution of water licences (2013-2021) in the Rio Corrente River watershed.

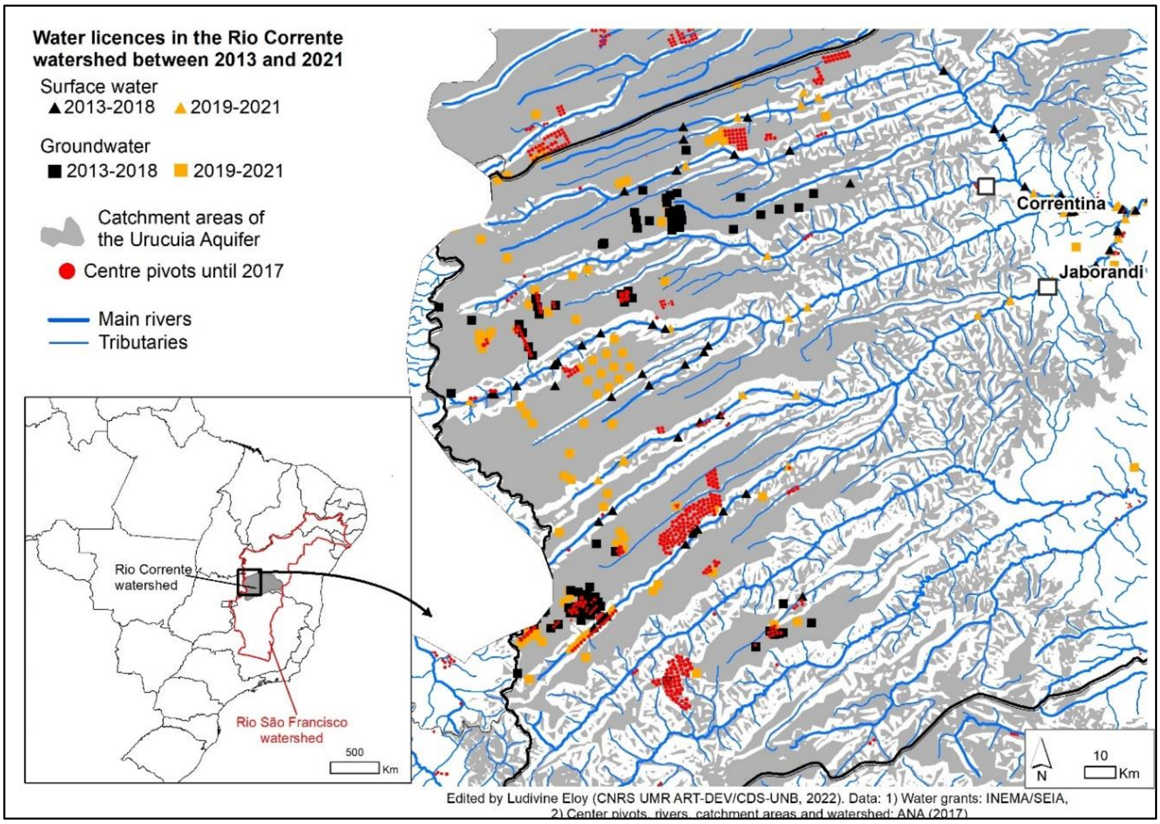


Figure 6 shows that these water licences are concentrated in the aquifer catchment areas (92%), i.e. the upper parts of the Formoso, Arrojado, and Corrente Rivers. This map also shows that some pivots do not correspond to water licences, which indicates that the actual volume of water pumped may be even higher, due to a lack of monitoring. On the other hand, several recent water licences do not overlap with centre-pivots, indicating a delay in starting exploitation or a possible strategy of land valuation through water rights.

Permissive and outdated parameters

The analysis of official documents revealed that increasing water allocation relies on permissive hydrological parameters and a lack of monitoring and enforcement.

INEMA uses a basic criterion for allocating surface water licences: the reference flow rate, based on averaged water flow (per year), measured from historic daily fluviometric records that are publicly available through digital databases. Since 1997, the state adopted the Q90[13] reference flow rate. Water volume corresponding to 80% of Q90 can be granted for different water uses (State Decree 6296/1997).

Q90 is a permissive flow rate[14] and has been calculated based on an outdated time series that does not take into account the seasonality of the flows, nor the decreasing flows since 2013 (Khoury, 2018).[15] In addition, the few watershed fluviometric stations that inform water agencies are located on the lower parts of the river, where the flow is higher.[16] Indeed, the volumes allocated for surface water have reached the official limits (80% of Q90) in many rivers, like in the upper Arrojado (Oliveira et al., 2022), prompting producers to apply for groundwater rights, which confirms the ongoing process of basin closure.

As for groundwater, the standard in force since 2022 (IN n° 003/2022) establishes the minimum spacing between wells and rivers, according to their pumping power, but without a volume threshold for each well or for the whole aquifer, as was the case with the previous standard (IN n°15/2010). In the face of decreasing river flows, INEMA has used these standards to promote the viability of the exploitation of the Urucuaia Aquifer (Maia and Rodrigues, 2020).

Lack of transparency, monitoring, and enforcement

Bahia state officers grant licences without monitoring the volumes actually pumped. The agency issues surface water licences without considering what has already been licensed in terms of groundwater and vice-versa (ANA, 2017). As a result, the integrated surface and groundwater management proposed by the national water policy (Law 9.433/97) is still underdeveloped (Hirata et al., 2017). Moreover, INEMA's 26 regional water districts do not have local or regional staff to carry out on-site inspections.

Until 2015, water management policy was under a period of relative water abundance coupled with poor hydrological data: environmental deregulation, promoted by both the state and agribusiness firms, seemed to have legitimised agro-industrial expansion and to have silenced local protests. As in Chile, the discourse of abundance was linked to new farmers' needs in order to legalise groundwater extraction (Budds, 2009). Our results confirm the close link between land grabbing and water grabbing, since "large-

[13] Q90 is the flow rate expected to be present in the river for at least 90% of the time, according to available fluviometric data.

[14] In 1995, the Bahia State Water Resources Secretary (SRH) had adopted a more restrictive reference flow rate (Q7.10) (Bahia, 1995). Q7.10 is based on a historical series of average minimum flows with a moving average of seven consecutive days with a return period of 10 years, and it is used by the State of Minas Gerais, among other Brazilian states, to confront water scarcity. However, after 1997, Bahia adopted a more permissive legislation than the federal agency and the northeastern Brazilian states (Agência Nacional de, 2011).

[15] The new basin plan proposes to update the reference flows (revised downwards) and to implement seasonal licences, i.e. based on a seasonal variation in river flows (INEMA, 2022).

[16] INEMA's Technical Note 24/2018 explains that the agency relies on data from only five flow monitoring stations in the Corrente River basin because historically they have the highest number of records and the lowest number of failures (Khoury, 2018).

scale land acquisitions are the quest for water resources (…) to sustain agricultural production" (Dell'Angelo et al., 2018), but also because the rush for water licences, even without irrigation, is a way of valorising land. In this sense, the increasing use of groundwater licences (see sub-section 'Decentralisation' above) is a response to the decreasing river flows but is also a safer form of investment. The fact that AIBA has been communicating extensively on the "groundwater potential" of the Urucuia Aquifer in recent years (AIBA, 2017) indicates a strategy for attracting investors in a context of uncertainty (water conflicts and droughts).

These results are consistent with other studies on neoliberal water reform policies in Latin America, such as in Peru (Damonte, 2019), Bolivia (Rocha López et al., 2019), Chile (Budds, 2008; Usón et al., 2017), and Ecuador (Boelens et al., 2015). Indeed, while Brazilian water reforms have contributed to democratising water management in some ways (Elabras Veiga and Magrini, 2013), they may not have prevented water grabbing (van Koppen, 2007; Mehta et al., 2012).

However, during the water scarcity phase starting in 2015, growing protest forced the agribusiness sector to produce its own explanations for the water crisis, in order to justify and sustain water allocation to agro-industrial companies. As in many other regions of agro-industrial expansion, the dispossession of downstream water users and the destruction of their long-established water management systems has been responsible for the emergence of violent social conflicts. Basin closure is not only a consequence of water exploitation by agro-industrial companies, but is also a driver of change: it fosters new social and legal protests over environmental deregulation, new partnerships, and new scientific research (Molle, 2003).

Participation and contesting deregulation

The last decade has been marked by growing protest amongst the populations of the Barreiras and Correntina municipalities over the water exploitation by agro-industrial companies. The Corrente River Basin Committee (*Comitê de Bacia Hidrográfica do Rio Corrente*, CBHC) was established in 2008 (Decree No. 11.224), 13 years after the creation of the state water policy.[17] As the committee started to contest the large volume of water licences, it became an internal space of dispute with the agribusiness actors (notably AIBA). In 2015, the CBHC recommended that INEMA suspend the granting of water licences.[18] This recommendation was not implemented, which motivated the State Public Ministry (MP-BA) to initiate legal action in the same year, based on the evidence of environmental deregulation (Bahia State Public Prosecutor, personal comment).

Water scarcity intensified in the dry season of 2017 and culminated in the Water War. After this violent conflict, federal and state public prosecutors, on the basis of a public hearing, suggested a set of requirements be implemented by the Bahia State government. These included a suspension of water licence allocations by INEMA until approval of the Corrente River Basin plan by the committee; the review of the technical parameters used to determine allocated volumes; and participatory river flow monitoring. Nevertheless, INEMA did not heed the committee's recommendations, and new licences have continued to be allocated since 2018 (Figure 4). In 2019, INEMA began to require companies to install water metres on irrigation pumps as a condition for the renewal of licences, but it has not extended this requirement to new applicants, and as of 2022, no data about these pumps and their withdrawals were publicly available (INEMA, 2019).

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[17] The CBHC is currently composed of 30 members and their respective deputies, maintaining the tripartite parity composition (state authorities, users, and civil society organizations). Available from: http://www.inema.ba.gov.br/wp-content/uploads/2011/09/Decreto_11.244_cria_CBH_Corrente.pdf

[18] According to the Corrente River Basin Committee minutes for 11 December 2015, the Committee requested a temporary suspension of the issuance of water use permits in the basin until further criteria for water permits could be defined (CBHRC, 2015). The watershed plan is mandatory for issuing water licences, according to Bahia State water law 11.612/2009, art. 11, 12, and 13.

After the Water War, disputes arose over the elaboration of new River Basin Management Plans for two important tributary basins of the São Francisco River (the Corrente and Grande rivers). In 2019, the state government hired a consortium of private companies (Consórcio Hydro-Engeplus) through a public tender to draft the Corrente River Basin Management Plan. The basin committee deliberated and approved the basin plan under reservations concerning forest recovery in the recharge areas of the Urucuia Aquifer. During these deliberations, social movements requested more precautionary flow rates, which was not taken into account by the environmental authority (INEMA, 2022). This reveals the challenges and limits of social participation when it comes to water issues in the region (da Silva et al., 2023).

Fadul et al. (2017) list several problems that affect the participation and representation process of the water committees in the State of Bahia, such as lack of water agencies; absence of water resource plans in most of the committees; society representatives' lack of resources to travel to the meeting locations; lack of understanding of the role of the watershed committee; inefficient mobilisation; and others. In our interviews, various social movements and the Public Ministry also expressed regret that, during the negotiations over the management plans, they lacked the technical capacity to address the issues of adequate hydrological parameters for monitoring and allocation.

Indeed, the production and mobilisation of divergent hydrological knowledge became central to the power relationships related to water governance in the region.

Divergent narratives of the water scarcity problem

Between smallholders and soybean farmers

Since 2015, farmers and scientists have been facing the aggravated problem of water scarcity, but the interviews show that soybean producers and smallholders differ in their understanding of the issue.

Most smallholders blame large-scale deforestation and irrigation in the flat uplands for these changes. For them, the drying up of river springs is evidence enough. In the valleys of the Formoso, Pratudão, and Pratudinho Rivers, the interviewees also noted the disappearance of lagoons (such as Lagoa Bamerindus or Lagoa Feia), which happened at the same time as the first eucalyptus plantations in the 1970s, as well as the increasing number of dried-up wells after the 2000s. Smallholders have also observed a significant reduction in rainfall over recent years, but no one considers it to be the primary cause of the drying up of the agroecosystem. They argue that even severe droughts, such as those in the 20th century (for example, between 1976 and 1978), never caused such a drying-up of river springs, lagoons, swampy forests, and irrigation ditches in the valleys.

In contrast, soybean farmers blame other factors for the changes in the hydrological cycle: climate variations and traditional agropastoral systems. For them, the reduction in rainfall in recent years has been responsible for the drying up of lagoons and springs; they consider it to be a natural phenomenon. For instance, one of the farmers considers the drying of Lagoa Feia (located on his property) as a "natural process that has occurred at the same time as other lagoons in the region". Soybean producers also blame traditional communities for the water scarcity because of their use of humid grasslands (*veredas*) that surround swampy riparian forests for pastoral management. For example, one interviewee shifted the focus of the discussion from the impacts of irrigation to the criminalisation of local populations in relation to the use of natural resources: "Our biggest environmental problem is this village down here [Pratudinho], free-range cattle ranching, fire, hunting, fishing". Indeed, the main action that INEMA has taken to mitigate water scarcity in the region is to fence riparian forests in the valley, occupied by smallholders, to "protect and restore river springs" (Governo da Bahia, 2016), while continuing to allocate water licences and deforestation licences to agricultural companies in the uplands. The AIBA has also developed its own river restoration program in smallholder communities downstream, which received an award from the National Water Agency (ANA) in 2020.[19]

In short, while smallholder communities blame large-scale deforestation and irrigation in catchment areas to explain water scarcity, soybean producers blame rainfall reduction and traditional pastoral management in the valleys. The naturalisation of the problem and its spatial shift (from upstream to downstream) help soybean farmers disclaim responsibility for water resource scarcity. Indeed, increased deforestation and water pumping take place in the catchment areas situated in the flat uplands dedicated to soybean cultivation, while evidence of associated water scarcity is found in distant lowlands located downstream, as much as 50 km away from the plantations. The perceived disconnect between centre pivots and deforestation in catchment areas, the aquifer, and the rivers flowing in the valleys shapes a local controversy on water issues.

Among scientists

Geologists have studied the risks and consequences of water exploitation since the beginning of the 'soybean boom' in western Bahia (Gaspar and Campos, 2007). They have evaluated the impact of deforestation on water infiltration, with possible adverse consequences for the recharge of the Urucuia Aquifer and warned of the risks associated with large-scale water pumping. These results were confirmed by a larger study undertaken by the National Water Agency (ANA, 2017). Since this work was not based on historical precedent, it does not clearly establish the causal relationship between agro-industrial expansion and the decrease in river flows. However, in 2016, a team of geologists from the State University of São Paulo explicitly noted the overexploitation of surface and groundwater and its role in declining baseflows in the Urucuia Aquifer (Gonçalves et al., 2016).

In this period of growing concern over the worsening of water scarcity (culminating in the Water War of 2017), the AIBA started to fund a research project in partnership with the Government of Bahia (the Environmental and Agriculture Departments) through the Prodeagro (Bahia State Agribusiness Development Institute). This study was conducted by a team of hydrologists and geologists from the University of Viçosa (Brazil) and was called Study of the Water Potential of the Western Region of Bahia (2017-2019), in partnership with the University of Nebraska (USA) and the Daugherty Water for Food Global Institute (linked to the University of Nebraska). Their findings are consistent with the work of other scientists regarding the widespread depletion of water resources in the region: hydrological, geological, and satellite data speak for themselves (Table 2).

However, the disagreements between scientists are about the causes of this water crisis. The models created by the hydrologists who work in partnership with AIBA show that climate change (e.g. decreasing rainfall and extreme decadal events such as El Niño), rather than more immediate anthropogenic factors, has been responsible for the reduced river flows in recent years (Pousa et al., 2019). In another publication, Marques et al. (2020) indicate a possible overexploitation of the aquifer but cast doubt on the weight of the "climate oscillation" and irrigation factors in the decreased water level: "It was not possible to link unequivocally such causes and the observed effect. The relative contribution of these individual conditionings remains, therefore, to be adequately quantified for longer monitoring periods" (p. 10).

This type of explanation is not shared by the geologists from the State University of São Paulo, who stated in a recent publication that water storage diminution was "driven by anthropogenic impacts rather than by natural climatic variability" (Gonçalves et al., 2020). Recent hydrological research studies in western Bahia (da Silva et al., 2021) and in the Cerrado indicate that the decrease in river flows cannot be explained solely by a reduction in rainfall and that agro-industrial expansion is primarily responsible for it (Mesquita et al., 2018). Moreover, some scholars argue that the decrease in precipitation in

[19] https://storymaps.arcgis.com/stories/2fe88dd9c06d4482b1916bcbdf8474c5

Table 2. Main scientific indicators of water resource evolution in western Bahia.

Dimension	Parameter	Evolution	Temporal/ spatial scope	Source
Surface water	Streamflow reduction	38%	1986-2018 /Pratudão watershed	da Silva et al. (2021)
		34% to 40%	1977-2017 /Upper Grande River watershed	Marques et al. (2020)
Groundwater	Rate of baseflow reduction	0.75% to 3.04%/year	1977-2013 /Grande River watershed	Gonçalves et al. (2016)
	Groundwater table decline	1 m to 3 m	1977-2015 /Ondas River watershed	Maia and Genz (2019)
		up to 6.63 m	1977-2017 /Upper Grande River watershed	Marques et al. (2020)
	Terrestrial water storage (TWS) depletion rate	6.5 ± 2.6 m/year	2002-2013/Urucuia Aquifer system	Gonçalves et al. (2020)

MATOPIBA is also the result of regional land use change, i.e. deforestation caused by agro-industrial expansion (Spera et al., 2016). Based on a large-scale study of the flows in 81 watersheds in the Cerrado biome over the last three decades (1985-2018), Salmona et al. (2023) stress that large-scale deforestation oriented towards the production of irrigated agricultural commodities has more significantly impacted river flows than global climate change. Based on a projected future deforestation and climate scenario up to 2050, the authors predict a decrease of about 34% of the river flows (23.7 m^3/s), which will cause severe streamflow discontinuity in many rivers and strongly affect agriculture, electric power production, biodiversity, and water supply, especially during dry seasons.

We found that this scientific controversy echoes the divergent explanations among farmers. The methodologies and data sets applied by the hydrologists who have been working in partnership with AIBA since 2016 offer a cause-effect narrative that connects climate change (e.g. rainfall reduction and extreme decadal events such as El Niño) to decreasing river flows in recent years – instead of blaming anthropogenic factors that lie closer to home (Pousa et al., 2019). Despite many counter-arguments that exist in the scientific literature, AIBA uses the results of its academic partners to communicate extensively on meteorological droughts and solutions for efficient water management. This allows them to redirect the focus to environmental sustainability and social responsibility through key ideas such as 'groundwater potential', 'efficiency', 'water monitoring', 'spring recovery in riverine communities', and 'firefighting' (AIBA, 2017, 2020, 2016). For example, according to the Secretary of Agriculture of the State of Bahia, speaking in 2020 in the magazine AIBA Rural:

> In western Bahia, the work is done efficiently, and this is a key word for me. This efficiency is in the essence of the Water Potential Study of Western Bahia, which is nothing more than showing, with scientific data, where irrigation can expand in the region (…). This promotes sustainability, with the rational use of rivers, groundwater, and all this combination of waters that is here, which is part of the fantastic Urucuia Aquifer. This study brings security to producers, because it frames water licences. And what is a water licence? A paper that ensures the producer's investment, indicating that a study proves the existence of so much water that he will be able to withdraw without problems, without environmental impacts. (AIBA, 2020), translated by the authors.

By selecting scientific results that emphasise climate change and by offering solutions focused on smallholder communities, AIBA reproduces and legitimises the local narrative, which consists of naturalising and simplifying the water problem but also of its spatial dislocation from upstream to downstream. Over the last years, it has been through its active involvement in the production of hydrological knowledge that the agribusiness sector in western Bahia has maintained its leadership in environmental governance despite water scarcity. This case also demonstrates the role of an "industry-affiliated science" (Goldstein, 2015) that can "conjure doubt and ambiguity (…) in support of continued agricultural development", like in other agro-industrial frontiers in the tropics (p. 13). As in other Latin American regions, hydrological information is selectively scaled and employed to position powerful interests and demands (Budds, 2009; Usón et al., 2017).

More research is needed to understand how knowledge of water is produced and circulated on the agricultural frontiers of the Cerrado. Agribusiness representatives will need to produce explanations and solutions to this environmental crisis in the next few years, despite divergent expertise and increasing social disputes at different scales. While critical political ecology has explored how international organisations enforce controversial environmental knowledge in the fields of climate change, forestry, and water (Forsyth, 2003; Molle, 2009), there is still a lack of thorough examination of the scientific discourse promoted by the agribusiness sector and its relationships with local mechanisms for resource exploitation, especially in Brazil (Rajão et al., 2022). This would require further exploration of the diversity of irrigation practices and environmental perceptions among farmers, especially within the agribusiness sector, which tends to present itself as a homogeneous block but is in fact home to competing interests (Wesz Jr, 2015; Pompeia, 2018). Indeed, competing knowledge claims may also exacerbate the water conflicts in the region (Birkenholtz, 2008; Usón et al., 2017).

CONCLUSION

In this paper, we have explored the spatial dimensions and temporal evolution of agribusiness strategies for exploiting the water resources of western Bahia since 2000, despite growing concerns and evidence of water scarcity.

We have shown that large-scale irrigation development has put western Bahia on a trajectory of basin closure, disrupting preexisting forms of water and land use in downstream areas. Water scarcity is constructed and experienced in concrete ways by different social and political actors. This process confirms disparities in the spatial and social distribution of the costs and risks associated with changes in technology and water use (Venot et al., 2006).

The Corrente River basin is a case where, even while the basin nears closure and sectoral allocation becomes a point of tension, pivot irrigation continues expanding through a public and free-of-charge system of water rights. In the context of water policy deregulation, supply augmentation through tapping groundwater resources remains the main response of the state to water scarcity. We argue that a controversy over the causes of water scarcity added to the simplification of environmental licencing procedures and the fragility of the instruments of social participation (basin committees and river management plans), may explain why supply augmentation is still the main response of the State of Bahia in the face of water scarcity, despite evidence of basin closure. This response directly benefits the agribusiness sector and questions larger-scale processes and basin-wide coordination, since western Bahia includes many tributaries of the São Francisco River.

More generally, our results call into question the water rights system that is supposed to rationalise abstraction and show the limits of Brazilian water management policy (basin committees, participation, and water tariffs).

Finally, a close look at a basin's trajectory offers a way to locate scientific controversies regarding water in contested territories. These findings highlight the role of scientific knowledge in (re)shaping the influence of agro-industrial companies in the environmental governance of developing countries.

ACKNOWLEDGEMENTS

We thank all our interlocutors who collaborated with this study and their institutional partners. We thank in particular our interlocutors for their kind hospitality during fieldwork. This work was supported by CNRS through its *International Emerging Actions Project* and postdoctoral fellowship of the Coordination for the Improvement of Higher Education Personnel (CAPES).

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