

16. Groundwater relevance for Brazilian semiarid development in the northeast: the need for protective environmental laws

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1. INTRODUCTION

The Brazilian semiarid region is ideal for analyzing the impact of groundwater for human development and equity and for the formation of resilient territories, considering the process of climate change and also the large number of rural properties in existence. The question is: precisely what is the relevance of groundwater for survival in the Brazilian semiarid region? In the international context, there is a growing need to map more precisely the potential of groundwater to complement existing water systems or even to support increasing demand for water, especially from the viewpoint of production of food for the export market in a profile focused on more sophisticated agribusiness on a larger production scale.¹

Groundwater has served to provide communities with adaptive mechanisms that assist in local and regional development, and their importance for the establishment of a milder reality is substantial, as it has been demonstrated that conventional urban systems have not reached these communities. However, it is essential to understand that these aquifers are fundamental for resilience in the process of climate change in regions with an ecosystem as delicate as the Brazilian semiarid region.² Huge investments like the transposition of the

¹ Jesiya NP, Girish Gopinath [2019] “A customized FuzzyAHP-GIS based DRASTIC-L model for intrinsic groundwater vulnerability assessment of urban and peri urban phreatic aquifer clusters” (8) 654–6 Groundwater for Sustainable Development www.sciencedirect.com/science/article/abs/pii/S2352801X18303011 Accessed November 8, 2019.

² Heba Abd el-AzizAbu-Bakr [2020] “Groundwater vulnerability assessment in different types of aquifers” 240 Agricultural Water Management <https://doi.org/10.1016/j.agwat.2020.106275> Accessed May 8, 2020.

São Francisco River have not yet been used by these populations; in fact, such works have had a negative impact on groundwater.

Presented in this chapter is a region of Brazil known as semiarid, in the portion corresponding to the northeast region of the country, whose rural life depends largely on reservoir waters and, mainly, wells drilled by governmental and non-governmental organizations. Where these structures do not exist, these populations survive by waiting for water that can be reserved in masonry structures known as slab cisterns, or by buying water or waiting for “pipa” cars, which are government-owned trucks providing water supply.

The scarcity of more accessible water sources drives the inhabitants of this region to seek water from below-ground points, whose uses are multiple—notably, agricultural production and raising animals such as sheep, oxen, and cows. In this regard, Barati et al³ present the absence of intelligent governance on the balance of water stocks as an impediment to the survival of these systems.

Local governments assist in the process of drilling urban and rural wells as a strategy to withstand the effects of drought. Although this region has benefited from the transposition of the São Francisco River, it only affects the installed water supply system, as there is no water utility network in rural areas. The communities in this region are consistently deprived of water supply and must use water from water trucks, which draw water from other reservoirs in and out of the state, as well as from drilled wells.

Water in these places is precious in the face of periodic scarcity, and in consequence it needs to be well-managed. Since the soil is crystalline and very rocky, the water in this region has a high salinity.⁴ However, it is possible to install systems that assist in the management of this water and its waste, with the reuse of water being a concrete possibility, since this region needs all possible water supply to increase its level of resilience.⁵

Low rainfall throughout the year is an expected feature, and community planning is essential in view of existing water use. It is important to emphasize

³ Ali Akbar Barati, Hossein Azadi and Jürgen Scheffran [2019] “A system dynamics model of smart groundwater governance” (2019) 502, 518 *Agricultural Water Management* <https://doi.org/10.1016/j.agwat.2019.03.047> Accessed May 8, 2020.

⁴ Marie Eliza Zamberlan da Silva Rosângela Getirana Santana Marcio Guilhermetti, Ivens Camargo Filho, Eliana Haru Endo, Tânia Ueda-Nakamura, Celso Vataru Nakamura, Benedito Prado Dias Filho [2008] “Comparison of the bacteriological quality of tap water and bottled mineral water” (2011) *International Journal of Hygiene and Environmental Health Issues* 5–6 504–9 <https://doi.org/10.1016/j.ijheh.2007.09.004> Accessed May 8, 2020.

⁵ National Institute of Semiarid—INSA, “Estimated population of the Brazilian semiarid region 2017” (first published 2017) https://portal.insa.gov.br/images/imagens-noticias/2017/11/MAPA_POPULACAO_2017.pdf Accessed October 9, 2021.

that the government maintains a “fresh water” program, which aims precisely to install desalination plants that are fundamental in complementing the process of distributing scarce water to semiarid communities.

This policy is inserted in a context of mitigating the effects of drought or the absence of rainfall, and the need to provide communities with adaptive instruments to create resilience mechanisms for a more acute process of drought brought about by the dynamics of climate change. Therefore, we present here the results of our studies conducted in this region, and we stress the importance and the possibilities of the Master’s degree course in Water Resources Management and Regulation. The study was conducted mainly through this Master’s course, in partnership between the Federal University of Campina Grande and the São Paulo State University.

This chapter aims to demonstrate the importance of groundwater for the development of a region that already has water scarcity as a reality in its daily life, where drought periods are very intense and water sources are fundamental to the maintenance of rural life.

2. HUMAN AND ECONOMIC CONFIGURATION OF THE BRAZILIAN SEMIARID

2.1 Regional Characterization

The Brazilian semiarid is a region that has very peculiar characteristics, such as its vegetation, soil, and climate, which relate to a territory in an advanced process of desertification. In addition, the population density of the region is remarkable: its most well-populated territories have considerable urban and rural occupation. Figure 16.1, extracted from the public database of the Brazilian Institute of Geography and Statistics (IBGE), shows the current area, which is expanding and is under periodic review by the Northeast Development Superintendence (SUDENE). According to information from Resolution n. 115/2017 of the Ministry of National Integration (MIN), there are 1,265 municipalities in this semiarid region alone.

The Brazilian semiarid is a region delimited by SUDENE (Northeast Development Superintendence) considering dominant climatic conditions of semi-dryness, especially rainfall. As a reflection of climatic conditions, the hydrography is fragile in its broad aspects and insufficient to sustain flowing rivers during long periods of absence of precipitation. The exception is the São Francisco River. Due to its hydrological characteristics, which allow its continuity throughout the year, the São Francisco River acquires a special significance for the riverside and Sertão zone populations.

In 2002 implementation of the water transposition project for the São Francisco River basin began, with the diversion of part of its waters to two



Source: Brazilian Institute of Geography and Statistics—IBGE, *Brazilian semiarid region. 1:12 000 000* (Map 2017), Brazil, https://geoftp.ibge.gov.br/organizacao_do_territorio/estrutura_territorial/semiarido_brasileiro/Situacao_23nov2017/mapa_Semiarido_2017_11_23.pdf accessed October 1, 2021.

Figure 16.1 Semiarid region in northeastern Brazil

axes, one to the north and one to the east.⁶ In 2017 the eastern axis part of the project was inaugurated, but it is still poorly functioning. This major project aims to ensure water supply for urban and rural communities. To date there have been no positive impacts for the rural population as the water is not benefiting rural communities.⁷ These communities essentially depend on groundwater and rainwater accumulated in cisterns and, in some cases, from reuse. It is interesting to note here the limited importance of the transposition of the São Francisco River to rural communities, since they have not yet benefited from these waters, and there are no prospects of this. Notably, many families

⁶ Jose Irivaldo Alves Oliveira Silva, “Ressignificação Ambiental e modernização ecológica no Semiárido: o projeto de integração e revitalização do São Francisco” (first published 2016, Hucitec), São Paulo.

⁷ Jose Irivaldo Alves Oliveira Silva, John Brehmer de Sousa Alves de Oliveira, “Água, meio ambiente e desenvolvimento” [2016] *Raízes: Revista De Ciências Sociais E Econômicas* (36)(1) 121,142 <https://doi.org/10.37370/raizes.2016.v36.451> Accessed September 9, 2021.

living in the area around the eastern axis, which is already in operation, depend on alternative sources of water to develop their family farming and animal husbandry.

At 1.56 million km² (18.2 percent of the national territory), the northeast region of Brazil comprises most of the Brazilian semiarid, which is located in the central portion of this region and also beyond its limits, encompassing the states of Piauí, Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, Sergipe, Bahia, and the northern part of the Minas Gerais state (southeast region).⁸ In 2014 the population reached almost 24 million inhabitants, according to data from the National Institute of Semiarid.

According to data collected in 2010, the Brazilian northeast has maximum annual precipitation of 800 mm, average sunshine of 2,800 h/year, average annual temperatures of 23°C to 27°C, average evaporation of 2,000 mm/year and average relative humidity around 50 per cent. The Brazilian semiarid characteristically presents strong insolation, relatively high temperatures and rainfall regime marked by scarcity, irregularity, and concentration of rainfall within a short period—on average three to four months—presenting insufficient volumes of water in its springs to meet the needs of the population.⁹ Therefore, it is in this context that alternative water sources have a positive impact and are indispensable for local and regional development.

2.2 Social, Economic and Environmental Data

This region has very strong social vulnerability in relation to the other Brazilian regions, which is potentiated by the climatic situation and, consequently, by the periodic droughts; therefore, water stocks are essential for the mitigation of this vulnerability. The Institute for Applied Economic Research (IPEA) released a study in 2015¹⁰ attesting that the northeast region is responsible for

⁸ José Almir Cirilo, “Políticas públicas de recursos hídricos para o semi-árido” [2008] *Estudos Avançados* 22 (63) www.scielo.br/scielo.php?script=sci_abstract&pid=S0103-40142008000200005&lng=en&nrm=iso&tlng=pt Accessed November 5, 2020; Brazilian Institute of Geography and Statistics—IBGE *Brazilian Semiarid* (first published 2018), www.ibge.gov.br/geociencias/cartas-e-mapas/mapas-regionais/15974-semiarido-brasileiro.html?=&t=sobre. Accessed September 10, 2021.

⁹ Pedro Carlos Gama da Silva, Magna Soelma B. de Moura, Lúcia Helena Piedade Kiill, Luiza Teixeira de Lima Brito, Lúcio Alberto Pereira, Iêdo Bezerra Sa, Rebert Coelho Correia, Antônio Heriberto de C. Teixeira, Tony Jarbas Ferreira Cunha, Clóvis Guimarães Filho, “Caracterização do Semiárido brasileiro: fatores naturais e humanos” (first published 2010, Embrapa), “Semiárido brasileiro: pesquisa, desenvolvimento e inovação” Petrolina.

¹⁰ IPEA—Instituto de Pesquisa Econômica Aplicada, *Atlas da vulnerabilidade social nos municípios brasileiros* (first published 2015, IPEA), http://ivs.ipea.gov.br/images/publicacoes/Ivs/publicacao_atlas_ivs.pdf Accessed December 10, 2020.

72.4 percent of the total municipalities with social vulnerability or low social prosperity, which year after year keeps them on the sidelines of development in the rest of the country, which is concentrated in the south and southeast.

The IPEA report points out that one of the factors that substantially contribute to this indicator of social vulnerability is lack of access to water and sanitation. These are basic items whose universalization was already part of goal 6 of the United Nations (UN) Millennium Development Goals (MDGs), having a direct relationship with the improvement of environmental quality and health.¹¹ It is possible to perceive the seriousness of the situation, especially in the northern part of the country, with the best indicators being the southeast and the south. Poorer regions suffer from chronic access to water and sanitation indicators, which has in fact become commonplace under the responsibility of public managers who do not prioritize certain population groups—an important factor when thinking about the resilience of communities to climate change.¹²

The problem of access to water and sewage treatment is especially precarious in the semiarid region, this being a region in which several municipalities, and especially farmers, do not have access to water or sewage collection and treatment. It is important to be clear that this is the existing framework; solutions have been sought very slowly, which increases the vulnerability of the poorer communities. In this case, the semiarid is already affected by existing cyclical climate factors, and with the worsening effects of climate change the semiarid will certainly face more consequences, just as ecosystems will suffer losses. Consequently, it is necessary to think of adaptation and resilience as

¹¹ Barbara Evans, “Understanding the urban poor’s vulnerabilities in sanitation and water supply” [2007] July 1–6 Financing Shelter Water and Sanitation www.researchgate.net/publication/265043187_Understanding_the_Urban_Poor%27s_Vulnerabilities_in_Sanitation_and_Water_Supply Accessed October 7 2021; Leo Heller, Priscila Neves-Silva, “O direito humano à água e ao esgotamento sanitário como instrumento para promoção da saúde de populações vulneráveis” [2016] *Ciência & Saúde Coletiva*, 21(6) 1861,1870 <https://dx.doi.org/10.1590/1413-81232015216.03422016> Accessed August 10, 2021.

¹² Barbara Evans, “Understanding the urban poor’s vulnerabilities in sanitation and water supply” [2007] July 1–6 Financing Shelter Water and Sanitation www.researchgate.net/publication/265043187_Understanding_the_Urban_Poor%27s_Vulnerabilities_in_Sanitation_and_Water_Supply Accessed October 7, 2021; Jeremy Paul Kohlitz, Joanne Chong, Juliet Willetts, “Climate change vulnerability and resilience of water, sanitation, and hygiene services: a theoretical perspective” [2017] *Journal of Water, Sanitation and Hygiene for Development* June 1 (7)(2) 181,195 doi: <https://doi.org/10.2166/washdev.2017.134>.

elements to be inserted in medium-term public policy planning.¹³ Adger et al comment:

we suggest that an adaptable society is characterized by awareness of diverse values, appreciation and understanding of specific and variable vulnerabilities to impacts, and acceptance of some loss through change. The ability to adapt is determined in part by the availability of technology and the capacity for learning but fundamentally by the ethics of the treatment of vulnerable people and places within societal decision-making structures.¹⁴

The data show that we have not yet begun or improved this adaptive capacity. It is necessary to interconnect the analysis of data, scenarios, and social, economic, and environmental variables in order to understand why a given region or territory does not have access to basic services such as water and sewage treatment. In general, it is clear that the average yield is lower in the northeast region than the others—even lower than the northern region. This is another factor that creates and characterizes its vulnerability.

The 2019 Human Development Index report¹⁵ demonstrates and reinforces what has been revealed by showing that Brazil's rankings in the human development quality index have stagnated or even declined (Table 16.1).

It is possible to use the Municipal Human Development Index to complement our information by attesting that the northeastern states need to see an improvement in the quality of human development, which is directly connected with the basic services that the population should receive.

Therefore, the picture of social, economic and environmental vulnerability of the Brazilian semiarid is characteristic, highlighting the environmental dimension. However, it is necessary to add the advance of desertification in this semiarid zone, either by loss of vegetation due to intensive and incorrect

¹³ Willian Neil Adger, "Vulnerability" [2006] (16) 268–81 *Global Environmental Change* www.geos.ed.ac.uk/~nabo/meetings/glthec/materials/simpson/GEC_sdarticle2.pdf Accessed October 20, 2020; Willian Neil Adger, Surage Dessai, Marisa Goulden, Mike Hulme, Irene Lorenzoni, Donald R. Nelson, Lars Otto Naess, Johanna Wolf, Anita Wreford [2009] Are there social limits to adaptation to climate change? (93) 335, 354 *Climatic Change* <https://link.springer.com/article/10.1007/s10584-008-9520-z> Accessed November 8, 2019.

¹⁴ Willian Neil Adger, Surage Dessai, Marisa Goulden, Mike Hulme, Irene Lorenzoni, Donald R. Nelson, Lars Otto Naess, Johanna Wolf, Anita Wreford [2009] Are there social limits to adaptation to climate change? (93) 335, 354 *Climatic Change*, p.350 <https://link.springer.com/article/10.1007/s10584-008-9520-z> Accessed November 8, 2019.

¹⁵ United Nations Development Programme—UNDP, "Human Development Report 2019" (first published 2019) <http://hdr.undp.org/sites/default/files/hdr2019.pdf> Accessed November 15, 2020.

Table 16.1 *Municipal Human Development Index of Brazilian states*

PLACE	MHDI	MHDI INCOME	MHDI LONGEVITY	MHDI EDUCATION
Brasil	0.727	0.739	0.816	0.637
Tocantins	0.699	0.690	0.793	0.624
Sergipe	0.665	0.672	0.781	0.560
São Paulo	0.783	0.789	0.845	0.719
Santa Catarina	0.774	0.773	0.860	0.697
Roraima	0.707	0.695	0.809	0.628
Rondônia	0.690	0.712	0.800	0.577
Rio Grande do Sul	0.746	0.769	0.840	0.642
Rio Grande do Norte	0.684	0.678	0.792	0.597
Rio de Janeiro	0.761	0.782	0.835	0.675
Piauí	0.646	0.635	0.777	0.547
Pernambuco	0.673	0.673	0.789	0.574
Pará	0.646	0.646	0.789	0.528
Paraná	0.749	0.757	0.830	0.668
Paraíba	0.658	0.656	0.783	0.555
Minas Gerais	0.731	0.730	0.838	0.638
Mato Grosso	0.725	0.732	0.821	0.635
Mato Grosso do Sul	0.729	0.740	0.833	0.629
Maranhão	0.639	0.612	0.757	0.562
Goiás	0.735	0.742	0.827	0.646
Distrito Federal	0.824	0.863	0.873	0.742
Ceará	0.682	0.651	0.793	0.615
Bahia	0.660	0.663	0.783	0.555
Amazonas	0.674	0.677	0.805	0.561
Amapá	0.708	0.694	0.813	0.629
Alagoas	0.631	0.641	0.755	0.520
Acre	0.663	0.671	0.777	0.559

Note: The numbers in the table represent the indices of income, education, and longevity, resulting in the Human Development Index. Programa das Nações Unidas para o Desenvolvimento—PNUD, “Índice de Desenvolvimento Humano Municipal Brasileiro” (first published 2013, PNUD) www.atlasbrasil.org.br/2013/data/rawData/publicacao_atlas_municipal_pt.pdf Accessed November 5, 2020.

use of the soil, the lack of rainfall, or the very crystalline soil composition,

as another variable that makes up the environmental variable.¹⁶ In addition, inadequate water management can cause or enhance desertification.¹⁷

3. GROUNDWATER , THE DEFICIENCY OF REGULATION IN BRAZIL AND ITS IMPACT ON THE HUMAN DEVELOPMENT OF THE SEMIARID

The process of territorial vulnerability is characterized as demanding systemic or interconnected actions. However, in this scenario we see a growing importance of groundwater for human supply and economic development, mainly through agriculture. This is a global issue that needs to acquire the necessary status on the public agenda, because these water stocks are exposed to various forms of pollution, whether through irregular use and occupation of the soil, waterproofing, or diffuse pollution of all kinds, among others.

The growing demand for energy, food, and water must permeate our daily lives going forward and should also inform decision makers and policy makers in their professional roles. Groundwater requires more effective management mechanisms and greater regulation, considering the need to make it more visible, especially in a local context, because of its local importance for human development, notably in regions such as the semiarid.¹⁸

¹⁶ Iedo Bezerra de Sá, Tony Jarbas Ferreira Cunha, Antônio Heriberto de Castro Teixeira, Francislene Angelotti, Marcos Antonio Drumond, “Processos de desertificação no semiárido brasileiro” (first published 2010, Embrapa) www.embrapa.br/busca-de-publicacoes/-/publicacao/861927/processos-de-desertificacao-no-semiarido-brasileiro Accessed 9 septembre 2021; Aldrin Martin Perez-Marin, Arnóbio de Mendonça Barreto Cavalcante, Medeiros, Leonardo Bezerra de Melo Tinôco, Salomão Sousa de Medeiros, Ignácio Hérrnan Salcedo, “Núcleos de desertificação no semiárido brasileiro: ocorrência natural ou antrópica?” [2012] *Parc. Estrat. Brasília-DF* (17) (34) 87, 106 Jan–Jun http://seer.cgee.org.br/index.php/parcerias_estrategicas/article/viewFile/671/615 Accessed November 5, 2020; Jose Roberto de Lima, Antonio Rocha Magalhães, “Institucionalidade e governança para o combate à desertificação” (first published 2016, IPEA) <http://repositorio.ipea.gov.br/bitstream/11058/9287/1/Institucionalidade.pdf> Accessed July 10, 2020.

¹⁷ Aldrin Martin Perez-Marin, Arnóbio de Mendonça Barreto Cavalcante, Medeiros, Leonardo Bezerra de Melo Tinôco, Salomão Sousa de Medeiros, Ignácio Hérrnan Salcedo, “Núcleos de desertificação no semiárido brasileiro: ocorrência natural ou antrópica?” [2012] *Parc. Estrat. Brasília-DF* (17)(34) 87,106 Jan–Jun http://seer.cgee.org.br/index.php/parcerias_estrategicas/article/viewFile/671/615 Accessed November 5, 2020.

¹⁸ Sharon B. Megdal, “Invisible water: the importance of good groundwater governance and management” [2018] *Clean Water* 15 www.nature.com/articles/s41545-018-0015-9.pdf Accessed November 15, 2020.

This is the most important aspect of our development model on important underground springs that need regulation so they can be properly managed, as a safety net that can assist humanity's resilience to climate change.¹⁹ This stock of water needs to be taken care of and considered in both medium and long-term aspects. However, groundwater consumption has been growing both worldwide and in Brazil.²⁰ The importance of regulating the sector, establishing clear rules regarding the use of these waters, imposing limits, and stipulating permits that must be verified is clear.

Brazil faces a major dilemma, having large water resources but constantly suffering water scarcity: the result of the great urban development model.²¹ Groundwater is indicated as an alternative solution for diffuse supply, that is, for communities that are far away, dispersed, and do not have access to the

¹⁹ Emilio Custodio, "Effects of groundwater development on the environment" [2000] (111)(6), 107, 120 *Boletín Geológico y Minero* www.igme.es/Boletin/2000/111_6-2000/6-EFFECTS.pdf Accessed September 18, 2021; FAO—Food and Agriculture Organization, *Groundwater management: The search for practical approaches* (first published 2007) www.fao.org/3/y4502e/y4502e00.htm Accessed August 10, 2021]; Ricardo Hirata, JL Zoby, Amélia Fernandes, Reginaldo Bertolo, 'Hidrogeología del Brasil: una breve crónica de las potencialidades, problemática y perspectivas' [2006] *Boletín Geológico y Minero* (117)(1) 25, 36 http://aguas.igme.es/Boletin/2006/117_1_2006/Art.2.PDF Accessed September 10, 2019; Henry Vaux, "Groundwater under stress: the importance of management" [2011] *Environ Earth Sci* (62) 19, 23 <https://link.springer.com/content/pdf/10.1007%2Fs12665-010-0490-x.pdf> Accessed October 9, 2021.

²⁰ Ricardo Hirata, JL Zoby, Amélia Fernandes, Reginaldo Bertolo, "Hidrogeología del Brasil: una breve crónica de las potencialidades, problemática y perspectivas" [2006] *Boletín Geológico y Minero* (117)(1) 25, 36. http://aguas.igme.es/Boletin/2006/117_1_2006/Art.2.PDF Accessed September 10, 2019; Sharon B Megdal, "Invisible water: the importance of good groundwater governance and management" [2018] *Clean Water* 15 www.nature.com/articles/s41545-018-0015-9.pdf Accessed November 15, 2020; Trata Brasil Institute, "A revolução silenciosa das águas subterrâneas no Brasil: uma análise da importância do recurso e os riscos pela falta de saneamento" (First published 2019) www.tratabrasil.org.br/images/estudos/itb/aguas-subterraneas-e-saneamento-basico/Estudo_aguas_subterraneas_FINAL.pdf Accessed November 15, 2020.

²¹ Ricardo Hirata, JL Zoby, Amélia Fernandes, Reginaldo Bertolo, 'Hidrogeología del Brasil: una breve crónica de las potencialidades, problemática y perspectivas' [2006] *Boletín Geológico y Minero* (117)(1) 25, 36 http://aguas.igme.es/Boletin/2006/117_1_2006/Art.2.PDF Accessed September 10, 2019; Marielle Aparecida de Moura Raid, "Soluções técnica de abastecimento de água e modelos de gestão: um estudo em quinze localidade rurais brasileira" [2017] Master's Degree UFMG Brazil, <https://repositorio.ufmg.br/handle/1843/BUOS-AWWP8Q> Accessed October 5, 2021.

water supply network.²² In addition to this solution, it is necessary to adopt sanitation solutions that can directly impact the quality of extracted groundwater.

Brazilian legislation establishes the National Water Resources Policy (PNRH), Law n. 9.433/1997, which, despite a set of regulatory instruments created for water management and governance, is lacking in groundwater regulation. So, we have no federal legislation about groundwater, although we have two large aquifers, the Guarani and the Alter do Chão. This means a lack of the very environmental regulation crucial for these ecosystems. It can be understood that the Brazilian legislation establishes who is responsible for dominating the groundwater, leaving it to the states of the federation to regulate these resources within its borders. It is up to the central government to take care of groundwater that crosses borders between states and between countries. Separated from this universe, groundwater with mineral properties is under the tutelage of the central government: a great contradiction.²³

This model of decentralization of management and governance, at least in the semiarid region, does not have the expected effect, notably on groundwater. A large number of wells are drilled without authorization and therefore without accurate studies of their viability and flow potentiality. Some state laws provide regulation, but there is a lack of enforcement of these laws.

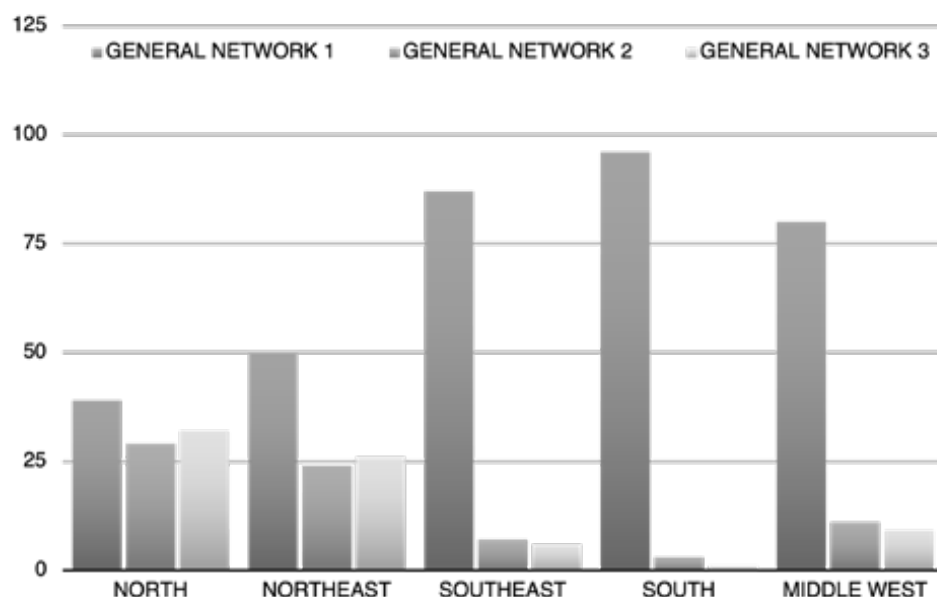
Figure 16.2 below shows the precariousness of rural sanitation in Brazil. Highlighting the northeast region, specifically the semiarid, the importance of groundwater for this territory can be perceived. Groundwater is fundamental for the semiarid,²⁴ mainly as a complementary system for small agricultural production. Without it, dependence on rain would be much higher and slab cisterns or other individualized water storage solutions would not be sufficient to supply populations.

²² Marielle Aparecida de Moura Raid, “Soluções técnica de abastecimento de água e modelos de gestão: um estudo em quinze localidade rurais brasileira” [2017] Master’s Degree UFMG Brazil, <https://repositorio.ufmg.br/handle/1843/BUOS-AWWP8Q>> Accessed October 5, 2021.

²³ Ricardo Hirata, JL Zoby, Amélia Fernandes, Reginaldo Bertolo, “Hidrogeología del Brasil: una breve crónica de las potencialidades, problemática y perspectivas” [2006] *Boletín Geológico y Minero* (117) (1) 25, 36. http://aguas.igme.es/Boletin/2006/117_1_2006/Art.2.PDF Accessed September 10, 2019.

²⁴ Aldo da C. Rebouças, “Água na região Nordeste: desperdício e escassez” [1997] *Estudos avançados* 11(29) www.scielo.br/scielo.php?script=sci_arttext&pid=S0103-40141997000100007 Accessed September 21, 2021; Laércio Santos, Jaime Joaquim da Silva Pereira Cabral, José Almir Cirilo, Dayana Freitas, Maurício Sens, Ricardo de Aragão, Timóteo HS Barros, “Aplicação da tecnologia de filtração em margem para população difusa no Semiárido Pernambucano” [2014] *Revista Brasileira de Recursos Hídricos* (19)(4) Out/Dez 49, 58 www.researchgate.net/publication/305306748_Aplicacao_da_tecnologia_de_filtrao_em_margem_para_populacao_difusa_no_Semiarido_Pernambucano Accessed September 9, 2021.

However, what still predominates in the groundwater extraction sector is empiricism and amateurism, as well as illegality, a fact that can cause serious damage to existing aquifers. There is depletion and contamination of the water source, as well as harm to the health of the community and agricultural production through direct consumption of water that has not been efficiently treated.²⁵ It is important to highlight that only 47 percent of rural households have some type of water supply from mains, wells, or springs.²⁶



Note: GENERAL NETWORK 1: well or spring with internal channeling and rainwater stored in cisterna; GENERAL NETWORK 2: general well or rising network without channel and water car; GENERAL NETWORK 3: other forms.

Source: Fundação Nacional de Saúde—FUNASA, “Panorama do Saneamento Rural no Brasil” [2017] www.funasa.gov.br/panorama-do-saneamento-rural-no-brasil accessed August 10, 2021.

Figure 16.2 Rural sanitation situation by region in Brazil

²⁵ Aldo da C. Rebouças, “Água na região Nordeste: desperdício e escassez” [1997] *Estudos avançados*, 11(29) www.scielo.br/scielo.php?script=sci_arttext&pid=S0103-40141997000100007 Accessed September 21, 2021; Pedro Carlos Gama da Silva, Magna Soelma B. de Moura, Lúcia Helena Piedade Kiill, Luiza Teixeira de Lima Brito, Lúcio Alberto Pereira, Iêdo Bezerra Sa, Rebert Coelho Correia, Antônio Heriberto de C. Teixeira, Tony Jarbas Ferreira Cunha, Clóvis Guimarães Filho, “Caracterização do Semiárido brasileiro: fatores naturais e humanos” (first published 2010, Embrapa), “Semiárido brasileiro: pesquisa, desenvolvimento e inovação” Petrolina.

²⁶ Trata Brasil Institute, “A revolução silenciosa das águas subterrâneas no Brasil: uma análise da importância do recurso e os riscos pela falta de saneamento” (first published 2019) www.tratabrasil.org.br/images/estudos/itb/aguas-subterraneas-e-saneamento-basico/Estudo_aguas_subterraneas_FINAL.pdf Accessed November 15, 2020.

Therefore, there are two serious problems regarding the quality of these waters in the medium and long term. One is the lack of effective regulation, effective management, and governance. The second is the lack of sanitation systems that can avoid diffuse contamination, including animal husbandry management techniques and use of individual systems in rural homes.²⁷

The quality of the water in built reservoirs (which are called “açudes”), of the rainwater accumulated in cisterns, of the water provided by water trucks (the “carros pipas”), and of underground water is worrying. The irregularity of rainfall, which allows the natural recharging of underground stocks, is also concerning. More complex technology which extracts groundwater intensively and promotes aquifer recharge, such as that found in Israel, is not yet used in Brazil. However, we highlight that Israel already faces problems of well stagnation and nitrate contamination because of overexploitation.²⁸

In the Brazilian semiarid region, due to its hydrogeological characteristics there are four similar significant hydrogeological provinces with a predominance of water extraction in the crystalline: Northeast Eastern Shield, São Francisco, Parnaíba, and Costeira.²⁹ The first of these is the largest—occupying the central region of the semiarid—and the one which needs greater investment in research and accurate technique to locate the groundwater accumulation sites. It is the largest region in territorial extension and the one that suffers the most from water scarcity. Any water source found has unmatched importance for that area.

However, the regions of São Francisco, Parnaíba, and Costeira have a higher incidence of groundwater, and also include part of the semiarid region. The water is present in about 50 percent of the northeastern territory, notably in the semiarid.³⁰

²⁷ Leo Heller, Priscila Neves-Silva, “O direito humano à água e ao esgotamento sanitário como instrumento para promoção da saúde de populações vulneráveis” [2016] *Ciência & Saúde Coletiva*, 21(6) 1861,1870 <https://dx.doi.org/10.1590/1413-81232015216.03422016> Accessed August 10, 2021.

²⁸ Aldo da C. Rebouças, “Água e desenvolvimento rural” [2001] *Estudos Avançados* (15)(43), www.scielo.br/pdf/ea/v15n43/v15n43a24.pdf Accessed September 21, 2021; Nir Becker, *Water Policy in Israel, Context, Issues and Options* (first published in 2013, Springer 2013).

²⁹ CPRM—Serviço Geológico de Brasil *Programa de água subterrânea para a região nordeste, programa anual de trabalho Geologic Brazilian Service* (2001) www.leb.esalq.usp.br/leb/disciplinas/Fernando/leb1440/Aula%208/Transparencias/agua%20subterranea%20zona%20arida.pdf Accessed December 5, 2020.

³⁰ Aldo da C. Rebouças, “Água na região Nordeste: desperdício e escassez” [1997] *Estudos avançados*, 11(29) www.scielo.br/scielo.php?script=sci_arttext&pid=S0103-40141997000100007 Accessed September 21, 2021; João Suassuna, “Água: um fator limitante para o desenvolvimento do Nordeste?” [2002] *Estudos Avançados*

Moreover, there is a strong and fundamental link between water and rural development,³¹ because there is neither food production nor work for the rural man without rational use of water, especially in the northeastern semiarid. Cities were created from rural development and maintain a high dependence on rural areas, with about 44 percent of workers living in the countryside.³²

Castro³³ highlights the possibility of developing irrigation projects in the northeastern semiarid region but indicates that the medium and the large projects carried out so far have been unsuccessful, mainly because of the model adopted—for example, strong and extensive agriculture. It is necessary to rethink the focus of a rural development public policy aimed at smaller yields for more rational uses of water, resulting in crops that would encourage local and regional production by more farmers. In addition to this, there is technical support for the use of groundwater for small and medium-sized crops.

In the case of the semiarid, desalination plants are needed to provide water for human supply and small agricultural production. This is being developed in the Águas Doce Program, linked to the Federal Government Ministry of the Environment, which has already installed around 1,300 community-managed desalination systems for various uses, including agricultural activity.³⁴

Therefore, it is possible to assess the relevance that this groundwater extraction and desalination system has for the semiarid region involving essentially rural communities that would have no other access to water, since they are on the fringe of the city's water infrastructure circuit. In addition, each well combines a family farming system that assists in the feeding of each family group, as well as the surplus that is sold in the cities. Hence it is possible to have reasonable initial conditions for agricultural production, which still require other items such as technical assistance and vegetation conservation for greater water retention and to recharge the underground system. But it should be noted that most farmers still depend on other income outside their rural area.³⁵

(11)(29) www.kas.de/c/document_library/get_file?uuid=6868dcf0-2010-3626-b134-81fb8d09fbec&groupId=252038 Accessed September 21, 2021.

³¹ Aldo da C. Rebouças, “Água na região Nordeste: desperdício e escassez” [1997] *Estudos avançados*, 11(29) www.scielo.br/scielo.php?script=sci_arttext&pid=S0103-40141997000100007 Accessed September 21, 2021.

³² National Water and Sanitation Agency, ANA, *Atlas nordeste: abastecimento urbano de água* (first published 2005, ANA, Brasília).

³³ César Nunes de Castro, *Sobre a agricultura irrigada no semiárido: uma análise histórica e atual de diferentes opções de política* (first published 2018), Institute of Applied Economics Politics.

³⁴ www.mma.gov.br/mma-em-numeros/programa-agua-doce

³⁵ Vlândia Pinto Vidal de Oliveira, Jefferson Roberto de Oliveira Marinho, “Os paradigmas orientadores do desenvolvimento do Semiárido Brasileiro e suas implicações para o manejo dos recursos naturais” [2013] *Rev. Econ. NE Fortaleza* 44 n. espe-

As of 2010, about 39.5 percent of income comes from rearing animals and other purposes, about 11.5 percent from agriculture, 29 percent from forests, 14.5 percent from agroforestry, and 5.5 percent from other purposes.³⁶ These activities depend essentially on water available for production. It should be considered that of Brazil's total of 5,073,324 agricultural establishments, 34 percent are found in the semiarid—a quite significant number in the national context.³⁷ Large water infrastructure projects such as the São Francisco river transposition are mainly focused on urban populations, leaving aside those activities developed by the rural population which are fundamental for the urban population.³⁸

4. SOME QUESTIONS ABOUT THE ENVIRONMENTAL LEGISLATION IN BRAZIL

The Brazilian Constitution establishes common legislative competence between the administrative levels; that is, both the central government, states, municipalities, and the Federal District can establish environmental rules. These administrative entities have different strengths and performances as well. It would be possible to say that the central government has a stronger structure through which to implement an environmental public policy, while the states have a more intermediate structure and the municipalities remain highly deficient in the regulation of the environment.

cial 239–50 https://bnb.gov.br/documents/80223/205365/ren_2013_3_os_paradigmas.pdf/b7508ca8-ccf4-4412-bc2e-f620c2b4ae7c Accessed November 21, 2020; Junior Ruiz Garcia, Antonio Marcio Buainain, “Desenvolvimento rural do semiárido brasileiro: transformações recentes, desafios e perspectivas” [2013] *Revue franco-brésilienne de géographie*, <http://confins.revues.org/8633> Accessed December 10, 2020; Marta Aurélio Dantas de Lacerda, Joacir Rufino de Aquino, “Magnitude e condições de reprodução econômica dos agricultores familiares pobres no semiárido Brasileiro: evidências a partir do Rio Grande do Norte” [2014] *RESR Piracicaba-SP* 52 Supl. 1 167, 188 www.scielo.br/scielo.php?script=sci_arttext&pid=S0103-20032014000600009 Accessed November 21, 2020.

³⁶ INSA—Instituto Nacional do Semiárido, “Estabelecimento agropecuários do semiárido brasileiro” (first published 2018, National Semiarid Institute Report) <https://portal.insa.gov.br/acervo-livros/1202-estabelecimentos-agropecuarios-do-semiarido-brasileiro> Accessed November 21, 2020.

³⁷ Brazilian Institute of Geography and Statistics—IBGE, *Brazilian semiarid region. 1:12 000 000* (Map 2017), Brazil, ftp://geoftp.ibge.gov.br/organizacao_do_territorio/estrutura_territorial/semiarido_brasileiro/Situacao_23nov2017/mapa_Semiarido_2017_11_23.pdf Accessed 1 October 2021.

³⁸ Jose Irivaldo Alves Oliveira Silva, “Ressignificação Ambiental e modernização ecológica no Semiárido: o projeto de integração e revitalização do São Francisco” (first published 2016, Hucitec), São Paulo.

However, despite national and subnational problems, the Brazilian judiciary has played a fundamental role in protecting environmental principles in general, including in relation to water, considering water bodies as entities with legal personality—symbolizing the importance of water for ecological balance.

Cases from the United States and Brazil provide examples of local achievements of the rights of nature and other actions by municipal authorities, as well as tribal and indigenous jurisdictions and councils, in response to inaction or violations at the state or federal level. A cases of recognition of the rights of nature in the US, in Southern Ohio, allowed a group of hippos to be interested parties in a process. In Brazil, bill n. 145/21 is being processed in the Federal Chamber allowing non-human animals to be individually party to lawsuits. While such measures often lack force, making them vulnerable to legal challenge or federal overturn, they can have moral and political force as part of a broader campaign. The simple fact of recognizing and proclaiming rights can help transform social and cultural values and increase the visibility of the rights of nature.³⁹ In the case of semiarid regions such as the Brazilian northeast, the need for more protective legislation for water courses and hydrographic basins becomes more urgent. Câmara and Fernandes⁴⁰ point out that it is a legal advance to transpose water as heritage, as a thing, into water as a living being.

It is important to say that Brazilian legislation has not yet made progress in this regard, that some initiatives have been in a sense isolated, and that there is still no more general understanding emanating from the Supreme Court or another court of justice, such as the case of Rio Doce, which filed a lawsuit requesting the defense of environmental interests and the legal personality of a river that was the victim of a major disaster in Brazil. But given the importance that the Brazilian Federal Supreme Court has given to environmental protection, such an advance could occur.

³⁹ <https://static1.squarespace.com/static/5f3c17d9c3c4d05be063a9c5/t/5f9352e8aba78b2ad602d3a0/1603490572225/DIGITAL+Right+of+Rivers+Report+Exec+Summary+Portuguese.pdf>

⁴⁰ Ana Stela Vieira Mendes Câmara, Márcia Maria dos Santos Souza Fernandes, “O Reconhecimento Jurídico do Rio Atrato como Sujeito de Direitos: reflexões sobre a mudança de paradigma nas relações entre o ser humano e a natureza” [2018] *Revista De Estudos E Pesquisas Sobre As Américas*, 12(1) <https://periodicos.unb.br/index.php/repam/article/view/15987>

5. CONCLUSIONS

Based on the literature and the collected data, the following conclusions may be advanced:

- Water is a scarce element in the Brazilian semiarid that has very advanced aridity characteristics and cyclical periods of great water shortage.
- Social, economic and environmental conditions form a context of extreme vulnerability for the population and the development of economic activities.
- Groundwater becomes a solution for maintaining life in the northeastern semiarid, notably in rural areas that do not have regular water supplies.
- Most of the rural populations in the semiarid region are not considered in large urban water infrastructure projects, such as the São Francisco river transposition, which increases their dependence on groundwater and other individualized systems that end up as the only available solution, such as cisterns and water trucks.
- Diffuse populations in rural areas, far from urban centers, have great difficulty in accessing public sanitation and accessing water policies, which increases the possibility of groundwater contamination as there is virtually no collective sanitation solution for these populations, requiring a systemic solution that considers sanitation and access to quality water as a priority.
- Productive spaces are fundamental for the economic maintenance of the semiarid, whose main activity is agriculture, with groundwater and desalination projects being of great relevance.
- The level of groundwater institutionalization in Brazil is low except in the case of waters with hydromineral characteristics, which allows the growth of legally permissible extraction to the detriment of regulated wells. It is important to say that advances have been seen, especially in the work of the judiciary, which has protected Brazilian environmental legislation from setbacks. However, it is important to recognize that the regulation of activities harmful to the environment has lost strength in Brazil, and it is easy to verify a failure to comply with legal norms that results in river pollution, deforestation, fires, and hunting, among other behaviors that degrade the environment.