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Socioeconomic and environmental impacts: an assessment of the surroundings of the Realejo dam, Crateús-CE

Impactos socioecônomicos e ambientais: uma avaliação do entorno do açude Realejo, Crateús-CE

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Abstract: In 1980, the Realejo Dam was constructed in the State of Ceará to meet the demands related to rural human water supply, agriculture, and fishing of native species. Following its construction, it is essential to understand the dynamics between water and the rural population concerning water availability, agricultural practices, and the socioeconomic well-being of the community. The study aims to assess the social, economic, and environmental impacts generated by the construction of the Realejo Dam, located in the Municipality of Crateús - CE, over four distinct periods: 1980-1990, 1991-2011, 2012-2017, and 2018-2022. Historical data, oral history, social cartography, and remote sensing were used to evaluate the use and occupation around the reservoir. It is noted that the construction of the reservoir favored the growth of irrigated agriculture and the increase of human settlements in the region (633.3% higher in 2022 compared to 1985), but it also drove the degradation of forest cover, the contamination of water resources, and a possible discharacterization in family farming in the area. The results reinforce the need for conducting preliminary studies before implementing hydraulic projects to assess the feasibility of execution, understand the social and environmental implications of construction, and support the development of strategies for the integrated and sustainable management of water resources.

Keywords: Brazilian semi-arid; Permanent preservation area; Rural communities.

Resumo: Em 1980, o Açude Realejo foi construído no Estado do Ceará a fim de atender demandas relacionadas ao abastecimento humano rural, a agricultura e a pesca de espécies nativas. Mediante sua construção, é fundamental compreender as dinâmicas entre a água e a população rural, no que diz respeito a disponibilidade hídrica, as práticas agrícolas e o bem-estar socioeconômico da comunidade. O estudo objetiva avaliar os impactos nos âmbitos social, econômico e ambiental gerados pela construção do Açude Realejo, localizado no Município de Crateús - CE, ao longo de quatro períodos distintos: 1980-1990, 1991-2011, 2012-2017 e 2018-2022. Utilizou-se dados históricos, história oral, cartografia social e sensoriamento remoto para avaliar o uso e ocupação do entorno do reservatório. Nota-se que a construção do reservatório favoreceu o crescimento da agricultura irrigada e o aumento dos aglomerados humanos na região (633,3% maior em 2022, em comparação a 1985), mas impulsionou a degradação da cobertura florestal, a contaminação dos recursos hídricos e uma possível descaracterização da agricultura familiar na área. Os resultados reforçam a necessidade de realização de estudos prévios à implantação de obras hidráulicas para avaliar a viabilidade de execução, entender as implicações sociais e ambientais da construção e embasar o desenvolvimento de estratégias para a gestão integrada e sustentável dos recursos hídricos.

Palavras-chave: Semiárido brasileiro; Área de preservação permanente; Comunidades rurais.

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1. Introduction

The Brazilian semi-arid region is characterized by a complex combination of distinct physical characteristics, with climatic conditions playing a dominant feature. The phenomenon of droughts, caused by irregular rainfall patterns and hydroclimatic dynamics, negatively affects the socio-economic and environmental spheres of these regions (NETO, 2017; SOUZA *et al.*, 2022).

With the creation of the Inspectorate of Works Against Droughts in 1909, demands for actions to address water scarcity increased. In this regard, "drought combat policies" are based on an economic and social development model centered on water resources, with dams and irrigation systems built to promote modern agriculture and settle the rural population, thereby preventing mass migrations (QUEIROZ, 2021).

According to Magalhães (1996) and Magalhães and Campos (1997) the Realejo Dam, built in the 1980s by the National Department of Works Against Droughts (DNOCS) in the municipality of Crateús, Ceará, was the first large-scale dam construction in the Poti basin. DNOCS indicated the reservoir's use for floodplain crop cultivation, native species fishing, and water delivery to the inhabitants (MAGALHÃES; CAMPOS, 1997).

Silva and Sousa (2019) emphasize that dam construction policies in Ceará were ineffective due to environmental, political, economic, and social factors, contributing to the lack of solutions for rural communities. Programs and projects for reservoir construction were not guided by the environmental and social aspects of these regions, neglecting water resource management and the perspectives of those living in semi-arid areas (BIZARRIA *et al.*, 2016). This contributed to deficits in water access and inefficiencies in reservoirs meeting the needs of these communities.

Understanding the dynamics between water and rural populations and the associated impacts is crucial for understanding strategies to coexist with the semi-arid environment and ensuring economic, social, and cultural development. In rural areas, these relationships become even more complex, given that the proximity of these societies to the varied ecosystem functions of water resources allows for the social construction of diverse realities expressed in cultural, economic, and political relationships in territorial planning specific to this universe (MARTINS, 2006; SANTOS *et al.*, 2019).

Over the years, the expansion of productive areas, the growth of human settlements, and the exploitation of natural resources have rapidly transformed land cover, which, combined with poorly planned development, has generated various effects on rural environments. In this scenario, Permanent Preservation Areas (PPAs), established by Law No. 12,651/2012, play a crucial role within a watershed, with functions related to preserving water resources, landscape, geological stability, and biodiversity. As spaces for work, participation, and sociopolitical organization, these areas strengthening community collectives within the territory (BRASIL, 2012; SANTOS, 2018; CALEGARE *et al.*, 2021; COSTA; BARROS FILHO, 2022).

Therefore, this article evaluate the social, economic, and environmental implications of the Realejo Dam building in Crateús, CE. The study aims to better understand the reservoir's historical relationship with the rural community of Realejo by collecting data from digital historical archives, oral history, and social cartography, while analyzing the spatiotemporal evolution of land use and occupation around the reservoir using remote sensing techniques.

2. Methodology

The methodology for conducting this research consisted of three major stages, as illustrated in the flowchart of Figure 1. These are (i) characterization of the study area, (ii) historical analysis of the relationship between the dam and the community, and (iii) spatiotemporal analysis of the use and occupation of the dam surroundings.

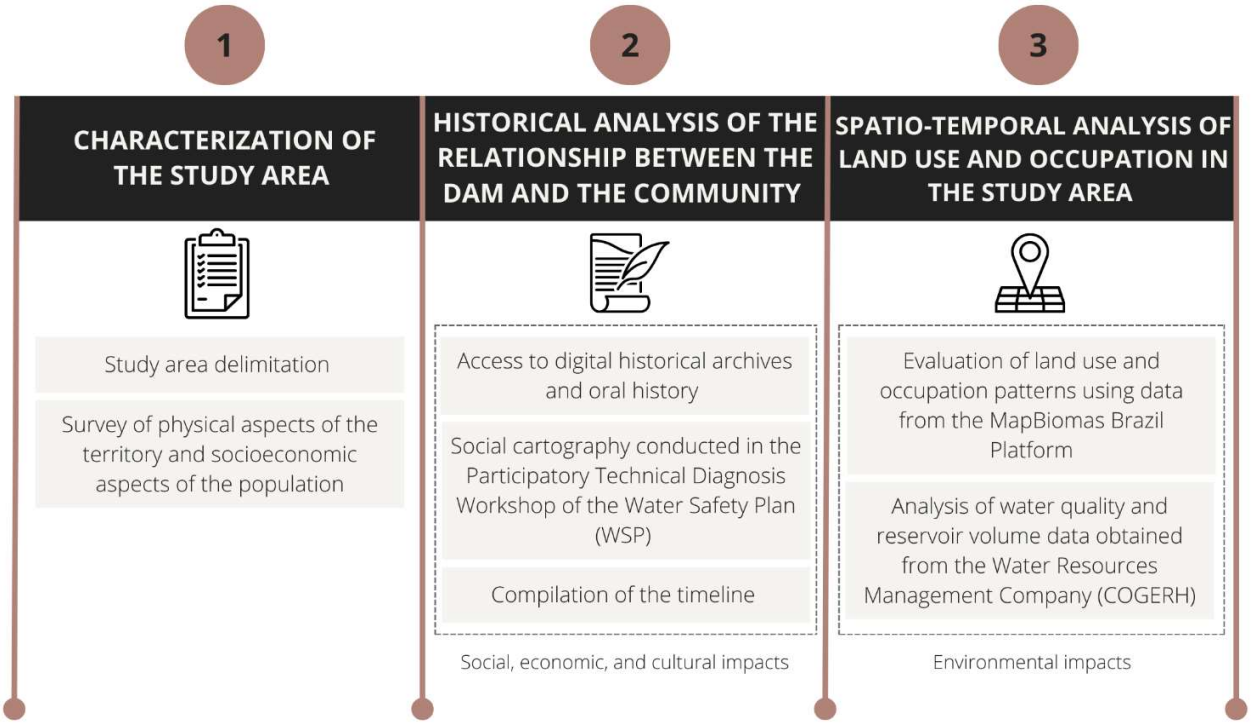


Figure 1 – Methodological flowchart of the study.
Source: Authors (2024).

2.1 Characterization of the study area

The study area (Figure 2) was delimited to encompass the Realejo Community and its irrigated perimeters, including the 100-meter buffer corresponding to the Permanent Preservation Area of the Realejo Dam, as established by Law No. 12,651/2012. The region is located within the Crateús Sertões Watershed, characterized by the Poti River as its main river, and typical physical and meteorological features of the semi-arid region: tropical climate with a dry season in winter, high temperatures with an average annual temperature of 27.4 ºC, high evaporation rates in reservoirs, and predominant vegetation composed of Arborized Savanna, scrubland, and areas susceptible to desertification (COGERH, 2021).

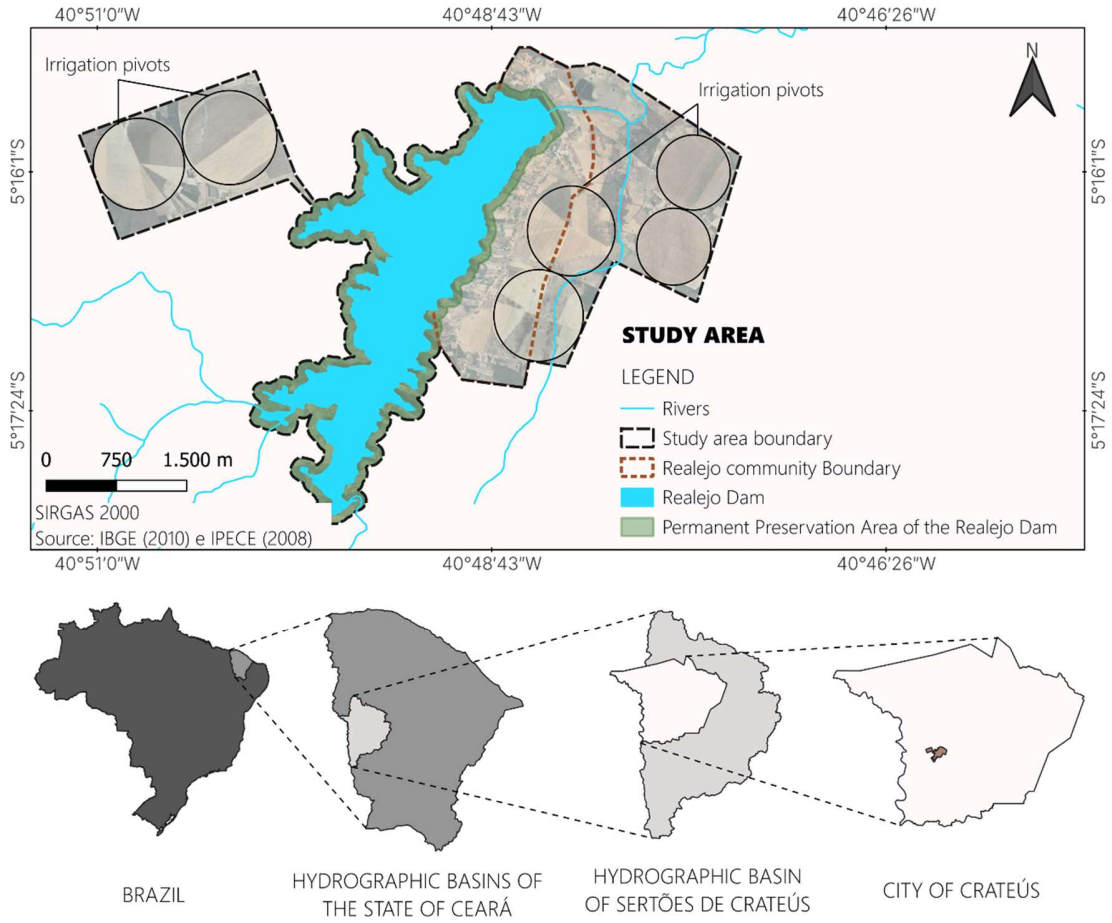


Figure 2 – Location of the study area, Realejo Dam and Community, Crateús - CE.
Source: Authors (2024).

The Realejo Dam (Figure 3), located in Crateús Municipality, it dams the Riacho dos Cavalos and is classified as a medium-sized reservoir, with a maximum capacity of 31,550,000 m³. The reservoir is situated in the Realejo Community which houses approximately 512 families, with livestock farming and cultivation of corn and beans as primary livelihoods (COGERH, 2021; FUNASA; UFCG, 2023).

Figure 3 – Realejo Dam, located in the municipality of Crateús/CE, photo from March/2022.
Source: Authors (2022).

2.2 Historical analysis of the relationship between the reservoir and the community

Historical research methods were utilized to investigate the evolution of water uses from the Realejo Dam and the economic, social, and cultural relationships between the reservoir and the community. Information was gathered from access to digital historical archive documents (MAGALHÃES, 1996; MAGALHÃES; CAMPOS, 1997; CORREA, 2006) and oral history through narratives about the dam's history and the community provided by the community health agent and the association president.

To complement and validate the data, social cartography was used and applied during the workshop for the Technical-Participative Diagnosis of the Water Security Plan for the Realejo community, promoted by Decentralized Execution Agreement No. 006/2021, a partnership between the National Health Foundation (Funasa) and the Federal University of Campina Grande (UFCG) (Figure 4). The methodology involved constructing maps from the perspective of different social actors, using pre-prepared stickers to represent the community's space and water supply system.

Figure 4 – a) Application of social cartography in the workshop for the Technical-Participative Diagnosis of the Water Safety Plan (WSP) for the Realejo community; b) Final map.
Source: Adapted from FUNASA; UFCG (2023).

The collected historical aspects were organized and analyzed along a timeline to understand the impact of dam construction on the social construction of the community's territorial organization.

2.3 Space-time analysis of land use and occupation around the reservoir

Remote sensing techniques were employed to understand the dynamics and patterns of land use and occupation around the Realejo Dam, using data obtained from the MapBiomas Brazil Platform (MAPBIOMAS, 2023), with the assistance of Google Earth Engine. Similar to the study by Costa and Barros Filho (2022), a 36-year data period (1985 to 2022) was used to assess natural, political, and social events that influenced the land occupation dynamics evaluated.

Thus, the data extracted from the platform were processed in Microsoft Office Excel and QGIS 3.22.5 software for statistical and spatial analysis. For the analysis of results over the years, the focus was on (i) evaluating the occupation around the Realejo Dam according to the Permanent Preservation Area (PPA) definition; (ii) water quality data using the Trophic State Index (TSI), as suggested by Silva *et al.* (2018), Pinho *et al.* (2018), and Gomes and Paula (2019); and (iii) reservoir volume estimates. It should be noted that for step (i), mapping obtained from the MapBiomas Brazil Platform (MAPBIOMAS, 2023) was used, and for steps (ii) and (iii), data provided by the Water Resources Management Company (COGERH), from 2004 to 2022, were used. This enabled the assessment of environmental impacts generated by changes in land occupation over the years.

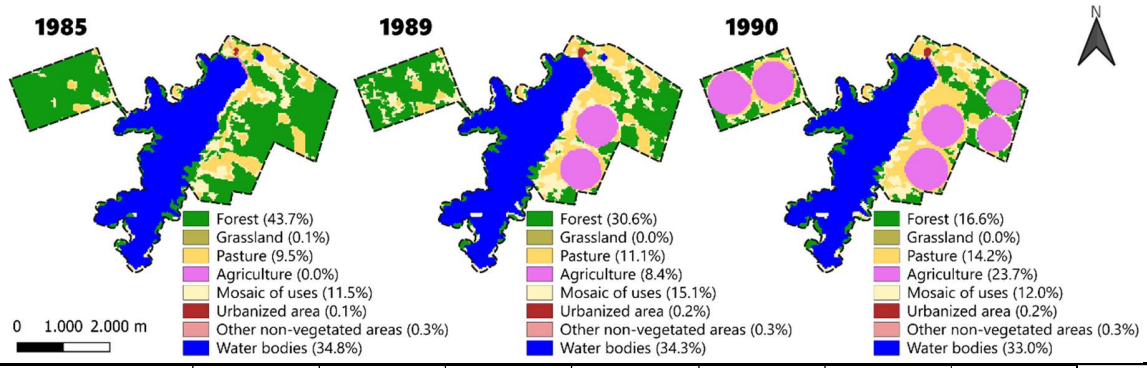
3. Results and discussion

Based on critical analyses of historical aspects, it was observed that the temporal delineation of the relationship between the reservoir and the community can be divided into four periods: construction of the Realejo Dam and establishment of irrigated perimeters (1980 to 1990); expansion of agricultural areas and adaptation to seasonal droughts (1991-2011); the most prolonged drought in the history of the semi-arid region (2012-2017); and current dynamics (2018-2022).

3.1 1980 to 1990: Construction of the Realejo Dam and establishment of irrigated perimeters

Built-in 1980 by the National Department of Works Against Droughts (DNOCS), the Realejo Dam initially addressed demands related to rural human supply, agriculture, and native species fishing. At the time, the Realejo Community consisted of only 82 settled families within the water perimeter (MAGALHÃES, 1996).

Figure 5 shows the land use and occupation configuration of the area between 1985 and 1990. It can be noted that, in accordance with Magalhães and Campos (1997), from 1988 to 1990, six pivots were installed by DNOCS for the irrigation exploitation of 400 hectares of land. The forest cover near the dam's Permanent Preservation Area (PPA) was replaced by agriculture and pasture areas, with a 60.3% reduction in native vegetation in just five years.



Land use and occupation		Forest	Grassland	Pasture	Agriculture	Mosaic of uses	Urbanized area	Other non-vegetated areas	Water bodies
Area (m²)	1985	6501826.2	16025.5	1413792.1	0.0	1703133.8	13354.7	45405.9	5173453.3
	1989	4546745.1	7122.4	1648831.8	1249963.6	2241763.5	28490.0	47186.2	5096888.7
	1990	2472345.3	0.0	2110006.1	3523790.0	1786819.4	26709.4	41844.3	4905476.9

Figure 5 – Land use and occupation of the study area in the years 1985, 1988, and 1990. Source: Adapted from MapBiomas (2023).

Silveira *et al*. (2018) highlight that the installation of Irrigated Perimeters (IP) in the northeastern semi-arid region was a policy implemented to promote agricultural activities due to climate irregularities. The construction of IPs in the community influenced territorial and social dynamics, with an increase in human settlements (urbanized area) near the system, suggesting area development (Figure 5).

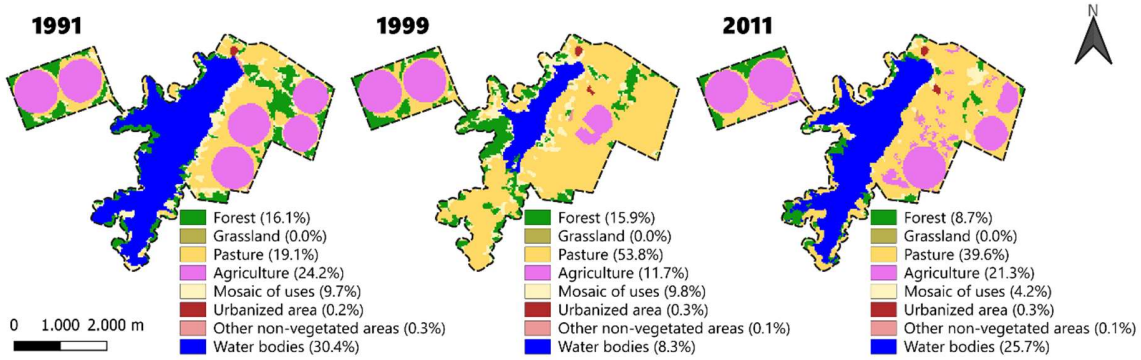
However, Pontes *et al.* (2013) explain that a more rigorous and comprehensive assessment of the effects of this policy infers issues that deviate from its legitimacy discourse - poverty eradication, job creation, and income generation. The public irrigation policy, later regulated by Law No. 12,787/2013 (BRASIL, 2013), contributed to the vulnerability of peasant communities by the State, mediating the interests of large producers.

The growth of agricultural area from 0.0% to 18.3% between 1985-1990 (Figure 5) may not have positively impacted the Realejo Community. This could be related to a possible double deterritorialization caused by the installation of IPs: the expropriation of plots and the imposition of a production model on family farmers, resembling current agribusiness models.

3.2 1991 to 2011: Expansion of agricultural areas and adaptation to seasonal droughts

The construction of the Realejo Reservoir favored the development of irrigated agriculture in the region. According to Oliveira (2015), reservoirs became a beacon of hope for the people of the sertão and their families to protect themselves from the effects of droughts, where they converged in search of work until the next rainy season.

From 1991 to 2011, the study area experienced its own semi-arid seasonality, marked by the expansion of agricultural areas during rainy periods and pasture areas during dry seasons (Figure 6). Despite the occupation dynamics by agricultural activities in the region, forest areas continued to decrease, particularly near irrigated perimeters, with a 46.2% decrease in area over the 20 years observed.



Land use and occupation		Forest	Grassland	Pasture	Agriculture	Mosaic of uses	Urbanized area	Other non-vegetated areas	Water bodies
Area (m²)	1991	2395778.3	0.0	2844499.8	3595904.2	1448502.8	27599.7	37392.7	4517313.7
	1999	2366395.4	6232.1	7992129.8	1742319.5	1458300.8	42734.8	17805.9	1241072.8
	2011	1288253.7	890.3	5888400.4	3172121.5	619646.1	51637.9	19586.6	3826454.8

Figure 6 – Land use and occupation of the study area in the years 1991, 1999, and 2011. Source: Adapted from MapBiomas (2023).

In 1999, the most critical water supply conditions were observed during the evaluated period. The medium size of the Realejo Dam was insufficient to guarantee water availability during drought periods, leading agricultural areas to transition to pasture and exposed soil. Between 1991 and 1999, there was a 72.5% reduction in water surface area and an 181.0% increase in pasture areas (Figure 6). Oliveira (2015) and Araújo *et al.* (2023) explain that livestock activities showed greater drought resistance compared to agricultural activities, favoring their practice in semi-arid regions to ensure food security and job creation.

According to Lima *et al.* (2016), in dry years like 1991, 1992, 1997, 1998, 2001, and 2002, there was a significant decrease in agricultural production throughout the Brazilian semi-arid region, indicating that producers, in general, were vulnerable to such phenomena. Correa (2006) recalls serious water supply problems in the Realejo Irrigation Perimeter, with water supply meeting 79.0% of human, industrial, and animal demands in 2000.

In the context of historical data and land use and occupation analysis, Figure 7 shows the Trophic State Index (TSI) evolution and reservoir volume estimates between 2004 and 2022. From 2004 to 2011, fluctuations in the Realejo reservoir volume were observed, with the lowest percentages of water intake observed in 2004 and 2008.

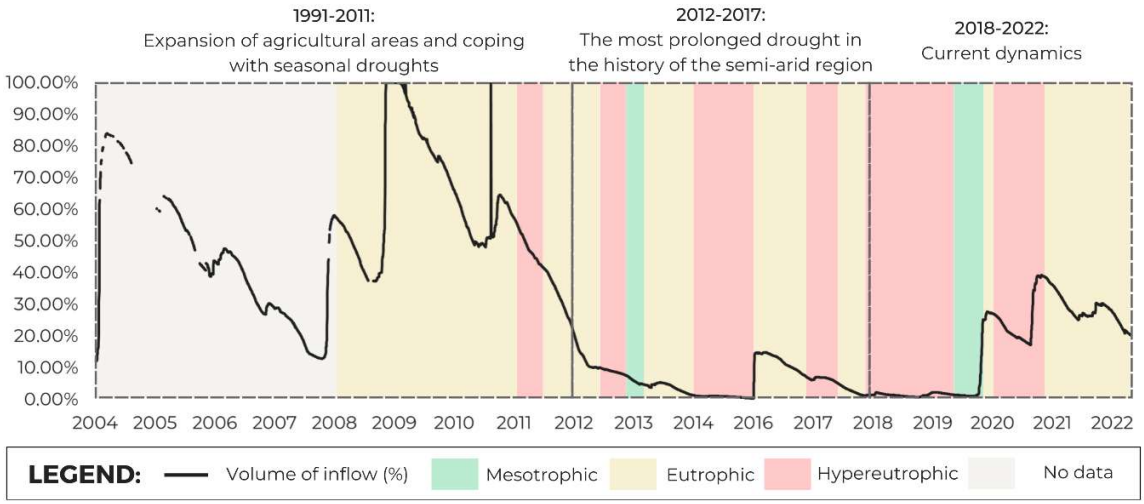


Figure 7 – Evolution of trophic state (2008-2022) and water volume (2004-2022) of the Realejo Reservoir. Source: Adapted from COGERH (2021).

According to TSI classification by Lamparelli (2004) and CETESB (2007), the predominant classification during this period was eutrophic, characterized by undesirable water quality changes due to increased nutrient concentrations and interference with multiple uses. Specifically, in 2011, when the forest cover was at its lowest, and the area was most heavily exploited for agricultural activities, the Realejo Reservoir reached hyper-eutrophic status, indicating severe water quality degradation and significant impairment of its uses.

3.3 2012 to 2017: The most prolonged drought in the history of the semi-arid region

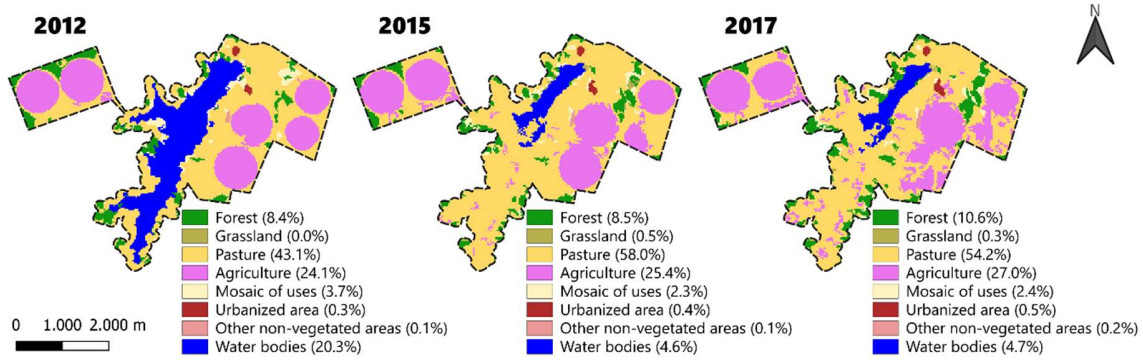
Between 2012 and 2017, the northeastern semi-arid region faced what was considered its longest drought period in history. At the Realejo Reservoir, there was a significant reduction in water surface area (Figure 8) and reservoir levels (Figure 7). Barbosa *et al.* (2021) estimated an 80% decrease in water surface area during this period.

In 2015, the reservoir reached its dead storage volume (Figure 7). During this year, as shown in Figure 8, areas previously occupied by reservoir waters transitioned to pasture activities, which increased by 34.6% compared to 2012.

According to IPECE (2016), 2015 was one of the worst years for the agricultural sector in Ceará. However, land use data presented in Figure 8 show no reduction in areas occupied by agricultural activities in the study area, which increased by 12.1% during this period. Nunes and Medeiros (2020) reiterate that dam-building policies led to concentrated water accumulation in medium and large reservoirs to primarily serve economic interests, rather than ensuring rural population water supply.

In this context, it was observed that from 2012 to 2016, the National Secretariat for Civil Protection and Defense recognized ten emergencies due to drought in Crateús/CE municipality. Thus, despite the presence of the Realejo Reservoir and a water supply system, water supply to the community during this period mainly relied on Army-provided tankers until 2015 for a collective cistern, and from this year 310 individual cisterns.

From the perspective of Figure 8, it's also possible to infer that there has been a natural regeneration of forest and grassland areas, which increased their coverage by 2.2% and 0.3%, respectively, between 2012 and 2017. These uses mitigate the degree of degradation in the region and contribute to maintaining water resources during droughts, ensuring their preservation and local biodiversity.



Land use and occupation		Forest	Grassland	Pasture	Agriculture	Mosaic of uses	Urbanized area	Other non-vegetated areas	Water bodies
Area (m²)	2012	1249081.8	890.3	6410099.4	3577208.4	545752.9	51637.9	19586.5	3012734.2
	2015	1269557.9	73895.2	8628690.1	3781083.2	341874.6	63211.8	22257.4	686421.0
	2017	1574926.2	48076.3	8058908.2	40098870.0	360569.2	75676.1	32940.9	706007.3

Figure 8 – Land use and occupation of the study area in the years 2012, 2015, and 2017. Source: Adapted from MapBiomas (2023).

Regarding the water quality of the Realejo reservoir, as seen in Figure 7, there is an observed relationship between deteriorating water quality and decreasing available volume in the reservoir, as affirmed by Lima *et al.* (2020). Approximately 44% of the period (2012 to 2017) saw the Realejo reservoir waters classified as hypereutrophic, with this classification concentrated during periods of decreased inflow volume.

3.4 2018 to 2022: Current dynamics

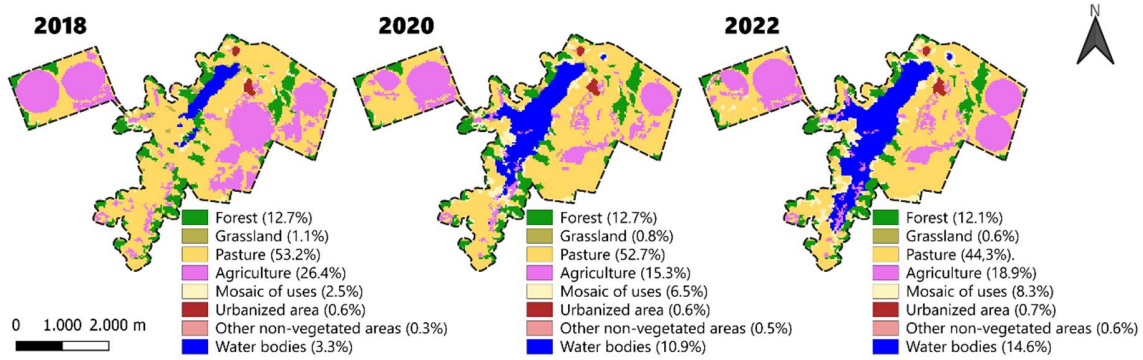
Although the period from 2012 to 2017 faced water scarcity, its consequences are reflected in the current dynamics in the studied area. As shown in Figures 7 and 9, the inflow volume and the surface area of the Realejo reservoir grew slowly during this period, with the reservoir not surpassing the 40% capacity mark.

Additionally, it was observed that this period brought negative implications for the water quality of the reservoir, as its waters transitioned from a predominantly eutrophic class in the years preceding the drought to alternating between eutrophic and hypereutrophic levels in subsequent years. Due to the water quality issues in the reservoir, water treatment processes were insufficient to achieve potable water for human consumption. Currently, the population relies on wells and rainwater collection in cisterns.

Further impacts from this period include a significant reduction (7.5%) in agricultural land use between 2018 and 2022. Currently, the Realejo Irrigation Perimeter only has one pivot covering 75 hectares. Concerns highlighted in the Crateús Sertões Basin Water Resources Plan, where the Realejo reservoir is located, include the release of reservoir water for grain production, considering uncertainties regarding its recharge, which could lead to water shortages in future years (COGERH, 2021).

Figure 9 illustrates the growth of the Realejo Community near the Permanent Preservation Area (PPA) of the reservoir, reaching 0.7% occupancy in 2022, with a total of 512 families currently. Although the community is located in an appropriate area according to Law No. 12,651/2012 (BRASIL, 2012), workshop analyses and on-site visits suggest that these populations may contribute to reservoir and PPA degradation through inadequate disposal of household solid waste and domestic sewage.

Evaluation of physical-chemical parameters such as Biochemical Oxygen Demand (BOD), electrical conductivity, total coliforms (TC), and *Escherichia coli* (*E. coli*) by the team developing the Realejo Community Water Safety Plan (FUNASA; UFCG, 2023) indicated contamination of the water body by domestic or industrial sewage discharge.



Land use and occupation		Forest	Grassland	Pasture	Agriculture	Mosaic of uses	Urbanized area	Other non-vegetated areas	Water bodies
Area (m²)	2018	1883854.5	159363.7	7911121.9	3920858.4	373033.0	86359.7	38282.8	494117.2
	2020	1883853.5	120190.6	7839904.0	2280940.6	963292.8	90811.2	67662.6	1620336.0
	2022	1801057.3	81907.6	6588156.2	2812447.1	1228600.0	97933.70	82797.6	2174091.9

Figure 9 – Land use and occupation of the study area in the years 2018, 2020, and 2022. Source: Adapted from MapBiomas (2023).

As observed in studies by Santos (2018) and Neto (2020), agriculture is the land use class responsible for the greatest environmental conflicts and degradation of PPAs and the reservoir. Despite being more intensively practiced during the 1980s to 1990s with the installation of irrigation perimeters, it was not until 2022 that the first water withdrawal permit for irrigation was approved by the Water Management Company (COGERH).

Furthermore, the use of pesticides in irrigated areas is a concerning factor highlighted by COGERH (2021), contributing negatively to Realejo Reservoir pollution. Based on França *et al.* (2015) study, pesticides used in the community can be classified as moderately to extremely toxic, posing potential contamination risks to surface waters and exacerbating imbalances in natural resources and public health for the population relying on the reservoir for water supply.

4. Final considerations

The study of the construction of the Realejo Dam and its impacts over time reveals a complex interaction between regional development and public irrigation policies. The temporal delimitation into four periods (1980-1990, 1991-2011, 2012-2017, 2018-2022) provided a detailed analysis of the region's transformations.

It was found that the construction of the Realejo Dam, a result of the dam policy, was intended to mitigate the problems caused by droughts but also led to various social, economic, and environmental impacts. Based on the methodology used, it is inferred that the installation of the reservoir favored the development of irrigated agriculture in the region and the increase in human settlements (633.3% higher in 2022 compared to 1985). On the other hand, it led to the degradation of natural forest cover, contamination of water resources by pesticides, and a possible mischaracterization of family farming in the area.

Considering only the first period evaluated (1980-1990), 60.3% of the native vegetation was reduced, giving way to agricultural activities. The water surface area showed significant variations during the evaluated period, with the lowest percentages of area occupation occurring between 2012 and 2017 when the most prolonged drought in the history of the semi-arid region occurred. In 2015, water bodies accounted for only 4.6% of the total area, 653.7% less than the area occupied by this class in 1985 (34.8%).

There is a notable need for prior studies before the implementation of hydraulic works to understand the social and environmental implications of construction and assess the feasibility of their execution. To complement the research, studies should be developed that estimate the degradation of the quality and quantity of the dam's water due to activities carried out in its surroundings, suggesting measures to mitigate the damage caused. In this way, it will be possible to

deepen the understanding of the impacts on the Realejo Dam and support the development of more effective strategies for the integrated and sustainable management of water resources.

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