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From the Scourge of Drought to the Third Largest Economy in the Northeast: Ceará's Overcoming and Implications for the Energy Transition According to Arnold Joseph Toynbee's Theory

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Abstract:
Background: *The State of Ceará has historically experienced recurring droughts that have significantly impacted agricultural activities and constrained regional socioeconomic development. In response, various strategies have been implemented to overcome these climatic adversities, fostering structural and strategic transformations that have elevated the state's prominence within the Northeast region of Brazil.*
Materials and Methods: *This research adopted a qualitative approach. The study was conducted through bibliographic and documentary analysis, drawing upon academic publications, technical reports, scientific articles, and reputable online sources.*
Results: *Findings indicate that Ceará has, over time, developed public policies and collaborative initiatives between public and private institutions that effectively mitigated the impacts of recurrent droughts. This trajectory of resilience and innovation aligns with the premises of Arnold J. Toynbee's Geopolitical Theory, illustrating how environmental challenges can drive adaptive and transformative responses.*
Conclusion: *The study concludes that Ceará's historical experience with drought has contributed to notable progress in the socioeconomic field, strategically positioning the state to engage in the global energy transition under increasingly favorable structural and institutional conditions.*
Keywords: *Drought; Geopolitics; Socioeconomic Field; Energy Transition.*

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I. Introduction

The State of Ceará has historical records, dating back to the 16th century, of recurrent droughts and irregular rainfall patterns, which have negatively impacted agricultural activities and directly influenced the region's socioeconomic development. Numerous challenges have been and continue to be faced by the people of Ceará in their efforts to overcome the effects of frequent droughts. On the other hand, institutions in Ceará, aware of the need to respond to these adversities, have undertaken a series of measures aimed at compensating for and overcoming the difficulties imposed by nature, yielding satisfactory results.

The methodology adopted in this study is distinguished by a qualitative approach, which is essential for a critical and in-depth understanding of Ceará's historical experience with environmental adversities (droughts and dry spells), its socioeconomic overcoming, and its growing potential to engage in the global energy transition. To achieve this, two research procedures were employed: bibliographic research, grounded in scientific works, and documentary research, based on the analysis of national sources, guiding the interconnection between socioeconomic transformation and energy transition.

Thus, the general objective of this paper is to demonstrate that the measures implemented throughout Ceará's history have been effective in overcoming the effects and challenges brought about by droughts in the region. As a result of these measures, the state has achieved notable economic prosperity within the Northeast region of Brazil, enabling it to take on a leading role in the global energy transition.

The specific objectives established for this study are as follows: to present the climatic characteristics of the state; to describe the historical background of droughts; to define the concept of geopolitics; to explain the "Challenge and Response" theory proposed by Arnold Joseph Toynbee (1934); to present political, economic,

and social actions and initiatives adopted by the state in response to the challenges of drought; to demonstrate how these efforts have led Ceará to become the third-largest economy in the Brazilian Northeast; and to justify the implications of this transformation for the state's participation in the energy transition process.

This article is organized into four sections. The first provides an introduction that outlines the research context, the adopted methodology, and the study's objectives. The second section discusses the methodological aspects, detailing the qualitative approach and the research procedures used. The third section comprises the theoretical framework, which presents Ceará's climatic conditions; describes the historical and socioeconomic consequences of droughts; explains the concept of geopolitics and Toynbee's theory; outlines the state's actions and initiatives in response to drought challenges; and justifies the implications of Ceará's overcoming for its engagement in the energy transition. Finally, the fourth section presents the concluding remarks, which summarize the main findings and suggest directions for future research.

II. Material And Methods

Even under the adverse circumstances of drought, this project focuses on the measures and actions that characterize Ceará's overcoming process, in accordance with Arnold Toynbee's Geopolitical Theory of Challenge and Response, considering the political, economic, and social dimensions, to the extent that such efforts contribute to the state's energy transition.

The methodology employed in the development of this research is distinguished by its qualitative nature, which holds scientific importance by enabling a deep and contextual understanding of the political, economic, social, and physiographic themes under study. As stated by Lakatos and Marconi (2019), qualitative research transcends mere quantification, aiming instead to interpret meanings, interrelationships, and underlying structures within the data. It is therefore particularly effective in investigations centered on Ceará's socioeconomic transformation and its implications for the state's energy transition.

The methods adopted included bibliographic and documentary research. The former was grounded in the analysis of national and international publications, reports, scientific articles, and reputable online sources, thereby providing a solid theoretical foundation. According to Pereira et al. (2018), this type of approach is essential for global science, as it allows for the systematization of existing knowledge and guides future research.

Documentary research was based on the analysis of publications from national institutions such as the Secretariat of Water Resources (SRH), the Ceará State Development Agency (ADECE), the Institute for Research and Economic Strategy of Ceará (IPECE), the Bank of the Northeast (BNB), the Ministry of Science, Technology and Innovations (MCTIC), the World Bank Group (WBG), the Federation of Industries of the State of Ceará (FIEC), and the Federation of Agriculture and Livestock of the State of Ceará (FAEC).

These documents facilitated an understanding of the interface between the historical climatic conditions of the state—which have had negative consequences for its socioeconomic development—and the political, economic, and social actions and initiatives that enabled Ceará to overcome structural challenges, ultimately allowing the state to participate in the global energy transition under increasingly favorable conditions.

According to Grazziotin, Klaus, and Pereira (2022), the combination of documentary and bibliographic research constitutes a powerful methodological tool for scientific advancement, as it not only systematizes consolidated knowledge but also establishes connections between socioeconomic resilience and Ceará's enhanced capacity to engage in the energy transition.

In this context, the articulation between bibliographic and documentary sources enabled a more in-depth analytical investigation, allowing for an integrated interpretation of physiographic, geopolitical, economic, and social factors. This approach highlights Ceará's capacity to overcome the challenges posed by recurrent droughts and dry spells and to emerge as a prominent economy within Brazil's Northeast region.

III. Literature Review

This theoretical framework was organized into six subsections. The first addresses the climatic characteristics of the state of Ceará. The second presents a brief historical overview of droughts in the region. The third discusses concepts and definitions related to geopolitics. The fourth explores Arnold Toynbee's Geopolitical Theory. The fifth subsection outlines the public and private actions and initiatives implemented in the political, economic, and social spheres in response to the challenges posed by adverse climatic conditions. Finally, the sixth subsection analyzes the implications of the state's successful resilience for Ceará's participation in the energy transition.

3.1 Climatic Characteristics of the State of Ceará

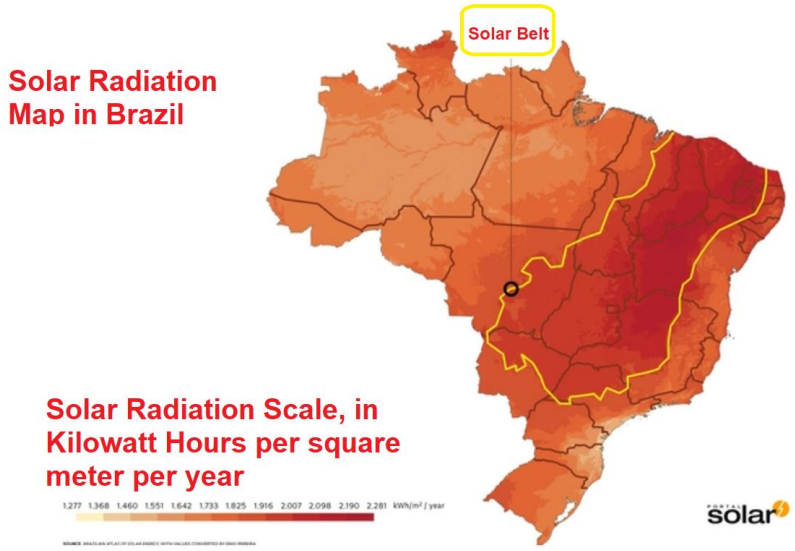
The National Institute for the Semi-Arid Region (INSA), part of the Ministry of Science, Technology, and Innovations (MCTI), defines the criteria that characterize a semi-arid region as follows: an average annual rainfall below 800 mm, an aridity index of up to 0.5, and a drought risk greater than 60% (INSA, 2025). In semi-arid regions, such as those in Brazil's Northeast, drought events are a frequent climatic phenomenon that have historically affected the social, cultural, and political life of the population.

Ceará, specifically, is characterized by a semi-arid climate and is one of the Brazilian states most severely impacted by drought (ADECE, 2019). Moreover, nearly the entire territory is located within what is commonly referred to as the "drought polygon," a region covered predominantly by caatinga vegetation—a type of flora adapted to withstand long dry periods (Cortez, 2013).

This results in a climate marked by aridity, water scarcity, spatial and temporal variability of rainfall, and soils that are poor in organic matter (IPECE, 2015). Throughout the year, the state experiences two distinct climatic periods: the rainy season (winter) and the dry season. The rainy season, locally referred to as the *"quadra invernosa"* (rainy quarter), occurs between February and May and is characterized by the highest annual rainfall averages, although the rains are irregular, short in duration, and of high intensity (Ximenes, 2013).

In addition to rainfall irregularities, another physiographic feature that directly influences the semi-arid environment of Ceará is solar irradiation. The "solar belt" was defined by the Brazilian Solar Energy Atlas, developed by the National Institute for Space Research (INPE). This atlas identifies the highest levels of solar irradiation in the country (Map 1).

Map 1: Solar Radiation in Brazil



Source: Portal Solar

The solar belt delineates an area extending from the Northeast region to the Pantanal, with the highest irradiation rates found between the sertão of Bahia and parts of Minas Gerais. As observed in Map 1, the State of Ceará lies entirely within the Brazilian solar belt (Barbosa and Gomes, 2024).

Thus, it can be partially concluded that the state exhibits physiographic characteristics—particularly related to climate, temperature, soil, and water scarcity—that have historically resulted in a persistent situation of environmental challenge and adversity, directly impacting Ceará's development.

3.2 Historical Overview of Droughts in the State of Ceará

Drought is a climatological phenomenon characterized by the absence, scarcity, reduced frequency, limited quantity, and poor distribution of rainfall during the rainy seasons, hindering the socioeconomic development and environmental integrity of the region (Luna, 2007).

The year 1583 marks the first recorded drought in Brazilian history, documented by the Jesuit priest Fernão Cardim. During this period, indigenous peoples abandoned the interior regions of Pernambuco and Rio Grande do Norte, which economically affected sugarcane and cassava cultivation (Castro and Cerezini, 2023).

According to the Secretariat of Water Resources of the State of Ceará (SRH), numerous drought periods have punctuated and influenced Ceará's history, notably those of 1877–1879, 1900, 1915, 1919, 1932, 1958, 1979–1983, 1987, 1990, 1992–1993, 1997–1998, 2002–2003, and 2012–2016. These episodes of water scarcity marked various developmental cycles of the State of Ceará (SRH, n.d.).

During the triennium 1877–79, the "Great Drought" extended across the entire Northeast region; in Ceará, the most severe year was 1878, when 118,900 people died. In December of that year, an average of 495 burials were conducted daily in Fortaleza's cemetery (Ximenes, 2013). In the same period, desperate drought victims looted government food supplies, and historical accounts indicate that nearly 200,000 people died in Fortaleza due to hunger and diseases spread by the influx of migrants fleeing the hinterlands after the catastrophic 1877 crop failure (Castro and Cerezini, 2023).

At the beginning of the 20th century, another severe drought struck Ceará in 1915, whose magnitude was depicted by the Cearense writer Rachel de Queiroz in the work *O Quinze*. The situation worsened in 1919, when rainfall levels were less than 60% of the climatological average (Ximenes, 2013).

The aforementioned historical droughts directly impacted both urban and rural populations in Ceará, particularly concerning social indicators. Water scarcity directly reflected poverty, as water is an essential element for human development and well-being. It strongly affected the loss of human capital, mainly due to the time spent—especially by women and children—searching for and collecting water for their families' survival (Luna, 2007).

Since the 16th century, due to the uneven rainfall regime in Ceará, various socioeconomic consequences have ensued: migration to major urban centers in Brazil (Rio de Janeiro and São Paulo), hunger, malnutrition (especially among children), diseases, and deaths (both human and livestock). Thus, the major challenge faced by the state has been to ensure water security, considered imperative for promoting sustainable development by guaranteeing adequate quantity and quality of water despite hydrological events such as droughts.

Therefore, it can be partially concluded that the historical droughts, coupled with Ceará's climatic characteristics, have negatively influenced the socioeconomic development of its people, imposing a prolonged period of obstacles and challenges for survival in this adverse environment.

3.3 Geopolitics: Concepts and Definitions

The Munich Institute of Geopolitics (Germany) defines geopolitics as the geographic awareness of the state and the science of the relationship between land and political processes. The German geographer Karl Haushofer defined it as the science that deals with the dependence of political facts on the land (Bonfim, 2005).

Thus, the understanding of the concept arises from a detailed comprehension of the interspatial relations of a territory, considering that geography conditions its political, economic, and social interests in the face of a stimulus-challenge situation in which it finds itself (ESG, 2009). Considered one of the pioneers of geopolitics in Brazil, Mario Travassos, in his 1931 work *"A Projeção Continental do Brasil"* (The Continental Projection of Brazil), defined geopolitics as an interpretative process of geographical facts, resulting in a judgment of a country's situation at a given moment (Travassos, 1938).

Similarly, Carlos de Meira Mattos, in his publications, stated that:
a. In *"Brasil: Geopolítica e Destino"* (Brazil: Geopolitics and Destiny), he defined geopolitics as an indicator of political solutions consistent with geographic realities and as the science of governing states, inspired by the geographical realities of their territories (Mattos, 1975);

b. In *"A Geopolítica e as Projeções do Poder"* (Geopolitics and the Projections of Power), he affirmed that the physical environment in which humans live provokes stimuli that inspire, guide directions, and awaken needs (Mattos, 1977); and

c. In *"Geopolítica e Modernidade: Geopolítica Brasileira"* (Geopolitics and Modernity: Brazilian Geopolitics), he defines it as the product of the gradual observation of human action in the exploitation of the natural environment—that is, the influence of geography on human action over the land and a politics applied to geographic spaces inspired by historical experience. He also emphasizes the importance of valuing the relationship between the state and the physical environment, quoting French emperor Napoleon Bonaparte: "Geography indicates the destiny of nations" (Mattos, 2002).

Therezinha de Castro, a Brazilian geopolitics scholar, defines it as the science linking geographical aspects with political events, with the primary objective of rationally leveraging all branches of geography in state planning activities aimed at immediate or long-term results (Castro, 1999).

Finally, according to Mafra (2002), geopolitics is the study of how geographical conditions influence studies and decisions, linking political, economic, and social planning to the constraints of the geographic environment.

3.4 Arnold J. Toynbee's Geopolitical Theory of Challenge and Response (1934)

From the concepts of geopolitics emerged the "Challenge and Response" theory of 1934, developed by the English historian Arnold Joseph Toynbee (1889–1975), which posits that the prominence of a nation depends on its ability to overcome its challenges.

In his work *A Study of History*, Toynbee argues that in this struggle with the environment, stimuli act favorably when they encounter a human nucleus capable of fighting, willing to accept the challenge posed by the physical environment, overcoming the unfavorable factors of geography—in other words, the destiny of peoples lies in the hands of their leaders (Mattos, 1975).

These conclusions were drawn after analyzing the trajectories of 21 civilizations, from the Sumerians to modern times. Civilizations that accepted and overcame their challenges—understood as obstacles or

disadvantages—developed within their respective contexts. Conversely, those that did not accept or no longer faced challenges stagnated, regressed, and eventually disintegrated (Bonfim, 2005).

For Toynbee, victorious societies were those capable of responding to the challenge of the physical environment (geography), while failures were societies unable to meet these challenges. The active human of any race, residing at any latitude or longitude, if able to respond to the Toynbeean challenge, could triumph in the evolutionary process of society (Mattos, 2002). Geographical disadvantages (obstacles) are challenges that hinder the nation-building process: either these are overcome and the nation affirms itself, or they are not overcome, condemning the society to stagnation or disintegration (Mafra, 2002).

Silva (2006) states that civilizations develop according to the responses they are able to provide to the challenges they face. Moreira (2007) analyzes the theory as a moment when high-level decision-makers (leaders and rulers of a society) seek to define, in the face of a challenge, a path to the future, pointing out that the dilemma of any country—and humanity as a whole—is to find, at each moment, an adequate response to the challenge posed by national and international circumstances. According to Cabral Filho (2009), the survival of a community, society, or civilization depends on the ways and means by which they confront difficulties during critical moments. In Toynbee's theory, the "challenge" refers to factors or events that may represent a threat to that society, impacting the well-being of its population; conversely, the "response" is based on actions taken to overcome those challenges, requiring vision and leadership from its rulers (Schmandt and Ward, 2020).

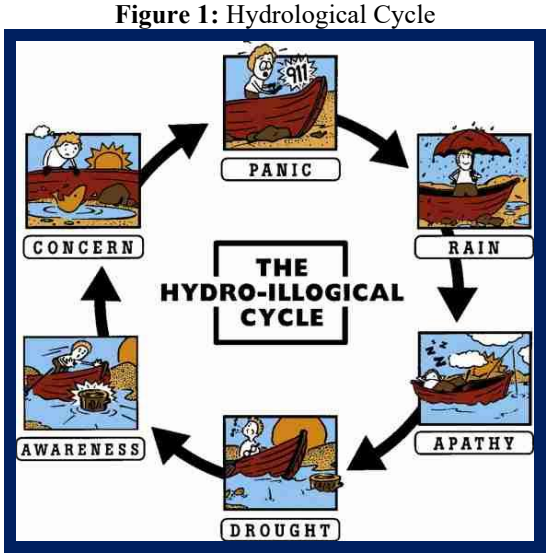
The incorporation of new technologies, the undertaking of economic activities, or a combination of multiple factors would be examples of responses to such challenges. The response is never predictable, and its outcome is only known over time. This is the risk humans face—resulting in either success or failure (Schmandt and Ward, 2020).

Thus, it can be inferred that the climatic conditions, rainfall regime, and historical droughts of the State of Ceará have imposed limitations on its socioeconomic development throughout its history, manifested in emergency services, deaths of the country people, and malnutrition among children and adults, leading to the conclusion that these circumstances align with the premises of challenges advocated by Toynbee's Theory. Accordingly, how has Ceará been overcoming these historical obstacles and natural adversities? How have the state and its population been confronting the challenges and uncertainties arising from climatic conditions (drought), which impose a constant risk of food and water insecurity? What are the implications of these responses, derived from these climatic challenges, in relation to the energy transition in the State of Ceará?

3.5 Actions and Initiatives of the State of Ceará in Response to Drought Challenges

Donald Wilhite, an American climatologist recognized as the world's leading expert in drought policy and management, established the hydrological cycle (Figure 1) that is common in countries facing water scarcity. Initially, there is the panic phase (the first stage of the vicious cycle); then comes the rainfall and, with it, apathy (neither the population nor politicians see the need to prepare for the next drought). However, when droughts recur, they again trigger concern and fear among those who failed to plan ahead (World Bank Group [WBG], 2023).

Figure 1: Hydrological Cycle



Source: Wilhite (2012 apud Souza Filho, 2024).

The decision of Ceará was to study, deepen, and work on the hydrological cycle in the State, grounded on three pillars: planning, strategic vision, and water resources management. To this end, three measures were adopted to reduce the severity of drought impacts: (1) water demand management (rational handling, efficient

use, and user training), (2) water supply management (planning, construction, operation, and maintenance of physical infrastructure for storage and water transfer), and (3) soil water regulation since rainwater regulation is unfeasible (Souza Filho, 2024). Under these circumstances, proper water management (short, medium, and long term) would enable a strategic vision of water resources policy, considered essential for adapting to water scarcity (Souza Filho, 2024). From the above considerations, the actions and initiatives in Ceará that characterize how the State has been responding to the challenges imposed by nature (irregular rainfall conditions) will be presented, demonstrating its capacity for coexistence, overcoming, and adaptation in favor of Ceará's socioeconomic development.

3.5.1 Political Sphere

The harsh reality in Ceará enabled the creation of the *State Plan for Coexistence with Drought*, a set of emergency and structural measures based on five pillars: water security, food security, social benefits, economic sustainability, and innovation (IPECE, 2015). Simultaneously, the government has conducted planning to ensure that available water resources are monitored and used for the benefit of Ceará's society and economy, some of which are described below:

3.5.1.1 Ceará Strategic Water Resources Action Plan

This plan is organized into six structuring axes of the state water resources policy (Water Resources Planning; Water, Time, and Climate; Water Infrastructure; Water Management; Water Governance; and Water). Its objective is to guide government action in the water resources sector, focusing on expanding water security, considering quantitative and qualitative water aspects, monitoring and inspection, developing strategies to promote water demand management (among users), expanding water supply to Ceará society, among others (SRH, 2018).

3.5.1.2 Proactive Drought Management Policy for Ceará's Water Resources

This policy aims to (1) manage drought risk in Ceará's water resources; (2) provide tools for water resource management actions throughout the State; (3) improve climate risk management associated with droughts, mitigating direct impacts on water uses (urban, industrial, agricultural, aquaculture and fishing, hydroelectric, and ecosystem-related), among other objectives (SRH, 2023). This policy demands measures and actions that move from reactive to proactive management, requiring the development of drought management based on preparedness plans containing short- and long-term actions and an early warning system, with lessons learned from previous drought periods maintained (SRH, 2023).

3.5.1.3 Proactive Drought Management Plans

These plans aim to preserve the memories and experiences accumulated by social actors living with drought between episodes. Their main goal is to reduce vulnerabilities to droughts by identifying impacts, problems, and conflicts caused or intensified by drought contexts, and the responses and measures adopted to minimize or resolve them (Ceará, 2023).

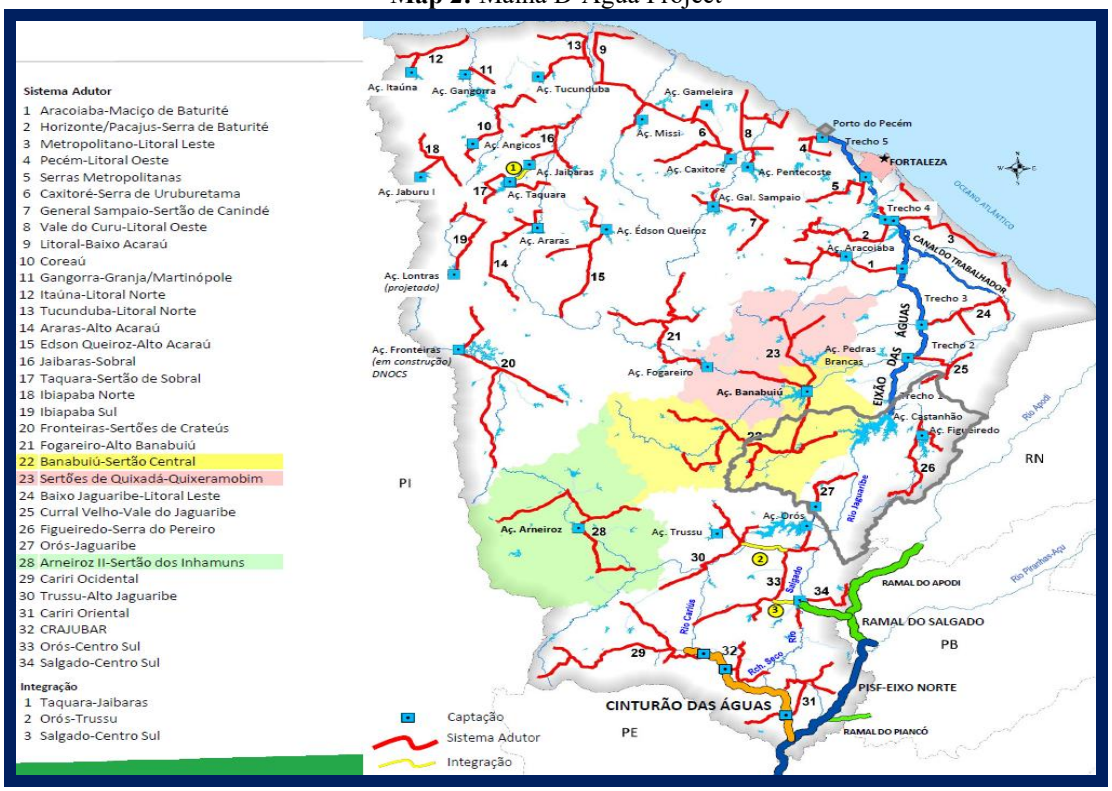
3.5.1.4 Strategic Center of Excellence in Water and Drought Policies

The Strategic Center of Excellence in Water and Drought Policies, linked to the Federal University of Ceará, is dedicated to research, development, and innovation in water resource management. With a multidisciplinary approach, it promotes water security and the sustainability of social and ecosystem water uses (UFC, 2025). Additionally, it develops technologies for water security, water efficiency, and water resource management, fostering ecosystem sustainability and disseminating knowledge in water resource and drought management (UFC, 2025).

3.5.1.5 Malha D'Água Project

According to Rodrigues (2024), this is a treated water conduit system with intake directly from strategic reservoirs to supply municipal and district headquarters. The project aims to increase the State's water security as well as promote greater water availability.

Map 2: Malha D'Água Project



Source: Rodrigues (2024).

The benefits of the project include, among others, the quantitative expansion of water supply for human consumption during periods of severe drought; improved water quality for human supply; greater efficiency in reservoir management; and the reduction of conflicts between water use for human consumption and rural economic activities (Rodrigues, 2024).

The data are significant: 34 water distribution systems with Water Treatment Plants, 4,300 kilometers of main pipeline, and 6,700 kilometers of branch lines. With an estimated investment of BRL 9 billion, the project is expected to reach 178 municipalities and approximately 6.3 million people in Ceará, encompassing both urban and rural populations (Rodrigues, 2024).

3.5.2 Economic Dimension

In the second half of the 19th century, Ceará, marked by a history of calamities (mainly droughts), showed little progress in the industrialization process, as its economy was primarily based on agriculture and livestock (Girão, 2000).

However, by the early 21st century, the economic situation of Ceará had evolved positively. In the economic field, one of the most relevant institutions contributing to regional development is the *Banco do Nordeste* (BNB). To promote and strengthen rural areas, BNB created the *Agroamigo* program, considered the largest rural productive microcredit program in Latin America. This initiative facilitates access to machinery and equipment for rural landowners, enabling them to reduce labor intensity, increase productivity and water efficiency, and improve rural property water infrastructure through actions that promote access to, use of, and reuse of water (Silva, 2024).

Since January 2022, BNB has signed more than 200,333 contracts related to water infrastructure in the region, totaling BRL 6.2 billion in credit. These resources have supported family farming mechanization, strategies for coping with semiarid conditions, the formation of strategic food reserves (silage and hay), and irrigation systems such as micro-sprinkling or drip irrigation (Silva, 2024). In the economic context, the *Federação da Agricultura e Pecuária do Estado do Ceará* (FAEC) also plays a significant role. FAEC is an institution established for the purpose of conducting studies, coordination, advocacy, and representation of stakeholders in the fields of agriculture, livestock, rural extractivism, fishing, forestry, and agribusiness (FAEC, 2025).

Among its objectives are increasing production and productivity in rural enterprises through the adoption of technologies suited to the region and encouraging producer organizations to participate in projects that enable the economic development of the rural sector in Ceará. The institution has been developing a robust database through the *Center for Intelligence and Innovation in Ceará Agribusiness*, whose objective is to

analyze the state's main production chains in order to monitor the performance of agribusiness activities (agribusiness, beekeeping, poultry farming, cattle ranching, shrimp farming, blue economy, horse breeding, fruit farming, goat and sheep farming, and fish farming), including the preparation and analysis of technical reports for each of these production chains (Soares, 2024).

In Ceará, with its semiarid climate and frequent droughts, FAEC's initiatives have significantly contributed to the development of the state's agribusiness. Unsurprisingly, according to Soares (2024), Ceará has emerged as a leading state in agribusiness within the Northeast region and Brazil as a whole (Table 1).

Table 1: Highlights of Ceará's Agribusiness Sector (2022).

In the Northeast	In Brazil
➢ Leading producer of fingerlings, accounting for 30.6% of national production; ➢ Top producer of eggs in the Northeast region, representing 26.8% of the regional output; ➢ Third-largest producer of milk, contributing 18.6% of total production; ➢ Third-largest producer of honey in the Northeast, with 18.8% of the region's output; and ➢ Leading producer of sweet potatoes, accounting for 33.2% of production in both the Northeast and Brazil as a whole.	➢ Leading producer of shrimp, accounting for 54.1% of national production; ➢ Top producer of shrimp larvae and post-larvae, representing 49.1% of national output; ➢ Leading producer of cashew nuts, contributing 65.1% of national production; ➢ Top producer of Bahia-type coconut, with 31.1% of national output; ➢ Leading producer of passion fruit, accounting for 12.4% of national production; and ➢ Second-largest producer of melon, representing 12.4% of national production.

Source: Soares (2024).

Another indicator of Ceará's resilience in overcoming the historical challenges of drought is its trade balance. According to the report "Foreign Trade of Ceará in 2023," considering only agricultural products—the sector most affected by drought—the figures are impressive, with exports totaling USD 164,047,988.00, an increase of 11.34% over 2022. Among the top ten export products are footwear (leather), fruits, animal waxes, horticultural products, and cotton (IPECE, 2024).

A survey conducted by the International Business Center (CIN) of FIEC reported a highly positive year for Ceará's agribusiness in 2023, with fruits, leather, and textiles standing out in exports. The report highlights bananas, coconut water, lingerie, and leather handbags. Banana exports increased by 37%, totaling USD 5.7 million; Ceará is Brazil's largest exporter of coconut water, posting a 24.2% increase over 2022 with sales of approximately USD 37 million; and leather handbag exports reached about USD 3 million (CIN, 2024).

According to CIN-FIEC, between January and May 2025, all exports from the state of Ceará totaled USD 770.48 million, representing a 49.3% increase compared to the same period in 2024. This indicates a strong recovery in the state's competitiveness. Although iron and steel remain the main highlights, products such as fresh fruits, footwear, and vegetable waxes have been increasingly gaining ground in demanding international markets (Cabral, 2025).

Ceará's economy concluded 2024 with a growth rate of 5.5% compared to 2023—the highest in the past 14 years and the third-best performance in the national growth ranking. These data are from the Regional Economic Activity Index, measured and published by the Central Bank of Brazil (Ceará, 2025).

This performance surpassed the national average (3.8%) and exceeded growth rates in the North (4.8%), Northeast (4.0%), Southeast (3.2%), South (4.2%), and Center-West (2.9%) regions. It placed Ceará ahead of major economies such as São Paulo (3.8%), Minas Gerais (3.0%), Pernambuco (4.7%), and Bahia (3.1%) (Ceará, 2025). Regarding Gross Domestic Product (GDP), the state recorded a 6.49% expansion in 2024—the best result since 2010—leading the Northeast region and ranking third nationally, nearly twice the national average (3.4%). Among the GDP sectors (Industry, Services, and Agriculture), Agriculture performed best with 25.16%, significantly above the national average (-3.2%). Industry grew by 10.65% and Services by 4.28%, compared to national rates of 3.3% and 3.7% respectively. Thus, all three sectors in Ceará outperformed their national counterparts in 2024 (IPECE, 2025).

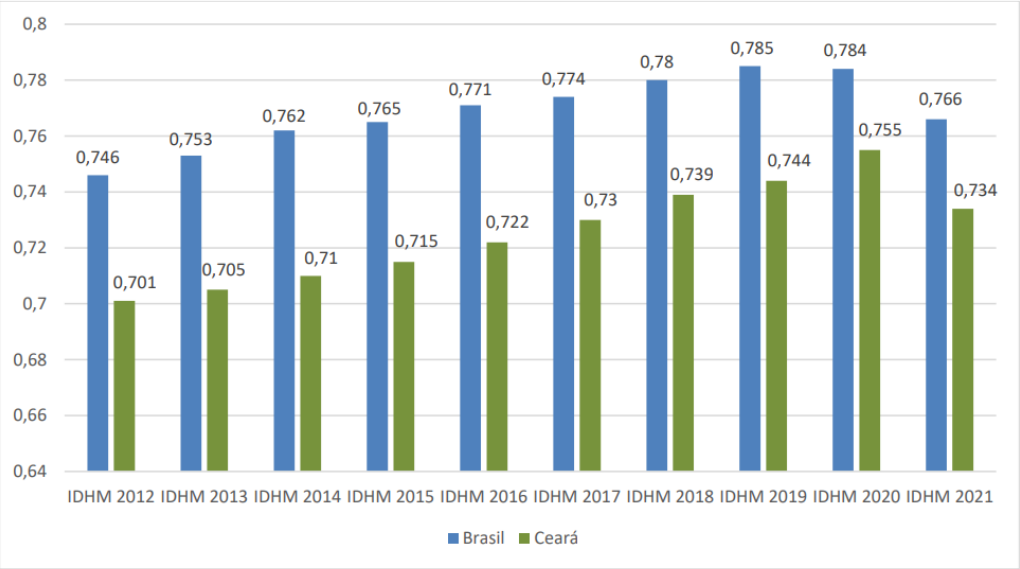
In light of these observations, it can be partially concluded that Ceará's extensive expertise in drought management had a positive economic effect, counteracting the adverse impacts of dry periods. Concurrently, public and private initiatives, especially those directed at water resource management, effectively responded to the climatic challenges and contributed to improved economic performance.

3.5.3 Social Sphere

In the social sphere, the Human Development Index (HDI)—designed to measure social development across geographic areas—was used as an indicator. Developed by the United Nations Development Programme,

the HDI evaluates social, economic, and educational progress (IPECE, 2023). Graph 1 illustrates the evolution of Ceará's municipal HDI compared to Brazil's between 2012 and 2021, showing an overall upward trend except for a decrease in 2021, likely due to the adverse effects of the COVID-19 pandemic.

Graph 1: Evolution of the Municipal Human Development Index (MHDI) in Brazil and Ceará — 2012 to 2021



Source: Atlas of Human Development in Brazil, UNDP/IPEA/FJP. Prepared by: IPECE (2023).

Regarding education, the educational policies adopted by the State have proven successful, positively reflecting on the educational level of the child and youth population. Recent data indicate that Ceará ranks among the top three states in the Ministry of Education assessments for elementary education, comprising 41 of the 50 best-rated public schools in the country. The technical and vocational education network has expanded by 34% in the last five years, while at the higher education level, the state hosts universities well positioned in the rankings of the best in Latin America (ADECE, 2019).

In the Basic Education Development Index of 2023, Ceará consolidated its excellent results in elementary education, achieving the best result in Brazil (from 1st to 9th grade), considering only the public education system. Furthermore, the state network registers the third-best index nationwide in the evaluation of traditional high school and high school integrated with vocational education (Ceará, 2024).

3.6. Implications of Ceará's Overcoming Challenges for the State's Energy Transition

Ceará's location in the Northeastern Salient is strategic, considering its shortened distances to the European continent and proximity to important maritime routes and consumer markets (ADECE, 2019, apud Barbosa & Gomes, 2024), facilitating access to major international trade flows. Regarding natural resources, it is well established that the state's geographical position allows for the economic exploitation of solar energy, generating a photovoltaic potential of 643 GW (Cavalcante, 2023, apud Barbosa & Gomes, 2024). Studies also indicate the installation of wind farms applying the Weibull probability distribution, used for estimating wind potential (Silva et al., 2020). The simultaneous combination of photovoltaic solar and wind energy allows for energy complementarity (different energy sources serving as alternatives at different times of the day), thus providing energy security.

These physiographic circumstances position Ceará naturally as a potential global player in the world energy transition through the production of green hydrogen (GH2), considered the fuel of the future and derived from renewable energies. In 2021, FIEC, the State Government, and the Federal University of Ceará signed an agreement to construct the GH2 hub at the Pecém Industrial and Port Complex (Bezerra, 2023). At the global level, the state has undertaken a series of initiatives with foreign governments and companies to develop the GH2 economy. German institutions such as GIZ (German Cooperation Agency) and the Fraunhofer Institute; Australian multinationals Fortescue and Enegix Energy; French companies Qair and Engie; Portuguese EDP; and Spanish Neoenergia are examples of agreements with significant private investments aimed at GH2 development and production in Ceará (Barbosa & Gomes, 2024).

It is believed that the benefits for Ceará's society, resulting from the hydrogen economy, will be evident in job creation, the neo-industrialization of the manufacturing complex, and growth in commerce, arising from the new energy matrix based on renewable energies (Barbosa & Gomes, 2024). As a legacy, the

energy transition in Ceará would have the capacity to generate socioeconomic value for the Ceará population, bringing development and well-being to current and future generations, contrasting with the harsh conditions imposed by droughts and dry spells in past centuries.

These circumstances—combining the judicious use of natural resources, the strategic vision of local political and economic actors, the strengthening of energy partnerships with foreign countries, and the invaluable lessons learned in the past (drought combat)—enable Ceará to leave behind the hardships of underdevelopment, hunger, and malnutrition, propelling it toward economic progress and social development, and positioning it better as a renewable energy provider to the globalized world.

This conviction stems from the fact that the state was able to respond in the past to the challenges imposed by adverse climatic conditions (droughts and dry spells), when the people, leaders, and governors of Ceará found the means and ways to face the difficulties imposed by the circumstances of the Ceará territory. From a state nationally known for droughts and dry spells, Ceará now stands out as the third largest economy in the Northeast, allowing it better conditions to proactively participate in the energy transition. Thus, Toynbee's theory is, in principle, demonstrated in Ceará, with these overcome challenges contributing, together with current political, economic, and social possibilities, to providing conditions for the energy transition process in the state for the benefit of both Ceará's population and the international community.

IV. Conclusion

Since the 16th century, numerous years of drought have directly impacted social indicators and negatively influenced the economic development of Ceará. Amidst this environment of great challenges, throughout its history, Ceará has been able to take appropriate and timely initiatives to coexist and adapt to the challenges arising from the effects of dry spells.

Thus, the research fully met all the proposed objectives, insofar as, in light of Arnold Joseph Toynbee's Geopolitical Theory of Challenge and Response, the studies conducted indicated that the State of Ceará has responded very satisfactorily—politically, economically, and socially—to the challenges historically presented by the adverse and unfavorable conditions of the drought phenomenon, overcoming them and becoming more resilient.

During the investigation, the studies demonstrated that, as a result of the lessons learned, planning, and a long-term strategic vision, the State showed the capacity to accept the challenge posed by the physical environment (adverse physiographic climate conditions) and to overcome the disintegrating factors of social collectivity (droughts and dry spells).

Regarding the first axis of the theoretical framework, the climatic characteristics of the State of Ceará were confirmed, noting that the conditions of climate, temperature, and soil aridity are realities that hinder the full socioeconomic development of the State. In the second axis, numerous periods of dry spells impacting the Ceará population since the 16th century were verified. During these periods, numerous socioeconomic consequences impeded or delayed the growth of agriculture and livestock. The study revealed that diseases, deaths, and social unrest arose from irregular rainfall, imposing a great challenge on the people of Ceará in past generations.

In the third axis, the main concepts of geopolitics were presented through definitions from numerous bibliographic sources, characterizing how physiographic conditions impose political and socioeconomic conjunctures on regions, reflecting positively or negatively on their development.

In the fourth axis, Toynbee's Theory of Challenge and Response was addressed, analyzing the importance of public agents assuming a proactive stance in the face of challenges imposed by environmental conditions. The research showed that only concrete and lasting measures would be adequate to overcome the difficulties and obstacles imposed by physiographic constraints.

In the fifth axis, it was possible to verify how the State, through policies, programs, and projects in the political, economic, and social spheres, has been strengthening the management of water resources. Thanks to the various economic indicators presented, it was possible to assess the positive results achieved. Finally, in the last axis, Ceará's overcoming of drought and dry spell conditions of the semi-arid region (obstacles and challenges) was demonstrated, allowing it to participate under better conditions in socioeconomic development in favor of the State's energy transition process.

Considering the results achieved, it is suggested that future studies analyze the interrelation between investments in water infrastructure in Ceará and the Human Development Index of the Ceará population, as well as the correlation between the impacts of water supply (in quantity and quality) and the nutritional level of the State's child and youth population.

Finally, by maintaining the ongoing planning and actions regarding the management of Ceará's water resource systems, the water supply would be guaranteed, making the State even more promising in the Northeast region, overcoming the difficulties imposed on the Ceará population by past droughts and dry spells.

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