IMPACT OF EXTREME WEATHER EVENTS ON THE HEALTH AND EDUCATION OF CHILDREN, ADOLESCENTS AND YOUNG PEOPLE IN THE BRAZILIAN SEMIARID REGION

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SALVADOR | APRIL DE 2020

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F981i

Fundo Internacional de Desenvolvimento Agrícola (FIDA).
Impacto de eventos climáticos extremos sobre a saúde e a educação de crianças, adolescentes e jovens no semiárido brasileiro – [Salvador] : Fundo Internacional de Desenvolvimento Agrícola (FIDA), 2020.
63 p. ; il. color.

Estudo coordenado pela equipe do Programa Semear Internacional (PSI) e desenvolvido por uma equipe técnica de pesquisadores da Universidade Federal da Bahia (UFBA). Contou também com a contribuição de especialistas do Unicef Salvador.
ISBN 978-92-9266-045-1

1. Saúde. 2. Educação. 3. Semiárido 4. Nordeste. I. Título.

CDU 308

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In addition, this study relied on the contribution of specialists from Unicef in Salvador in order to define the most relevant indicators and themes for studies on children, adolescents and young people.

As ilustrações que abrem os capítulos foram desenvolvidas pelo artista Gildemar Sena de Oliveira especialmente para esta publicação. Técnica: Nanquim sobre papel.

Table of contents

Map of IFAD in Brazil

Viva o Semiárido Project (PVSA)
- Benefited Families: 22,000
- Families Headed by Young People: 6,600
- Families Headed by Women: 9,500
- IFAD Funding: US$ 20 million
- Government Funding: US$ 10.1 million

Paulo Freire Project (PPF)
- Benefited Families: 60,000
- Families Headed by Young People: 16,052
- Families Headed by Women: 10,800
- IFAD Funding: US$ 40 million
- Government Funding: US$ 40 million

PROCASE Project (Sustainable Development of Cariri, Seridó and Curimataú)
- Benefited Families: 22,000
- Families Headed by Young People: 1,570
- Families Headed by Women: 10,800
- IFAD Funding: US$ 25 million
- Government Funding: US$ 15.5 million

Dom Távora Project (PDT)
- Benefited Families: 12,000
- Families Headed by Young People: 3,600
- Families Headed by Women: 4,800
- IFAD Funding: US$ 16 million
- Government Funding: US$ 12.2 million

Pró Semiárido Project (PSA)
- Benefited Families: 70,000
- Families Headed by Young People: 20,200
- Families Headed by Women: 40,500
- IFAD Funding: US$ 45 million
- Government Funding: US$ 50 million

Dom Hélder Câmara Project 2 (PDHC 2)
- Benefited Families: 74,000
- Families Headed by Young People: 39,000
- Families Headed by Women: 37,000
- IFAD Funding: US$ 18 million
- Government Funding: US$ 42 million

IFAD's performance in Brazil with Semear Internacional Program

The International Fund for Agricultural Development (IFAD) is a financial agency of the United Nations (UN) that, in partnership with state and federal governments, enters into loan and grant agreements to support rural development. In Brazil, IFAD's main investment focus is the semi-arid region, where it performs actions aimed at promoting productive projects to generate agricultural income, cooperatives, associations and access to markets. With promotion of nutritional food security and reduction of poverty in rural areas among its pillars, IFAD encourages the strengthening of activities whose priority audiences are women, young people and traditional communities.

IFAD has already provided an amount of approximately US$ 300 million for the implementation of 13 projects in Brazil. Six projects are in execution in 2020, with direct benefit to 250,000 families. Five of them are in partnership with state governments, through bilateral agreements: Paraíba (*Procase* Project – Sustainable Development of Cariri, Seridó and Curimataú), Bahia (*Pró-Semiárido* Project), Sergipe (*Dom Távora* Project), Piauí (*Viva o Semiárido* Project), and Ceará (*Paulo Freire* Project). In partnership with the federal government, the *Dom Hélder Câmara* Project (PDHC) covers 11 states: Pernambuco, Ceará, Rio Grande do Norte, Alagoas, Bahia, Piauí, Paraíba, Sergipe, Maranhão, Minas Gerais, and Espírito Santo.

In parallel with the projects, IFAD seeks to carry out actions that go beyond productive development in the communities served, encouraging access to information through donation programs, such as the *Semear Internacional* Programme (PSI), whose operationalization is supported by the Inter-American Institute for Cooperation on Agriculture (IICA). Operating in Brazil, PSI has the following axes: Knowledge Management; Monitoring & Evaluation; Communication; Policy Dialogues; and South-South and Triangular Cooperation. PSI works with the six projects supported by IFAD in Brazil, strengthening their capacities by carrying out activities that stimulate knowledge. The objective is to facilitate access to contextualized knowledge and innovations for coping with the semi-arid region.

Among the PSI's activities, there are exchange programs; training; workshops and seminars with technicians and project beneficiaries; technical training for public managers; institutional articulations; support for gender equality; support for the collection of socioeconomic data and methodization of results; book publications, and production of journalistic and communicational content in print and digital formats. In this way, the program has been making a significant contribution to the systematization and dissemination of good rural practices in IFAD's projects, both nationally and internationally.

Operation of each PSI's action component:

KNOWLEDGE MANAGEMENT

Training, exchange programs, thematic meetings and seminars are the main activities developed to strengthen knowledge and the knowledge exchange between projects, involving technician and beneficiaries. The most addressed themes are: access to markets, agroecology, gender, gastronomy, and goat farming. Many of these events result in publications that, in print and/or digital format, contribute to the enhancement and increased visibility of these good practices and successful experiences.

MONITORING & EVALUATION

Periodic training courses for technicians from these areas are carried out, with promotion of meetings in working groups and the involvement of professionals from other institutions. All IFAD's projects in Brazil use an integrated management system called *Data.Fida*, a great product developed by *Semear Internacional* for this component, which contributes to improving quality and accuracy of the information collected and processed by the projects.

COMMUNICATION

A component that permeates all others, *Semear Internacional*'s Communication uses several channels, such as the portal and social networks, to make knowledge and information reach the most different audiences. Publications (books, booklets, manuals and studies), a collection of videos and photos and the database of good practices already listed can be found on the website, as well as texts created weekly and disseminated among IFAD's projects A recent product in this area is the ***Prêmio Semear Internacional de Jornalismo***, award in its first edition that honors the best news reports in Brazil on good rural practices.

SOUTH-SOUTH AND TRIANGULAR COOPERATION AND POLICY DIALOGUES

The objective of South-South and Triangular Cooperation is to foster new knowledge and networks through the internationalization of its actions. Through exchange programs, training and seminars involving countries in Latin America and Africa, topics of common interest in family farming are addressed, identifying techniques and practices that can help rural workers in their daily lives. In addition, PSI seeks to facilitate the dialogue on public policies, with a view to supporting spaces aimed at the debate between civil society, governments, academia, and partners.

Learn more about PSI's actions; visit the virtual library and access the events held to join the network for the dissemination of good rural practices in the semi-arid region, accessing www.portalsemear.org.br.

Foreword

Water is a key element not only for survival, but also for the well-being of individuals. Thus, water availability and scarcity are decisive for communities to reach satisfactory levels of economic and social development.

Currently, the greatest threats to the achievement of these development goals are linked to rapid climate changes, driven by global warming. These changes are evidenced by the increase in the frequency of extreme events, which directly impact the availability and/or quality of water in a given region. This scenario, in itself potentially catastrophic, is compounded by the fact that water consumption has been on the rise for the last 20 years.

Addressing this issue, the United Nations (UN) included the availability of drinking water, its sustainable use and the access to sanitation in its 2030 Agenda for Sustainable Development, under the "Clean Water and Sanitation" indicator. This fact demonstrates the Organization's commitment to and understanding of the theme's relevance and impacts (direct and indirect) on health, education, work and income.

To this end, the International Fund for Agricultural Development (IFAD), through the *Semear Internacional* programme, partnered with the United Nations Children's Fund (Unicef) in order to develop a study on the impact of extreme weather events on the lives of children and adolescents in the semiarid region of the Brazilian Northeast. This study originated from a dialogue proposed by Helena Oliveira, coordinator of the Unicef office in Salvador, with the aim of strengthening the prospects of development focused on childhood and adolescence in the aforementioned region.

This articulation was made possible by the intersection between the most relevant themes for the two agencies in Brazil: the semiarid, childhood and youth, approached from the perspective of improving people's capacities.

During the study's conceptualization, Unicef Salvador – which is recognized for carrying out relevant work in this area, aimed at improving the living conditions of children and adolescents in the Northeastern semiarid – introduced the Federal University of Bahia (UFBA) team, which became responsible (through a specifically designated research group) for the preparation of the study and for the development of its entire research and analysis work. Moreover, Unicef Salvador also tasked specialist Francisca Maria Andrade with providing technical contributions to the UFBA teams and to the *Semear Internacional* programme.

Methodologically, the study was made possible by the construction of three municipal-level databases for the Northeast region: climatic (rainfall and monthly temperature; emergency and public disaster situations); health (Unified Health System Informatics Department – Datasus); and education (National Institute for Educational Studies and Research "Anísio Teixeira" – Inep). Descriptive and econometric analyzes were carried out in order to measure the potential impacts of extreme weather events on the selected populations.

Results confirm that climatic shocks and the absence of rainfall are associated with worse health and education indicators. Their negative effects are stronger in the semiarid region. The evidence supports the existence of connections between infant mortality increase and the availability and quality of water, for example. Another expressive effect concerns the impact of drought periods on school progress, corroborating that the lack of adequate hydration also has an impact on the cognitive development of children and adolescents in the Brazilian Semiarid Region, contributing to its historical and chronic problem of human underdevelopment.

Good reading!

1.Introduction

Droughts correspond to more than 5% of worldwide natural disasters, affecting 1.1 billion people, causing more than 22,000 deaths, and leading to material losses to the tune of US$ 100 billion (over a 20-year period) (CRED/UNISDR, 2015). Climate change – manifested mainly by the increase in the frequency of extreme events – may lead to an intensification of this scenario over the coming years, impacting the availability and quality of water. Another aggravating factor is the fact that water consumption has increased six times in the last six years and continues to increase by 1% per year. According to the Organization for Economic Cooperation and Development (OECD, 2012), water consumption in the world is expected to grow by around 55% between 2000 and 2050.

Considering that water is a fundamental asset for the well-being of individuals – especially children –, directly impacting health, education, work and income, the UN has included "Clean Water and Sanitation" as one of its 17 Sustainable Development Goals for 2030. In this sense, access to water is not the sole concern: adequate water quality, hygiene and management practices are also paramount, as the scarcity of this resource directly impacts food production. Moreover, poor water quality and inadequate water management are the greatest causes for the spreading of diseases such as diarrhea, dengue and other vector-borne diseases (Unesco, 2020).

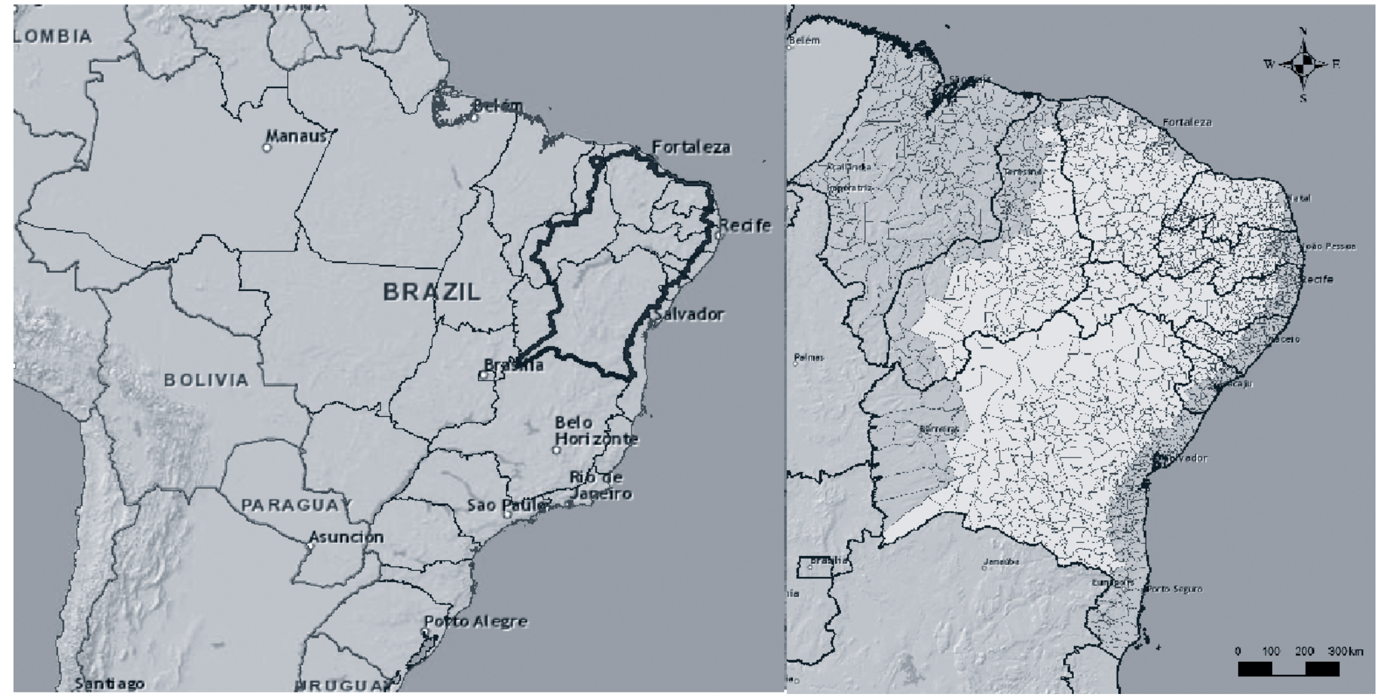
The Lancet (2018), one of the most reputable health journals in the world, warned that climate change is the biggest threat to health in the 21st century. The report also emphasizes three main areas affected by such change when it comes to health-related policies: (i) impacts of heat waves on health and work productivity; (ii) climate-sensitive infectious diseases; (iii) deforestation and land use management. Building health policies that mitigate the climate-change phenomena permeating these areas is essential if we are to adapt to a world that is already changing.

The impacts of climate change on public health are enormous. In the case of middle- and low-income countries, the situation is even worse. According to Cissé (2019) and Ashrafuzzaman & Furini (2019), poor regions or developing countries will be the first to feel the consequences of global warming. The former study estimates that food- and drinking water-related issues will be accentuated by climate change factors, especially the rise in average temperature, making poor populations even more vulnerable. In the latter study, the authors advise that the best strategy for mitigating the effects of climate change is an effective public health infrastructure system, able to aid in adaptive measures and in the development of sustainable disease prevention and control programs.

In Brazil, one of the main concerns emerging from climate change is the Brazilian Northeast, and especially its Semiarid Region, comprising 1,262 municipalities distributed among the area's nine federative states. Approximately 22 million people inhabit the Semiarid, which accounts for 12% of the total Brazilian population and 37% of the Brazilian Northeast population. The region corresponds to approximately 855,450 km², an area that is almost equivalent to France's entire territory. The semiarid region is characterized by high levels of poverty and by low social indicators. Approximately half of the Brazilian population below the poverty line lives in this region, where around 8 million people are beneficiaries of the Brazilian government's income transfer program, the Bolsa Família (ASA Brasil, 2017).

According to Da Mata & Resende (2020), in 2005 the Brazilian semiarid region was redefined according to new criteria. From then on, a municipality could be considered part of the region by meeting at least one of the following criteria: (i) annual rainfall below 800 millimeters (the only criterion used in the previous definition, meaning that no municipalities had to be excluded); (ii) Thornthwaite Moisture Index between 0.21 and 0.50; and (iii) water shortages more than 60% of the time. The new criteria were established in order to include regions with higher levels of rainfall that were arid nonetheless. Figure 1 shows the delimitation of the Brazilian semiarid region.

FIGURE 1: MAP OF THE BRAZILIAN NORTHEAST SEMIARID REGION



Source: Authors' elaboration.

For academics and policymakers, the greatest concern in regards to this region is its persistent climate vulnerability – especially to extreme climate shocks. In this sense, drought is the utmost preoccupation. Water shortages have direct effects on agricultural production, impacting household income through reductions in families' agricultural production and job opportunities (Branco and Feres, 2018; Oliveira, Palialol and Pereda, 2019). However, the lack of access to drinking water can impact other dimensions of life in the semiarid, such as population health – especially when it comes to children (Rocha and Soares, 2015) –, educational indicators (Shah and Steinberg, 2013), and civil conflicts (Hidalgo *et al*., 2010). In Chart 1 and Figure 2, respectively, we present the potential impacts of drought and a logical model of how it may affect children, adolescents and young people.

Promoting access to water is still a major challenge in Brazil's Northeastern Semiarid. Over the years, several water-access policies have been implemented. The most recent ones were the transposition of the São Francisco River and the One Million Cisterns Program (*Programa um Milhão de Cisternas*). Moreover, several institutions such as the Superintendency for the Development of the Northeast (Sudene) and the Banco do Nordeste have devoted considerable attention to this problem. Nevertheless, empirical results containing evidence of these programs' socioeconomic impacts are scarce.

CHART 1: POTENTIAL IMPACTS OF DROUGHT

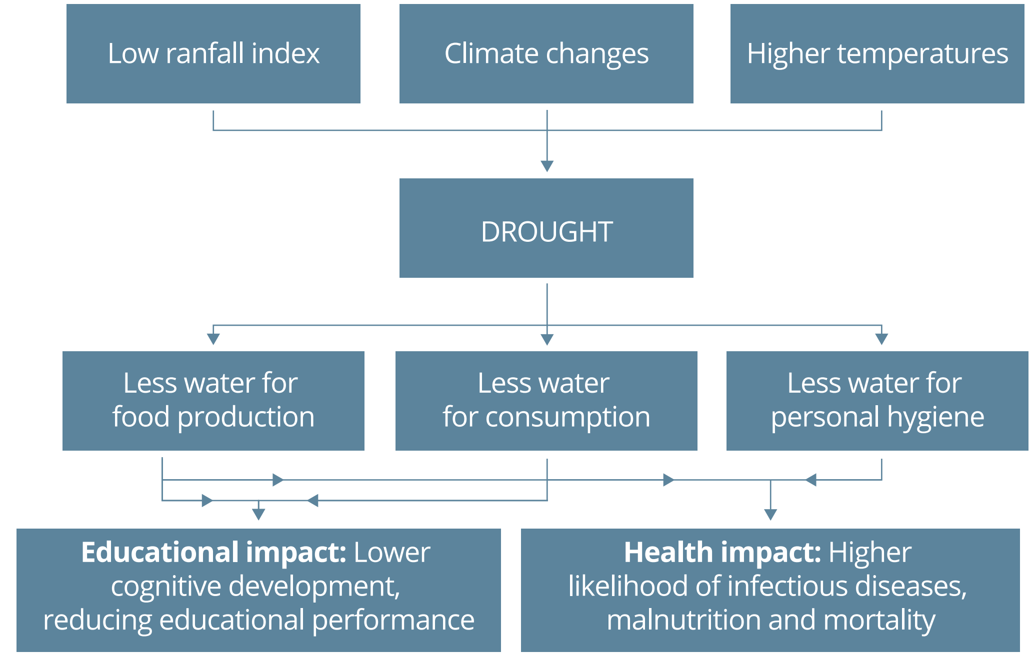
Potential impacts on water availability	Potential impacts on health and other outcomes
• Less water available for cleaning, cooking and hygiene, increasing exposure to water contamination. • Increased concentration of pollutants under drier conditions. • Reduced groundwater levels and surface water flows can cause wells to dry out, increasing the distances people have to cover in order to collect water (which may even be unhealthy/ unfit for consumption); may also result in the pollution of water sources. • Decreased food security due to low food production in the tropics; and less access to food due to reduced supply and higher prices.	• Increased burden/quantity of diseases transmitted by food and water. • Fluoride: dental and bone/skeletal fluorosis. • Arsenic: skin alterations (changes in pigmentation, hyperkeratosis), cancer (of the skin, bladder, lung) etc. • Iron and manganese: change in water color, unpleasant taste. • Increased risk of health impacts associated with malnutrition, which results from the interaction between higher rates of infectious diseases and decreased production and consumption of food in poor regions. • Combined effects of malnutrition and infectious diseases; chronic effects of underweightness and underweightness-by-height in children.

Source: Adapted from Unesco (2020).

This study analyzes the impact of extreme weather events on children, adolescents and young people. To this end, we built a database with monthly rainfall and temperature information for each municipality in the Northeast region. This made it possible for drought indicators to be developed. The *Reconhecimentos Federais de Situação de Emergência e Estado de Calamidade Pública*[1] (Federal Recognition of Emergency Situations and Public Disaster Declaration) database was also used as a data point to characterize drought situations. Health indicators were constructed on the basis of public data records made available by the Ministry of Health (via Datasus). Educational indicators, meanwhile, relied on public data provided by the Ministry of Education (via Inep).

[1] Source: https://s2id.mi.gov.br/paginas/series/

FIGURE 2: LOGICAL MODEL OF DROUGHT IMPACT



Source: Authors' elaboration.

1.1. WATER SCARCITY IN THE WORLD AND IN BRAZIL'S NORTHEAST REGION

According to Cunha *et al*., drought is a complex natural phenomenon corresponding to reduced water availability, with substantial effects on agriculture and basic socio-economic activities developed in the affected locations (2015). For these authors, drought can be defined as a period in which rainfall falls below the annual average, leading to water shortages.

Generally, droughts are classified as: (i) meteorological drought, in which there is scant precipitation over a region during a certain period of time; (ii) hydrological drought, when hydric resources become scarce either on the surface or underground; (iii) agricultural drought, a period of declining soil moisture and crop failure caused by insufficient water resources; or (iv) socioeconomic drought, when water supply does not meet current demands, directly or indirectly impacting human activities (Udmale, 2014).

Water availability-related issues can be analyzed through various metrics, with changes in rainfall and temperature levels being one of the most important. Schewe *et al*. (2014) has developed a hydrological model to demonstrate that climate change has a direct impact over water availability. The study's findings are shown in Figure 3, in which the regions that will suffer most from climate change appear in blue. In the case of Brazil, this color gradient is concentrated on the Northeast region.

FIGURE 3: TEMPERATURE VARIATIONS CAUSED BY CLIMATE CHANGE

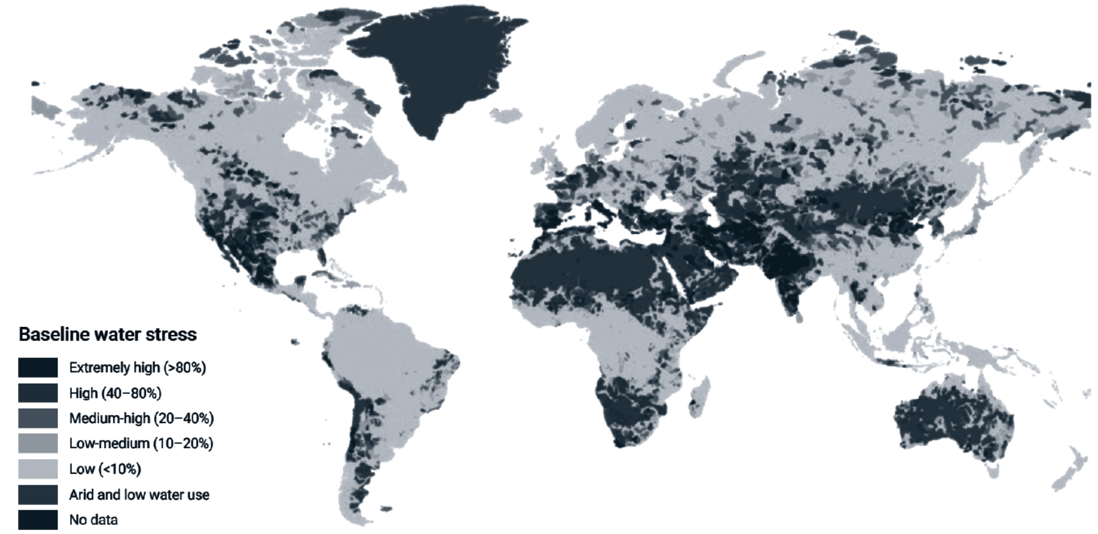
Source: Schewe *et al*. (2014).

A widely used indicator is water stress, that is, the difference between water demand and the available amount, as shown in Figure 4 (WRI, 2019). Darker colors also appear predominantly in the Northeast, indicating that this region has the greatest water stress problems.

Annually, the UN releases the *World Water Development Report* (WWDR), a document addressing water access and climate change globally. The material allows researchers to compare Brazilian indicators with those of other countries. Finally, in Figure 5, it is noteworthy that, considering its Palmer Drought Severity Index, the Northeast region is among the worst affected by this type of climatic event in Brazil (Unesco, 2020).

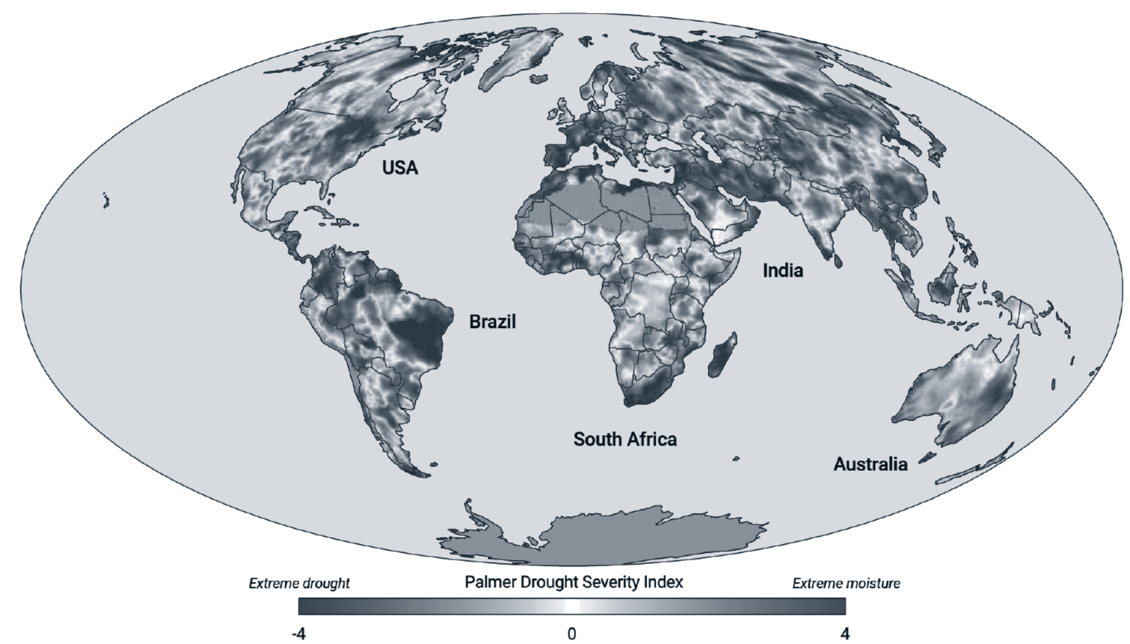
Drought monitoring policies are essential to mitigate its impacts on human health. Droughts tend to give rise to potentially prolonged arid conditions, affecting the regular parameters under which government interventions in semiarid regions take place. Severe drought conditions jeopardize the administrative and institutional management of these programs, considering the danger of empty reservoirs and its consequences for food production, survival, and the functioning of local institutions (Awange *et al*., 2016).

FIGURE 4: WATER STRESS (DEMAND – SUPPLY)



Source: WRI (2019).

FIGURE 5: PALMER DROUGHT SEVERITY INDEX



Source: UNESCO (2020).

2. Literature review

This section reviews some studies carried out in Brazil and other countries that attempt to measure, through econometric instruments, the impacts of adverse climatic events, particularly drought, on the health and education of children, adolescents and young people. Besides presenting evidence corroborating this research, the analyzes developed in these works will serve as a point of reference for the empirical strategy that will be adopted in this data analysis phase of the study.

According to Krol and Bronstert (2007), water scarcity in semiarid regions increases societal vulnerability, considering its effects in terms of restricting both the use of natural resources and the population's access to basic goods and services, such as food and sanitation. Issues such as food insecurity, access to water and sanitation, health care for the most vulnerable populations, among others, continue to be a major challenge to be overcome by families in the Northeastern Semiarid region, despite the expansion of income transfer programs starting in the 2000s. Furthermore, rural populations in semiarid areas are more sensitive to climate variations, leading to lower productivity (Lemos *et al.*, 2016).

Rocha and Soares (2015) evaluated water scarcity as a possible health determinant among young individuals in the Brazilian semiarid between 1996 and 2010. The authors observed that idiosyncratic adverse rainfall events during pregnancy imply higher infant mortality, especially due to infectious diseases and malnutrition, lower birth weight and an increase in the number of children born prematurely. They argue that these effects are caused by lower agricultural production and difficulties in accessing drinking water. Combined, these two factors result in decreased ingredient intake and a higher incidence of infectious diseases. In a supplementary analysis, the authors also show that locations with greater drinking water availability – provided by tanker trucks, for example – and better coverage of sanitary infrastructure are able to minimize climatic impacts.

Maccini and Yang (2009) analyzed the effects of rainfall shocks early in life on men and women born between 1953 and 1974 in Indonesia. The authors found that climatic shocks had a discernible impact on indicators that characterize these individuals' adult life. More specifically, women who have been exposed to positive climate shocks are less likely to report poor health, besides having greater height, more years of schooling and more accumulated assets. For men, no statistically significant results were found.

Deschênes and Greenstone (2011) studied the impact of climate change on mortality in the USA and found that extremely hot or cold days are associated with increased mortality. Unlike other works, the authors focused on temperature, not rainfall. They conclude that, throughout the 21st century, climate change will account for about 3% of the increase in mortality in the USA.

Carrilho (2017) contributes to the literature regarding the impact of climate shocks on well-being by investigating, based on exact date-of-birth information, how exposure to adverse rainfall-volume conditions during the gestational period impacts individuals' long-term socioeconomic outcomes. The author's data set involved cohorts born throughout a period of 40 years (from 1942 to 1981) in Colombian municipalities. Colombia is regarded as one of the places with the highest incidence of extreme weather events. The study's empirical strategy starts from a combination of monthly, municipal-level meteorological data sets – together with microdata concerning date and place of birth – in order to identify the rainfall conditions prevalent during pregnancy. On this basis, the author compares the later-life outcomes of individuals who were exposed to extreme droughts or floods during pregnancy with the later-life outcomes of individuals who experienced less severe climatic conditions during gestation.

The main results indicate that exposure to adverse shocks in rainfall volume during pregnancy leads to worse indicators of well-being in adulthood. For example, a one-point standard deviation increase in floods during pregnancy is associated with a 3.2% increase in the likelihood of developing serious mental illness, a 0.21% decline in school years, a 1.7% increase in illiteracy rates, and a 0.36% reduction in the probability of working. Prenatal droughts incur similar effects, but to a lesser extent. All results have a greater magnitude among men in comparison to women, when considering educational and health indicators. When exposure measures are considered separately for each trimester, it becomes clear that the long-term effects on educational and health outcomes occur due to exposure during the first trimester of pregnancy (Carrilho, 2017).

Andalón *et al*. (2016) conducted a similar study in Colombia, investigating how fetal exposure to climate shocks affected health indicators. The research evaluated temperature shocks and their impact on health outcomes shortly after birth (weight and length at birth). Using records from nearly 1.5 million births in rural municipalities in Colombia from 1999 to 2008 and a fixed effects model, the authors found that temperature shocks had negative effects on health outcomes at birth. Main results indicate that the moment of temperature-shock exposure is decisive: exposure to high temperature shocks during the third trimester of pregnancy reduces the child's birth weight by about 4.1 g, while exposure to low temperature shocks during the first and second trimester of pregnancy reduces length at birth by 0.014–0.018 cm.

Shah & Steinberg (2013) analyzed the impacts of rainfall shocks on educational indicators, both early in life and in the long-term, as well as job market indicators. According to the authors, in India, 66% of men and 82% of women rely on agricultural activities, meaning that they are severely exposed to climate change. The study shows that during droughts children have higher grades in mathematics and greater school participation. In rainy periods, however, they have lower grades in mathematics and reading, besides higher evasion. The authors' explanation is that rainy periods lead to an increase in agricultural production, prompting families to use child labor in the harvest. Meanwhile, drought periods lead to food shortages, and children have to go to school in order to benefit from the free meals offered by most units.

When shock occurs early in life, however, the effect on children is quite heterogeneous. Negative shocks during pregnancy, for instance, lead to worse educational indicators, and this result remains valid for shocks occurring up to 4 years of age. Positive shocks occurring from the gestational period to 2 years of age, meanwhile, imply better grades and greater school participation. This is consistent with the literature that relates higher nutrient consumption in childhood with cognitive development. When analyzing adult life, however, Shah and Steinberg (2013) found that rainfall shocks reduced people's likelihood of studying, increased women's probability of working, and reduced that same probability for men, while leading to increased wages.

Björkman-Nyqvist (2013) studied the effect of rainfall shocks on the academic performance of boys and girls in Uganda. The author found that negative shocks impact girls' participation in school and that these impacts are worse for older girls. Moreover, negative shocks reduced girls' academic achievement. There were no statistically significant effects for boys. The author points out that these effects are explained by the use of older girls as labor to supplement family income.

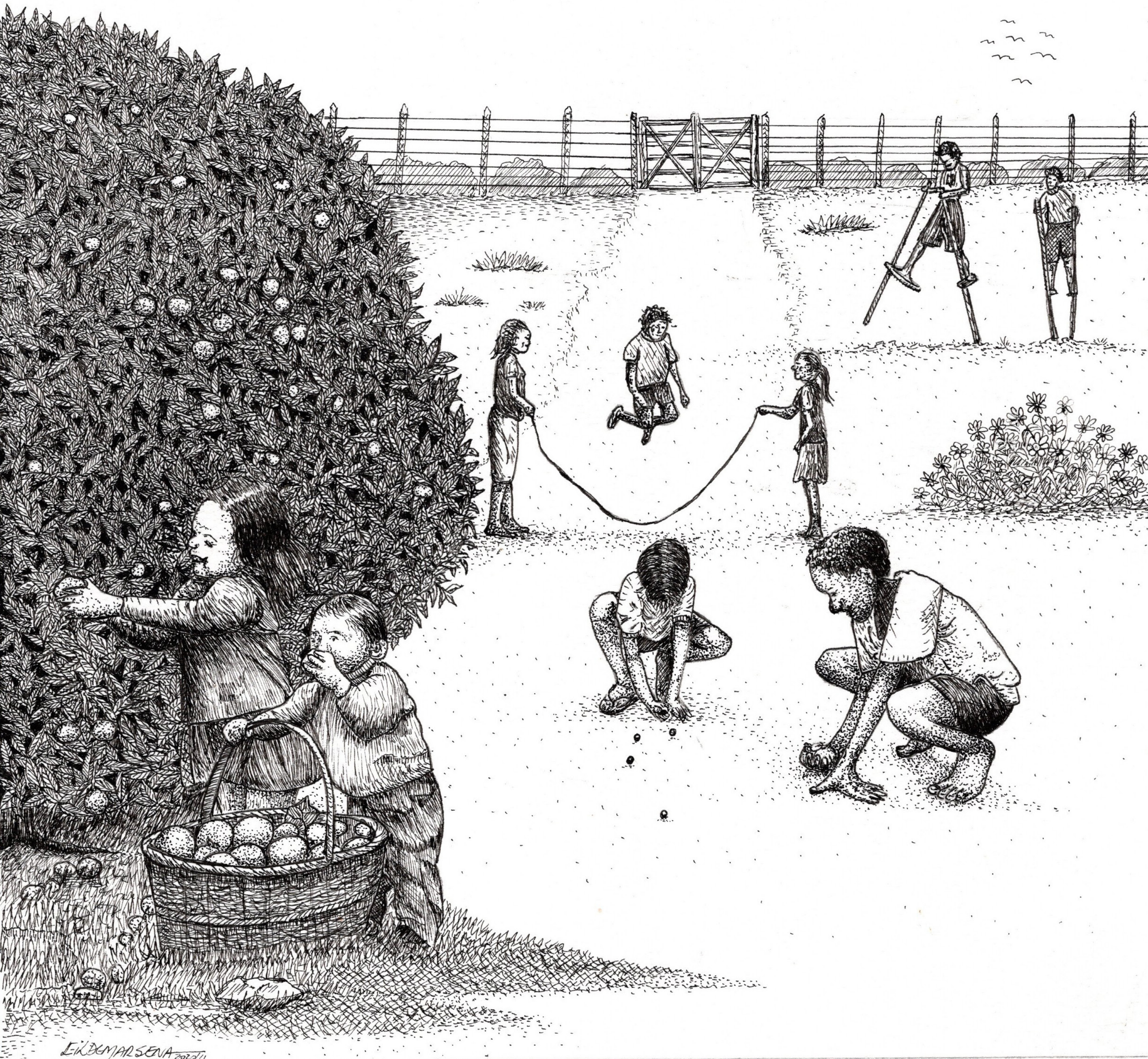
Kim (2008) analyzes the impact of extreme weather events on educational achievement. To this end, the author used information regarding schooling per age group in a cross-sectional data set involving developing countries, estimating the impact of historical climate shocks that may have affected people when they were school-age children, using the difference-in-difference method. The study's results suggest that extreme weather events have a negative long-term impact on educational performance. In Cameroon, for instance, the drought reduced the chances of women completing primary school by 8.7 percentage points. In Mongolia, a forest fire reduced the likelihood that individuals would finish high school by 14.4 percentage points.

Amaya (2020) contributes to the literature on the relationship between climate change and human capital by investigating the impact of the strong climate shocks that affected Colombia from 2010 to 2011 on the results of the *Pruebas Saber 11* examination, carried out from 2010 to 2012. *Pruebas Saber 11* is a national standardized test that assesses students at the end of high school, and is used as doorway to higher education. Main results point to a negative relationship between climatic shock and student grades. This relationship is stronger in magnitude and significance for language, philosophy and mathematics than for the disciplines of biology, physics, social sciences, chemistry and English. In addition, shocks had a stronger impact on male students living in urban areas.

However, this impact was less severe for students who lived in a municipality that had suffered above-average shocks during the previous years. Amaya (2020) hypothesizes that this finding is associated with possible mechanisms of adaptation and coping developed in response to a climatic shock. Another relevant finding was that the impact of these shocks was not limited to the grades of the most economically vulnerable students, also extending to the grades of middle- and upper-class students.

Thai and Falaris (2011) analyzed the effects of rainfall shocks on the health and education of children in rural Vietnam. Considering that the majority of Vietnamese rural families are involved in agricultural production and depend on rainfall, insufficient annual rainfall leads to income shocks that can have negative consequences for children's health and intellectual development. The authors examine the impact of rainfall shocks (lower than average annual rainfall) early in life through a variable measuring school delay and school progress. Health is measured through height by age.

Results mainly indicate that rainfall shocks during pregnancy led to greater delay in entering school, besides lower school performance. Similar rainfall shocks in the third year of life also negatively affected these two variables, in addition to the child's height in relation to age. Furthermore, these effects are greatest in regions where families find it more difficult to transition to a lower standard of consumption in the face of adverse income shocks.



3.Methodology

In this study, we measured the impact of extreme weather events (droughts) on health and education indicators of children, adolescents and young people. To estimate the relationships between these variables, we relied on econometric instruments. However, before explaining the empirical model adopted here, a detailed description of the relevant variables is in order.

3.1.DATA

3.1.1. Health

The databases employed here were municipal-level databases. Health indicators, meanwhile, were obtained from the Unified Health System (SIHSUS) Hospital Information System, from the Mortality Information System (SIM), and from the Live Birth Information System (Sinasc). All of these databases are public, made available by Datasus on a monthly basis and collected through the *Tabwin/Tabnet* software, from the Ministry of Health.

The SIHSUS is managed by the Ministry of Health's Health Assistance Department, in conjunction with the state and municipal health departments. In this system, information on the hospitalization of patients in public health units affiliated to the Unified Health System (SUS) is obtained by means of Hospitalization Authorizations (AIH), which gather variables related to personal identification, medical procedures, diagnostic exams etc. For the present study, variables such as the following were tabulated: hospitalizations due to infectious diseases (chapter I, codes A00-B99 of the International Classification of Diseases – ICD-10); hospitalizations due to respiratory diseases (chapter X, ICD-10 codes J00-J99); hospitalizations due to endocrine, nutritional and metabolic diseases (chapter IV, ICD-10 codes E00-E90); hospitalizations due to malnutrition, vitamin A deficiency, other vitamin deficiencies, sequelae of malnutrition and other nutritional deficiencies (chapter IV, ICD-10 codes E40-E64); hospitalizations due to circulatory-system diseases (chapter IX, ICD-10 codes I00-I99); hospitalizations due to digestive-system diseases (chapter XI, ICD-10 codes K00-K93); hospitalizations due to genitourinary-system diseases (chapter XIV, ICD-10 codes N00-N99); hospitalizations due to injuries, poisonings and other external causes (chapter XIX, ICD-10 codes S00-T98); and hospitalizations due to external causes of morbidity and mortality (Chapter XX, ICD-10 codes V01-Y98).

The SIM database is managed by the Department of Health Situation Analysis, associated with the Health Surveillance Department of the Ministry of Health, in partnership with the state and municipal health departments. Through Death Certificates (DO), departments have access to information such as age, place of residence, sex, cause of death, etc. In Brazil, causes of death have been classified according to the ICD-10 since 1996. Statistics regarding infant deaths and fetal deaths are also available from the SIM.

The Sinasc database is also managed by the Department of Health Situation Analysis. Information on live births is collected by specific departments through Declarations of Live Births (DN), which contain essential data such as the mother's place of residence, duration of pregnancy, type of delivery, birth weight, sex, among others.

Birth-related health indicators have always been computed in terms of rates, as indicated in Equation 1:

$$i\ rate = \frac{Variable\ i\ total\ in\ municipality\ j}{Live\ births\ in\ municipality\ j} * 1.000 \quad (1)$$

In which *i* may be:

- infant mortality (0 to 1 years);
- fetal mortality;
- maternal mortality;
- low weight; or
- prematurity.

For variables unrelated to birth, the denominator was the size of the population within the same age bracket (Equation 2):

$$i\ rate = \frac{Variable\ i\ total\ in\ municipality\ j}{Population\ in\ municipality\ j} * 1.000 \quad (2)$$

Municipal information on the nutritional status of children under 5 years of age was obtained from public reports released by the Food and Nutrition Surveillance System (Sisvan Web) (Brazil, 2018), a Datasus health information system which consolidates and generates reports containing food and nutrition data on SUS users, including beneficiaries of the Bolsa Família Program (as part of the program's health requirements). Guidelines and procedures for collecting and analyzing anthropometric data in health services have been standardized by the Sisvan (Brasil, 2011).

In order to assess the nutritional status of children under 5 years old, the Sisvan Web platform contains information on the following anthropometric indices: height by age (H/A), weight by age (W/A), weight by height (W/H), and body mass index (BMI) by age (BMI/A). The child growth curves and cutoff points proposed by the World Health Organization (WHO) serve as a reference for the classification of children's nutritional status (WHO, 2006). The most recent record concerning each individual in each year is the basis for consolidating public reports and calculating the municipal prevalence of nutritional indicators (Brasil, 2017). A similar strategy was used by Uzeda *et al*. (2019) to analyze individual data in the National School Health Survey. Therefore, using the Sisvan, we calculated prevalence rates for chronic and acute malnutrition as indicated in Equation 3:

$$Prevalence\ of\ D = \frac{Total\ cases\ of\ i\ in\ municipality\ j}{Total\ children\ in\ the\ same\ age\ bracket\ in\ municipality\ j} \quad (3)$$

3.1.2. Education

The impacts of drought on educational performance were measured by means of standardized tests applied to students undergoing different stages of education. The identification of the effects of drought on elementary school students and on students who were undertaking or had undertaken high school relied on the *Prova Brasil* and National High School Exam (Enem) databases, respectively. In addition to each student's performance in the evaluated areas of knowledge, both databases have information on individual socioeconomic characteristics. This allowed us to employ these characteristics as explanatory control variables for the estimates, obtaining a more accurate parameter of the effects of drought on educational performance.

For elementary school students, the effects of drought on the performance of 5th-year students were evaluated through the *Prova Brasil* Portuguese and mathematics tests, held once every two years. It was also possible to identify information about gender, age, race, and child labor, as well as school location (urban or rural) and administrative attribution (municipal, state, federal or private). The 2011, 2013, 2015 and 2017 *Prova Brasil* editions were used to build the database.

The Enem database provided information on the performance of approximately 22 million candidates who took the exam in Northeast Brazil between 2010 and 2018. Exam results were divided into: languages, mathematics, human sciences, natural sciences, and writing. On this basis, it was also possible to include socioeconomic variables as controls for the estimates, such as: level of income, gender, race, age, and parents' education. The Enem and the *Prova Brasil* databases allowed for the identification of the municipality and the year in which individuals participated in the exams, enabling the use of fixed effects in the estimates.

3.1.3. Climate

A historical series of precipitation and temperature was constructed using data from the Terrestrial Air Temperature and Terrestrial Precipitation Gridded Monthly Time Series (Matsuura and Willmott, 2009). This database has monthly information on these two variables, with a 0.5° × 0.5° (0.5° corresponds to approximately 56 km) resolution. Procedures mirrored those adopted by Rocha and Soares (2015).

From the monthly data of each municipality, the following variables were established:

- average annual rainfall;
- historical average rainfall volume (1950–2017);
- standard deviation of the historical average rainfall volume;
- annual average temperature.

These variables served as the basis for this study's two main indicators of climate impacts. The first indicator points out whether, in year *t*, the average volume of rain was lower than the historical average annual volume (Equation 4):

$$\textit{Insufficient rain}_{jt} = \begin{cases} 1, \textit{ if rain}_{jt} < (\textit{rainfall average}_j - \textit{rainfall standard deviation}_j) \\ 0, \textit{ if not} \end{cases} \quad (4)$$

The second indicator – crucial for our analysis – relates to the occurrence of droughts in each month *t* for each municipality *j*. The construction of this variable follows the same approach adopted by Rocha and Soares (2015):

$$\textit{Drought}_{jt} = \begin{cases} 1, \textit{ if rain}_{jt} < (\textit{rain hist. avg.}_j - \textit{hist. rain standard deviation}_j) \\ 0, \textit{ if not} \end{cases} \quad (5)$$

In Equation 5, *j* is a subscript for each municipality, and *t* is the month in which the rainfall indicator was computed. The average rainfall is calculated on the basis of the municipality's average rainfall between 1950 and 2017, and the standard deviation refers to the same period. Besides these variables, we also computed the total number of drought months in the municipality *j* during year *n* in order to account for annual databases (Equation 6).

$$\textit{Total number of drought months}_{jn} = \sum_{t=1}^{12} \textit{Drought}_{jt} \quad (6)$$

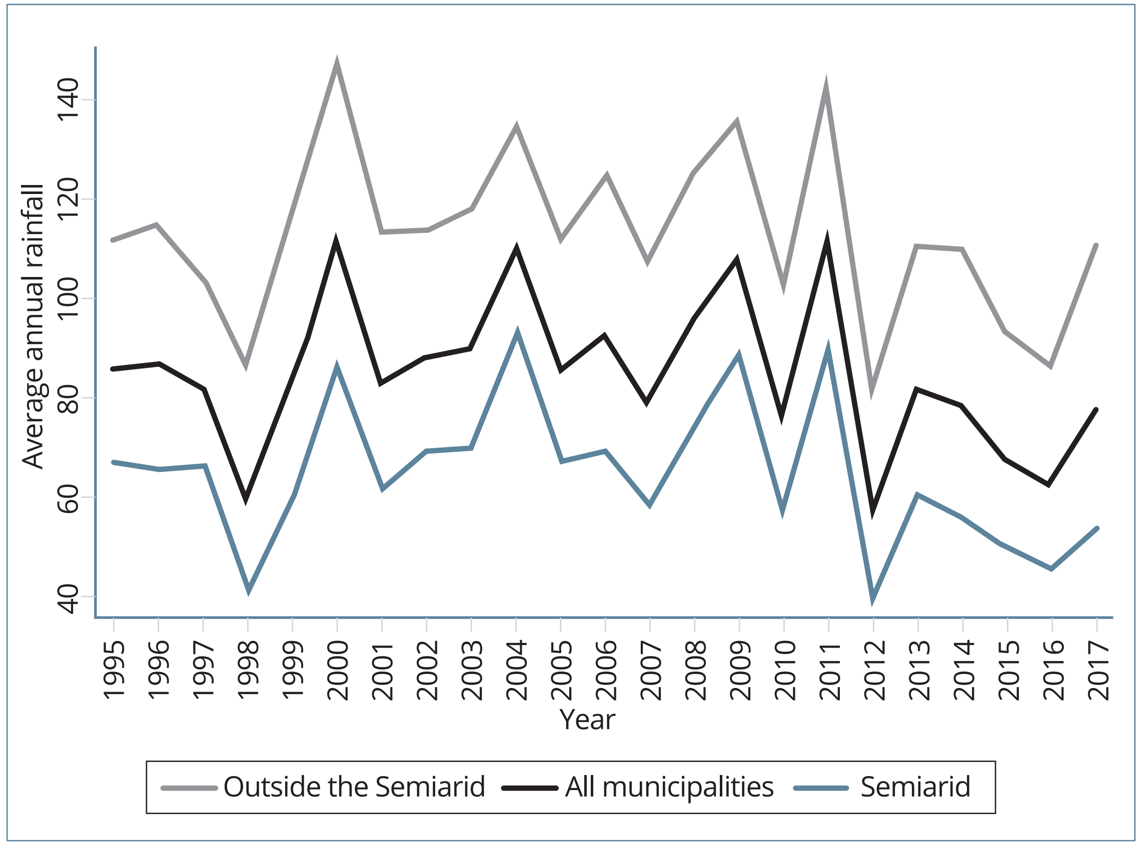
Moreover, in order to identify which municipalities suffered the most from strong reductions in rainfall and to establish a different measure of drought events, information was collected on the municipalities that declared a state of public disaster due to drought or dry spell. These data are available from the Integrated Disaster Information System (S2ID), which belongs to the National Secretariat for Civil Defense and Protection (Sedec).

3.2 INITIAL EVIDENCE

In this subsection we present precipitation and temperature data over time and across regions, as well as health and education data. These initial pieces of evidence make it possible to verify patterns in the variables, which were analyzed in terms of time and space. They are fundamental to understand the results of the econometric model.

In Figure 6, we present the average annual rainfall between the years 1995 and 2017. There is an evident pattern of greater rainfall in municipalities outside the semiarid region. Furthermore, the average rainfall in the semiarid region is less than the average rainfall for all municipalities in the region. The second important piece of evidence is that during this period there were two years of especially severe drought – in 1998 and 2012.

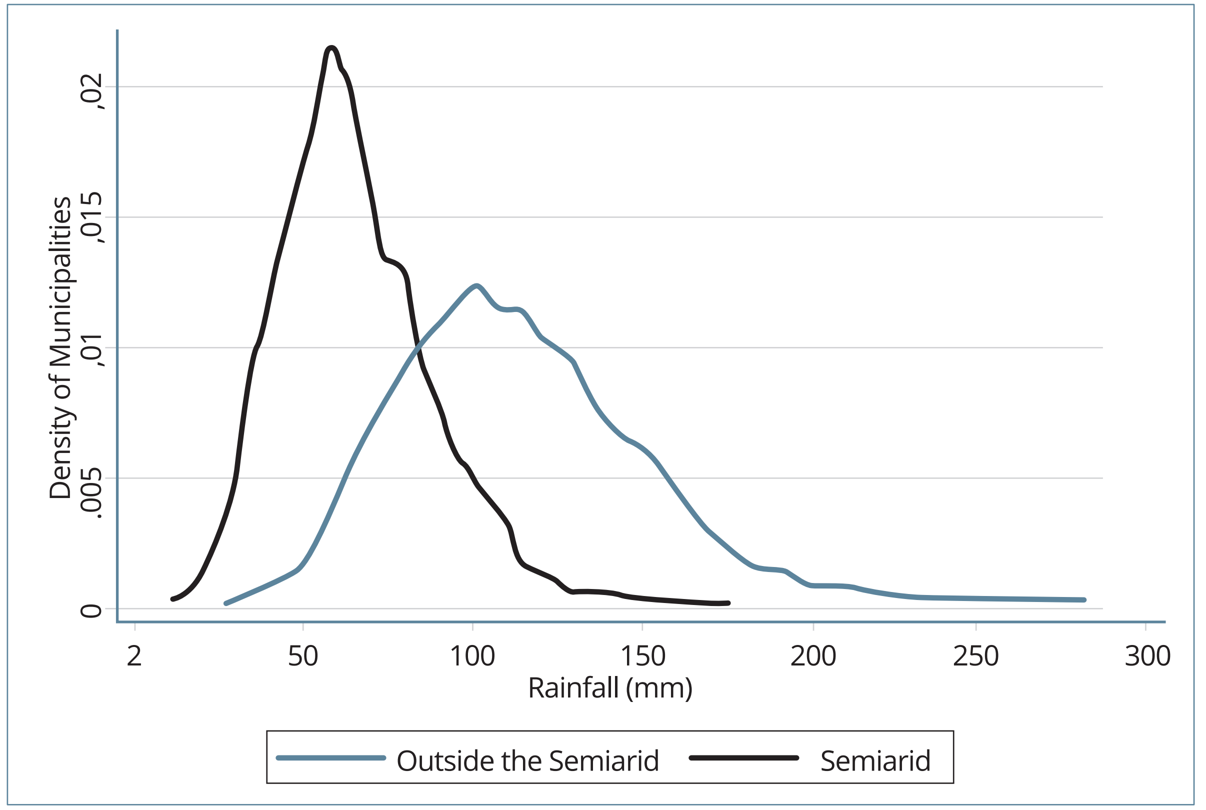
FIGURE 6: **PRECIPITATION OVER TIME IN THE NORTHEAST**



Source: Authors' elaboration.

Figure 7 presents density plots of municipalities according to rainfall index. The vertical axis corresponds to the number of municipalities, while the horizontal axis corresponds to rainfall. It is worth noting that in the semiarid region the dispersion of municipalities by degree of precipitation is much lower than for municipalities outside the semiarid. Furthermore, municipalities in the semiarid region are concentrated in a rainfall range of around 50 millimeters of rain per month, while in municipalities outside the semiarid region this concentration is around the 100-millimeter range.

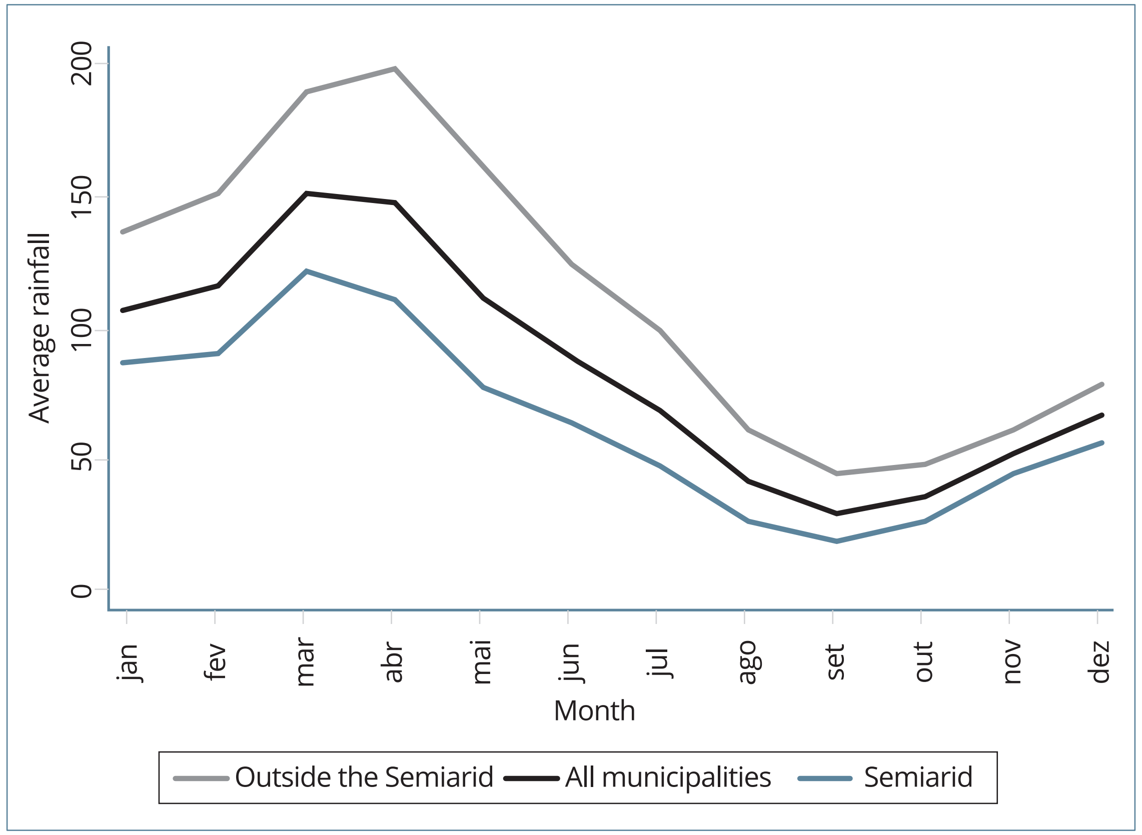
FIGURA 7: **DISTRIBUIÇÃO DE MUNICÍPIOS POR NÍVEL DE PLUVIOSIDADE**



Source: Authors' elaboration.

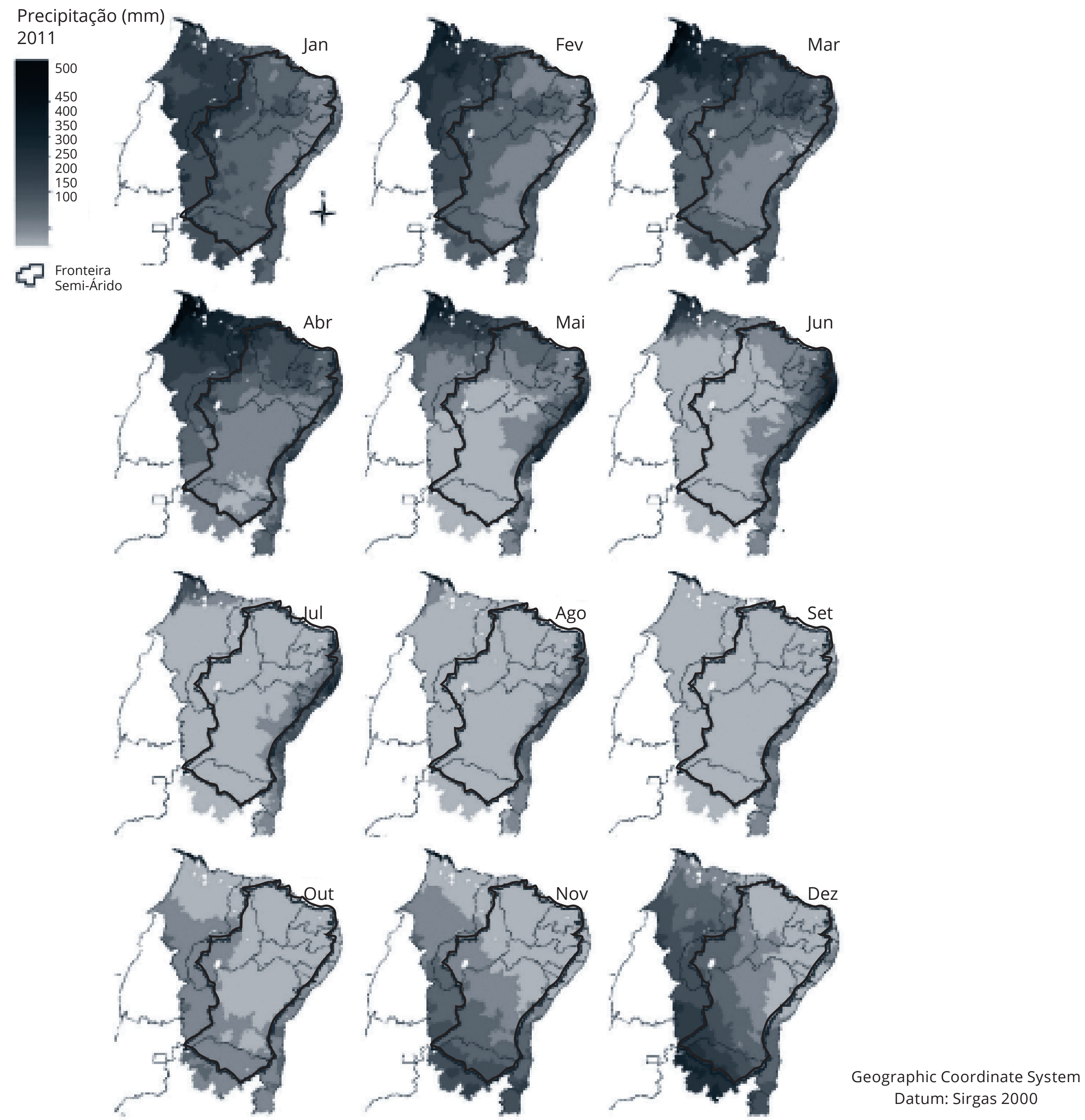
Figure 8 presents the behavior of the rainfall indicator throughout the months. Generally speaking, the second half of the year is characterized by lower rainfall. This result is corroborated by Figures 9 and 10, which presents monthly maps of the region for the year 2000. These figures show that in the second half of the year there is a more pronounced period of reduced rainfall, with temperatures rising higher.

FIGURE 8: **AVERAGE RAINFALL PER MONTH (1995–2017)**



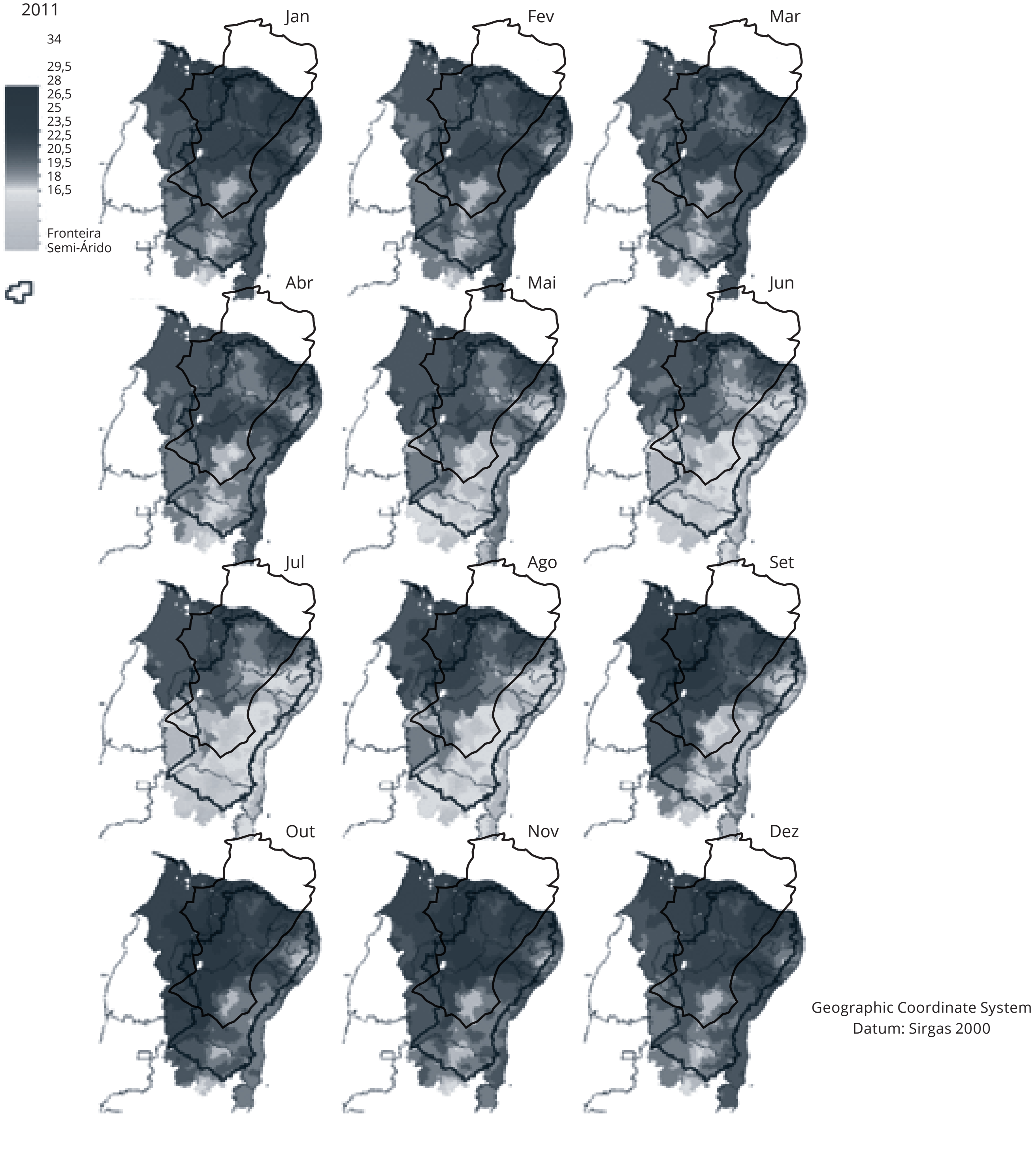
Source: Authors' elaboration.

FIGURE 9: **NORTHEAST REGION RAINFALL INDEX BY MONTH (YEAR 2000)**



Source: Da Mata *et al*. (2019).

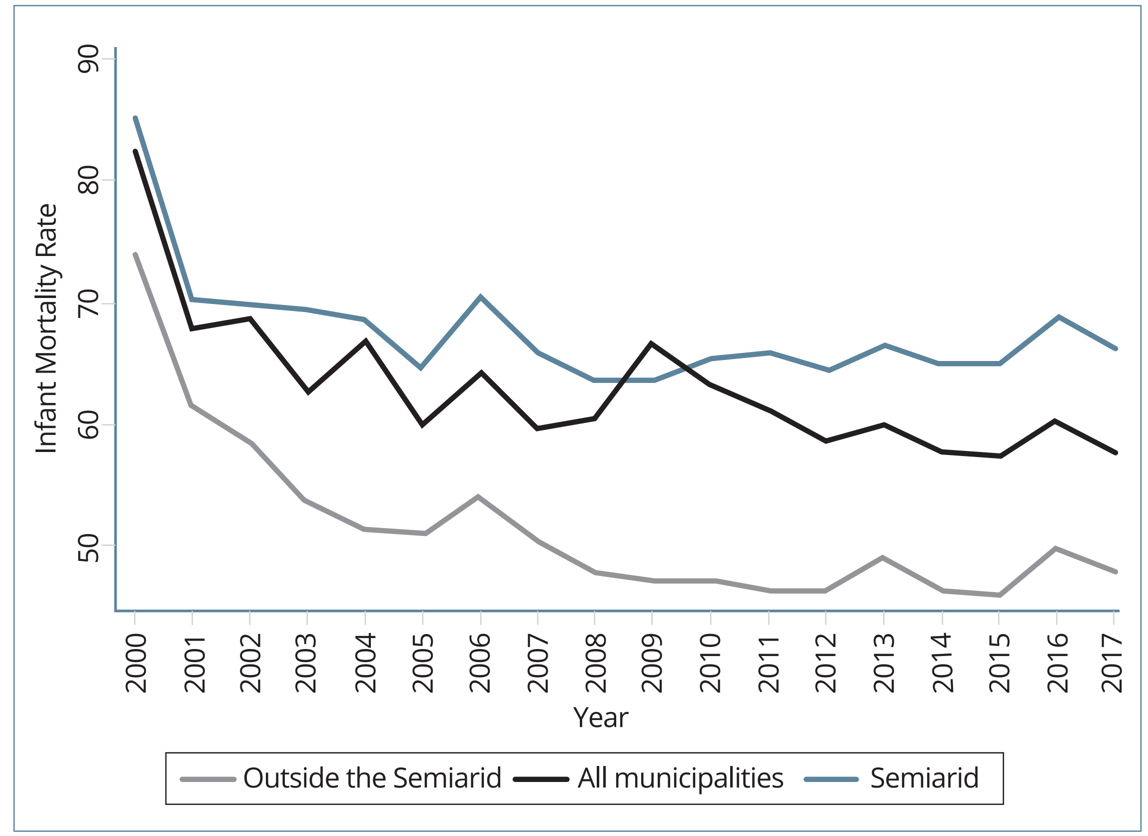
FIGURE 10: NORTHEAST REGION TEMPERATURE INDEX BY MONTH (YEAR 2000)



Source: Da Mata *et al*. (2019).

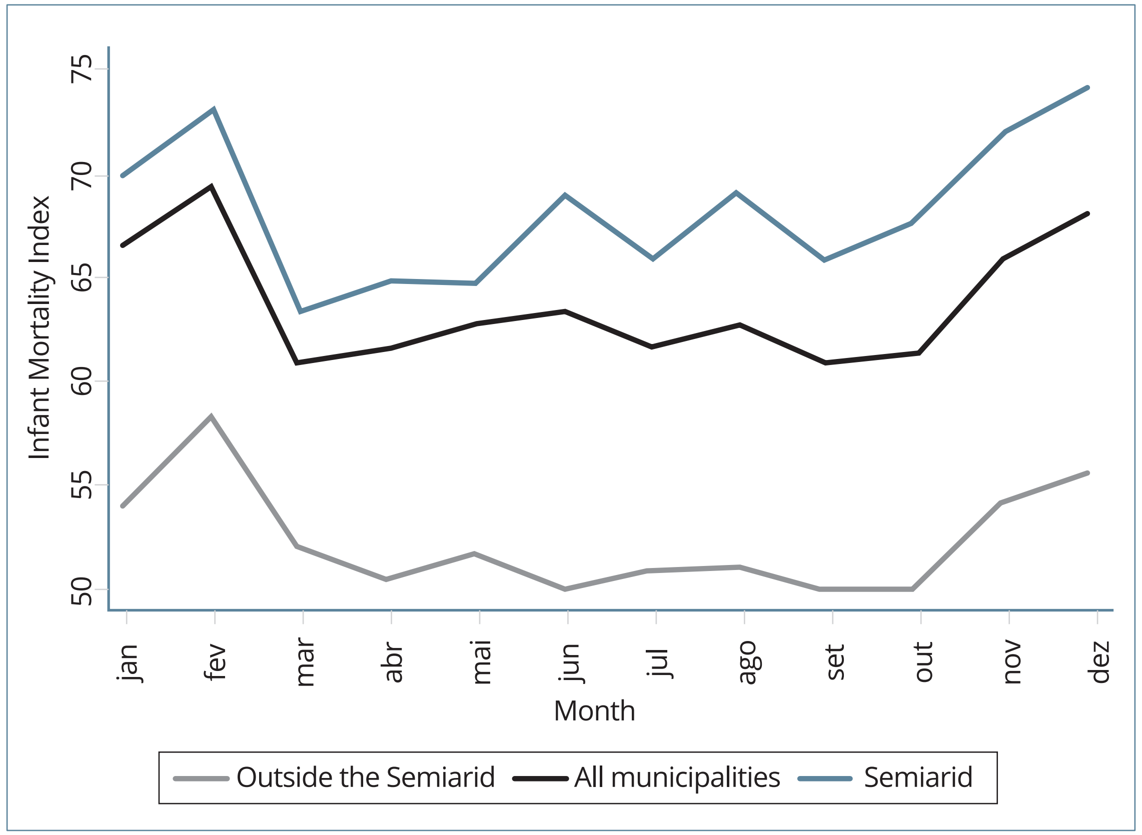
Figures 11 and 12 present yearly and monthly infant mortality rates, respectively. As can be seen in Figure 11, over time there was a sharp drop in infant mortality rates. However, this drop was much more pronounced in municipalities outside the Northeastern Semiarid region. Figure 12 indicates that infant mortality rates are highest between November and February, the period with the highest temperatures, which comes after the months with the greatest amounts of drought.

FIGURE 11: INFANT MORTALITY RATE PER YEAR



Source: Authors' elaboration.

FIGURE 12: INFANT MORTALITY RATE PER MONTH



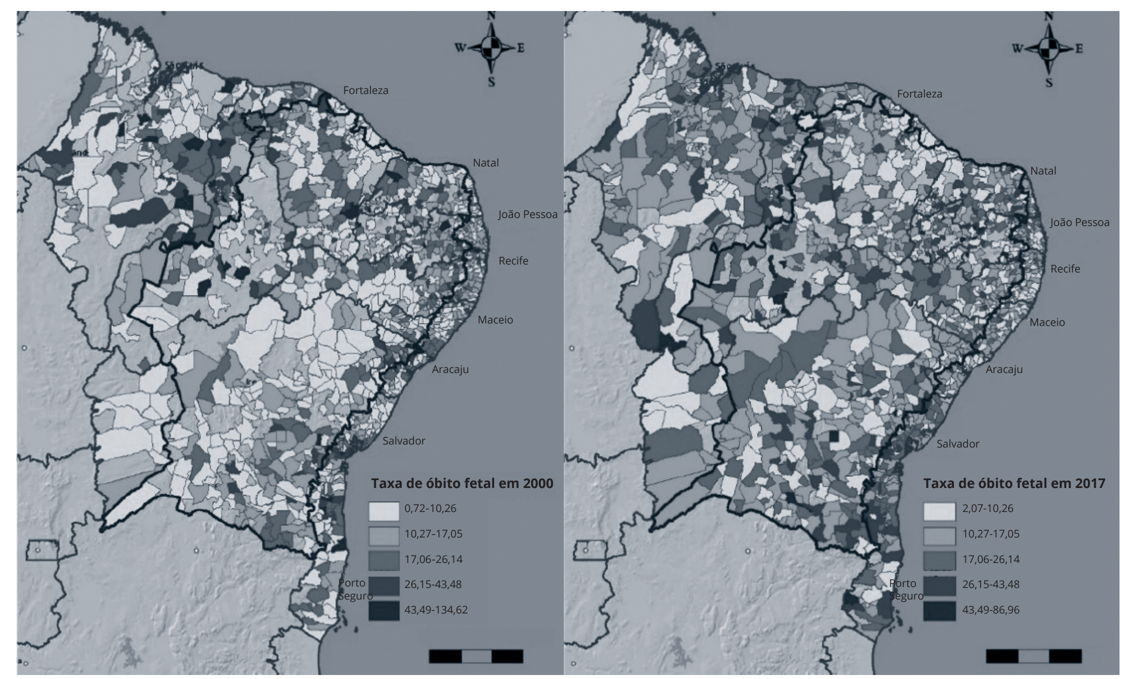
Source: Authors' elaboration.

Figures 13 and 14 present infant and fetal mortality rates per municipality. The map in Figure 13 indicates a significant reduction in infant mortality rate among analyzed municipalities. The map in Figure 14, on the other hand, suggests an underreporting of cases of fetal mortality in the year 2000, which was corrected over time. Thus, we do not interpret these maps as indicative of an increase in mortality cases over time.

FIGURE 13: INFANT MORTALITY RATE PER MUNICIPALITY IN 2000 (LEFT) AND 2017 (RIGHT)

Source: Authors' elaboration.

FIGURE 14: FETAL MORTALITY RATE PER MUNICIPALITY IN 2000 (LEFT) AND 2017 (RIGHT)



Source: Authors' elaboration.

3.3 EMPIRICAL APPROACH

3.3.1. Health

In this study, we will use econometric instruments to measure the impacts of extreme weather events on children, adolescents and young people. More specifically, we aim to estimate a panel data model with fixed effects. To measure the impact of drought on health and educational indicators, the main assumption is that the occurrence of drought in municipality *j* during month *t* is an exogenous, that is, unpredictable event. In other words, there would be no correlation with the occurrence of drought, defined in this study as a situation in which the rainfall index is below the standard deviation of the historical average rainfall of the respective municipality.

In addition, the panel data model allows us to use any characteristics of the municipalities that remain fixed over time – but vary between locations – as controls. For example, a municipality may have a mineral reserve that generates royalties that are reinvested in public services. As the existence of this mineral reserve is fixed in time for the municipality that owns it, the fixed-effect parameter may be used to capture it. The same goes for all municipal characteristics that follow this pattern. Based on these considerations and following the specialized literature, we were able to estimate the model presented in Equation 7:

$$Y_{jt} = \beta_1 \; Drought_{j,t\text{-}12} + \theta_j + \tau_t + \gamma \; Temp_{jt} + \varepsilon_{jt} \qquad (7)$$

In which:

- Y_{jt} assumes the values of the health indicator studied in municipality *j* during month *t*;
- $Drought_{j,t\text{-}12}$ indicates whether there was a drought during the last 12 months before death;
- θ_j is a municipality-related fixed effect;
- $Temp_{jt}$ is the average temperature for month *t* in municipality *j*;
- ε_{jt} is a stochastic error term.

This specification is widely used, above all in studies that seek to analyze the impacts of drought on infant deaths or childbirth-related health outcomes. However, it should be noted that shorter climatic shocks may lead to short-term events, such as mortality and hospitalization due to diarrhea. In this case, the variable $Drought_{j,t\text{-}3}$ was used as a measure of climatic impact instead of $Drought_{j,t\text{-}12}$. This variable indicates whether the combined rainfall in the last three months before the analyzed health outcome was lower than the historical average, pointing to extreme drought.

A potential limitation of this strategy is the fact that some health data is only available on an annual basis. In order to circumvent this limitation, we used the number of drought months in each municipality and year as a climatic-impact variable (Equation 8).

$$Y_{jt} = \beta_1 \; Drought_{jjt,3m} + \beta_2 \; Drought_{jjt,4m} + \beta_3 \; Drought_{jjt,5m} + \theta_j + \tau_t + \gamma \; Temp_{jt} + \varepsilon_{jt} \qquad (8)$$

In which:

- Y_{jt} assumes the values of the studied health indicator;
- $Drought_{jjt,3m}$ is a binary variable equal to 1 if the number of drought months in year *t* in the municipality *j* is equal to three months;
- $Drought_{jjt,4m}$ is a binary variable equal to 1 if the number of drought months in year *t* in the municipality *j* is equal to four months;
- $Drought_{jjt,5m}$ is a binary variable equal to 1 if the number of drought months in year *t* in the municipality *j* is equal to five months;
- θ_j is a municipality-related fixed effect;
- τ_t is a time-related fixed effect;
- $Temp_{jt}$ is the average temperature for year *t* in municipality *j*;
- ε_{jt} is a stochastic error term.

In this case, our result of interest will be measured from estimated parameters β_1, β_2 and β_3, in order to capture the impacts of the number of drought months in each municipality, as well as the impact of each drought year on the selected health and education indicators. The other variables aim to reduce possible biases and improve the estimates' accuracy.

3.3.2. Education

Due to the characteristics of educational data, it was necessary to use other empirical strategies to observe how climatic impacts affect education. As these are data on individuals, we observed each only once, across different years. On the other hand, the fact that the educational data are based on questionnaires allows the introduction of several control variables. Moreover, unlike health indicators, monthly educational data is not available. Therefore, to analyze the *Prova Brasil* educational performance of students in the 5th year of elementary school, we established variables meant to capture the effects of climatic events prior to the exam's date of application, which is generally in November. For these estimates, we employed the econometric specification expressed in Equation 9:

$$Y_i = \beta\ Drought_j + \delta\ School_i + \theta\ X_i + \gamma\ Temp_j + \varepsilon_{ij} \qquad (9)$$

In which:

- Y_{jt} assumes the values of education indicators for student *i* of municipality *j*;
- $Drought_j$ indicates whether there was a reduction of 1 standard deviation in the volume of rainfall for a given period of analysis in municipality *j*;
- *School* is a vector of observed school characteristics;
- $X_{i,t}$ is a vector of observed individual characteristics;
- $Temp_{jt}$ is the average temperature for month *t* in municipality *j*;
- ε_i is a stochastic error term.

In this case, the parameter of interest is β, the result of which will indicate whether the climatic shock in a given municipality may imply effects on student performance in Portuguese and mathematics standardized tests. The following were used as explanatory control variables: gender, race, how many hours the student dedicates to housework, and whether the student works outside the home. To control for differences between schools, binary variables were included to indicate whether the school is federal, state, municipal or private, in addition to differences in averages between schools located in rural or urban areas.

Furthermore, to identify the municipalities that were most exposed to drought scenarios, information was collected from official records published in the *Official Gazette of the Federal Government* regarding municipalities that declared a state of public disaster due to drought or dry spell. In this case, our econometric specification will be an analysis of cross-sectional data, as per Equation 10:

$$LnY_{i,j,t} = \beta_1\ Drought_{j,t} + \beta_2\ Dry\ spell_{j,t} + \theta_j + \tau_t + \gamma\ Temp_{jt} + \delta\ X_{i,t} + \varepsilon_{i,j,t} \qquad (10)$$

In which:

- $LnY_{i,j,t}$ assumes the values of the logarithm of the educational performance indicator of individual *i*, in year *t*, in municipality *j*;
- $Drought_{j,t}$ is a binary variable equal to 1 if a state of public disaster was declared due to drought in year *t* in municipality *j*;
- $Dry\ spell_{j,t}$ is a binary variable equal to 1 if a state of public disaster was declared due to dry spell in year *t* in municipality *j*;
- θ_j is a municipality-related fixed effect;
- τ_t is a time-related fixed effect;
- $Temp_{jt}$ is the average temperature for year *t* in municipality *j*;
- $X_{i,t}$ is a vector of observed individual characteristics;
- $\varepsilon_{i,j,t}$ is a stochastic error term.

Furthermore, considering that 2012 was the year in which the most severe drought since 1998 occurred, we opted to include an interactive dummy variable in order to verify the same effects as in Equation 10, but specifically for the year 2013. Thus, Equation 11 was estimated as follows:

$$LnY_{i,j,t} = \beta_1\ Drought_{j,t} + \beta_2\ Dry\ spell_{j,t} + \beta_3\ Drought2013_j + \beta_4\ Dry\ spell2013_j + \theta_j + \tau_t + \gamma\ Temp_{jt} + \delta X_{i,t} + \varepsilon_{i,j,t}$$

In which:

- $Drought2013_j$ is a binary variable equal to 1 if a state of public disaster has been declared due to drought in the year 2013 in municipality *j*;
- $Dry\ spell2013_j$ is a binary variable equal to 1 if a state of public disaster has been declared due to dry spell in year 2013 in municipality *j*;

It is important to note that between 2012 and 2016 there was a greater reduction in the volume of rainfall compared to the historical average and, consequently, more municipalities declared a state of public disaster during that period. Therefore, models were estimated considering all individuals in the complete database and, later, the same models were re-estimated using only the most severe drought period, between 2012 and 2016.

4. Results

4.1. HEALTH

In this section, we present the results of econometric-model estimates in order to analyze the impact of climate shocks. Initially, the focus will be on health impacts. Educational impacts will be discussed later on.

Table 1 presents the results of Equation 7, with the objective of verifying the effect of climatic impacts on children's health. Three measures of climatic effects were used: volume of rainfall in the last 12 months before birth; deviation of rainfall volume from the historical average; drought event. Panel A contains results for all the sampled municipalities, while panel B refers only to municipalities in the Northeastern Semiarid region. The employed indicators are municipal-level measures for the number of live births, mortality rate, rate of premature children per thousand inhabitants, and rate of underweight children per thousand inhabitants.

Results suggest that higher rainfall volumes are positively related to higher number of births, lower infant mortality rate, lower prematurity rate and lower underweightness rate for both the analyzed samples. The annual deviation is negatively related only to the infant mortality rate. This means that the higher the level of rainfall in relation to the annual average, the lower the infant mortality rate.

The impact of the occurrence of drought in the 12 months prior to birth – i.e., the child's exposure to periods of drought during the gestational period – was also investigated. Results suggest that exposure to drought during pregnancy has negative impacts on children's health. These negative impacts are stronger in the semiarid region. More specifically, in this region, drought implied an increase of 1.8 percentage points in infant mortality, 34 percentage points in the rate of premature children, and 6.8 percentage points in the rate of children born underweight.

TABLE 1: IMPACT OF THE LAST 12 MONTHS' CLIMATE ON HEALTH OUTCOMES OF CHILDREN BETWEEN 0 AND 1 YEAR OF AGE

Panel A: all municipalities				
	Live births	**Infant mortality**	**Prematurity**	**Underweight**
Rainfall volume (12 months)	4,004***	0.945	−47.292***	−8.004***
	(0.380)	(0.845)	(1.141)	(0.615)
Annual deviation	0.146	−3.420***	0.815	−0.673
	(0.124)	(1.243)	(0.821)	(0.662)
Drought	−2.801***	0.164	29.815***	4.477***
	(0.227)	(0.548)	(0.773)	(0.469)
Panel B: Semiaridw				
	Live births	**Infant mortality**	**Prematurity**	**Underweightness**
Rainfall volume (12 months)	3.503***	−2.025*	−47.927***	−10.058***
	(0.178)	(1.140)	(1.415)	(0.730)
Annual deviation	0.308***	−4.910***	1.626	−0.816
	(0.086)	(1.796)	(1.026)	(0.811)
Drought	−2.794***	1.789**	34.241***	6.784***
	(0.139)	(0.861)	(1.074)	(0.655)
Municipality-related fixed effect	**Yes**	**Yes**	**Yes**	**Yes**
Month-related fixed effect	**Yes**	**Yes**	**Yes**	**Yes**

Note: Standard errors in parentheses. Errors clustered at the municipal level. Significance level: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

In Table 2, we analyze the impact of drought over the last three months, measured as the difference between the sum of the last three months and the monthly average. A sum smaller than the average indicates that drought has occurred. As can be seen, the parameter signals are moving in the same direction; however, only the parameters for variables "live births" and "prematurity" are statistically significant.

In order to understand the specific causes of infant mortality, we estimated the impacts of drought on them. These results are shown in Tables 3 and 4. Although the variables have positive signs – indicating that both deviations and the existence of droughts increase mortality from specific causes – only in Table 4 do we see a statistically significant impact on mortality from infectious causes. This finding may be related to the consumption of untreated water or the lack of water for personal hygiene and for adequate handling of food.

TABLE 2: IMPACT OF THE LAST 3 MONTHS' CLIMATE ON HEALTH OUTCOMES OF CHILDREN BETWEEN 0 AND 1 YEAR OF AGE

Panel A: all municipalities				
	Live births	**Infant mortality**	**Prematurity**	**Underweight**
Deviation in the last three months	0,472***	0,504*	−3,167***	−0,404**
	(0,151)	(0,302)	(0,242)	(0,180)
Drought within the last three months	0,244***	0,275	−3,539***	−0,539**
	(0,059)	(0,477)	(0,305)	(0,231)
Notes	384.958	128.934	384.958	384.958
Panel B: Semiarid				
	Live births	**Infant mortality**	**Prematurity**	**Underweight**
Deviation in the last three months	−3,397***	0,250	16,038***	3,878
	(0,465)	(2,472)	(3,353)	(3,081)
Drought within the last three months	−4,848***	2,218	20,858***	4,940
	(0,732)	(4,543)	(4,346)	(4,623)
Notes	225.256	68.044	225.256	225.256

Note: Standard errors in parentheses. Errors clustered at the municipal level. Significance level: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

TABLE 3: IMPACTS OF THE LAST 12 MONTHS' CLIMATE ON MORTALITY OF CHILDREN BETWEEN 0 AND 1 YEAR OF AGE DUE TO SPECIFIC CAUSES

	Endocrine and nutritional	Infectious	Respiratory
Panel A: all municipalities			
Annual deviation	−0,103	−4,121	0,437
	(1,875)	(3,270)	(1,372)
Drought	1,157	1,392	0,760
	(1,418)	(1,045)	(1,007)
Notes	6.231	18.430	10.497
Panel B: Semiarid			
Annual deviation	0,321	−8,104	−0,003
	(2,963)	(5,687)	(2,380)
Drought	3,244	3,648	0,778
	(3,361)	(2,270)	(2,151)
Notes	2.863	9.133	4.498

Note: Standard errors in parentheses. Errors clustered at the municipal level. Significance level: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

TABLE 4: IMPACTS OF THE LAST 3 MONTHS' CLIMATE ON MORTALITY OF CHILDREN BETWEEN 0 AND 1 YEAR OF AGE DUE TO SPECIFIC CAUSES

	Endocrine and nutritional	Infectious	Respiratory
Panel A: all municipalities			
Deviation in the last three months	−0,487	0,605	0,646
	(0,748)	(0,446)	(0,417)
Drought within the last three months	14,019	9,990***	5,011
	(12,465)	(3,547)	(3,069)
Notes	6.231	18.430	10.497
Panel B: Semiarid			
Deviation in the last three months	−1,354	0,465	1,294
	(1,212)	(0,851)	(0,877)
Drought within the last three months	25,431	12,860**	3,440
	(19,886)	(5,103)	(3,407)
Notes	2.863	9.133	4.498

Note: Standard errors in parentheses. Errors clustered at the municipal level. Significance level: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Then, using the variable 'drought occurrence in the last three months before the death record,' Table 5 shows that this factor increases the chance of death from diarrhea by 11 percentage points for all municipalities, and by 14.7 percentage points for semiarid municipalities.

TABLE 5: CLIMATIC IMPACTS ON DIARRHEA MORTALITY IN CHILDREN BETWEEN 0 AND 1 YEAR OF AGE

	All municipalities			Semiarid		
Rainfall volume (3 months)	0,726			1,354		
	(0,550)			(0,996)		
Deviation in the last three months		0,726			1,354	
		(0,550)			(0,996)	
Drought			11,02**			14,68**
			(4,634)			(5,719)
Notes	10.739	10.739	10.748	5.534	5.534	5.541
Municipality-related fixed effect	Sim	Sim	Sim	Sim	Sim	Sim
Month-related fixed effect	Sim	Sim	Sim	Sim	Sim	Sim

Note: Standard errors in parentheses. Errors clustered at the municipal level. Significance level: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Finally, considering that there are no monthly nutrition data, the impact of drought on nutrition was analyzed using annual data. The results presented in Table 6 suggest that the number of months of drought has a positive relationship with both chronic malnutrition events and acute malnutrition events. It should be noted that the impacts are higher in the semiarid region and for children between 2 and 5 years old.

TABLE 6: CLIMATIC IMPACTS ON NUTRITIONAL INDICATORS

	Chronic malnutrition					
	All municipalities			Semiarid		
	0 to 2 years	2 to 5 years	0 to 5 years	0 to 2 years	2 to 5 years	0 to 5 years
Three months of drought	0.023	0.004	0.013	0.066	0.035	0.035
	(0,025)	(0,019)	(0,019)	(0,041)	(0,029)	(0,029)
Four months of drought	0,086***	0,050**	0,063**	0,118***	0,023	0,023
	(0,031)	(0,024)	(0,024)	(0,038)	(0,034)	(0,034)
Five or more months of drought	0,050	0,095***	0,080***	0,092*	0,137***	0,137***
	(0,036)	(0,027)	(0,027)	(0,050)	(0,041)	(0,041)
	Acute malnutrition					
	0 to 2 years	2 to 5 years	0 to 5 years	0 to 2 years	2 to 5 years	0 to 5 years
Three months of drought	−0,032	−0,019	−0,013	−0,013	0,002	0,002
	(0,030)	(0,021)	(0,021)	(0,044)	(0,033)	(0,033)
Four months of drought	0,051	0,059**	0,066**	0,075	0,094***	0,094***
	(0,037)	(0,026)	(0,026)	(0,051)	(0,034)	(0,034)
Five or more months of drought	−0,015	0,044	0,031	0,080	0,041	0,041
	(0,045)	(0,031)	(0,031)	(0,059)	(0,045)	(0,045)
Notes	15.633	15.914	15.935	9.155	9.309	9.309
Municipality-related fixed effect	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Year-related effect	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

Note: Standard errors in parentheses. Errors clustered at the municipal level. Significance level: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

4.2. EDUCAÇÃO

Empirical literature from different parts of the world shows that drought can have a negative impact on the educational performance of children and young people (Kim, 2008; Thai and Falaris, 2011; Shah and Steinberg, 2013; Björkman-Nyqvist, 2013; Amaya, 2020). There are several documented factors that may explain how reductions in rainfall volume affect educational performance.

Drought can have impacts on the individual's health, on the family's income level, on the nutritional value of their food and on their decision to participate in the labor market. All of these factors are closely related to individuals' educational performance, so it is reasonable to think that droughts can have negative effects on education. Therefore, in this section we intend to estimate the impacts of drought on education, focusing on the strong reductions in rainfall volume that occurred in many cities in the Northeast during some years of the past decade.

Tables 7 and 8 estimate the effects of rainfall volume reduction – considering the municipalities in the Northeast that declared a public disaster status due to drought or dry spell – on the performance of 5th grade students in mathematics and Portuguese tests. As our dependent variables are expressed logarithmically, parameters can be multiplied by 100 in order to be interpreted as percentages.

Table 7 shows the effects of drought on math scores from 2011 to 2017, a period during which four instances of the *Prova Brasil* exam were held (one every two years). We observed a barely significant effect among municipalities that declared a state of disaster due to drought, while there is a negative effect of about 2% for municipalities that declared a state of public disaster due to dry spell. However, as seen in the fourth column, municipalities that decreed a state of public disaster due to drought or dry spell in 2013 suffered a negative effect of 1.5% and 3%, respectively, on students' math performance. This means that municipalities that declared a state of public disaster in other years have not experienced such a major effect on students' educational performance.

As for performance estimates regarding the Portuguese section of the exam, in Table 8 we also see a more robust effect on the group of municipalities that have declared a public disaster due to dry spell. For the year 2013, on the other hand, the estimated effects are negative for both groups of municipalities, which indicates that the reduction in rainfall volume has a negative effect – to the tune of 0.56% to 2% – on young people's performance in Portuguese.

Some of the possible reasons for the fact that this effect appears in greater magnitude in 2013 are the following: (i) 2012 was the worst drought year, so municipalities that declared a state of public disaster in 2013 underwent a more severe reduction in rainfall volume as compared to other years; (ii) since there was a strong drought in 2012, both the population and policymakers may have devised new strategies to reduce the impacts of drought, making this effect less likely in later periods; and (iii) the declaration of a state of public disaster gives policymakers access to more resources, which can be spent in a less bureaucratic way, allowing the government to more efficiently minimize the effects of droughts.

In other words, in addition to the reduction in the estimated effect due to the lower intensity of droughts after 2012, it is reasonable to conclude that these municipalities were exposed to an unexpected period of severe drought between 2012 and 2013, and then began implementing proactive strategies that reduced its effects on education during the following years.

TABLE 7: IMPACT OF DROUGHT ON 5TH-GRADE STUDENTS' MATH PERFORMANCE

	Log. Mathematics	Log. Mathematics	Log. Mathematics	Log. Mathematics
Drought	0,00258	−0,00432*	−0,00203	0,0151***
	(0,00359)	(0,00251)	(0,00241)	(0,00269)
Dry spell	−0,0219***	−0,0196***	−0,0192***	−0,00166
	(0,00249)	(0,00222)	(0,00217)	(0,00232)
Drought in 2013				−0,0313***
				(0,00381)
Dry spell in 2013				−0,0303***
				(0,00322)
Municipality- and year-related fixed effect	Yes	Yes	Yes	Yes
Socioeconomic controls	No	Yes	Yes	Yes
Child labor controls	No	No	Yes	Yes
No. of observations	7.515.059	6.481.935	6.232.230	6.232.230

Note: Standard error in parentheses. Errors clustered at the municipal level. Significance level: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. Log.: logarithm.

TABLE 8: IMPACT OF DROUGHT ON 5TH-GRADE STUDENTS' MATH PERFORMANCE

	Log. Portuguese	Log. Portuguese	Log. Portuguese	Log. Portuguese
Drought	0,00961***	0,000116	0,00224	0,0116***
	(0,00327)	(0,00229)	(0,00223)	(0,00254)
Dry spell	−0,0145***	−0,0134***	−0,0138***	−0,00240
	(0,00227)	(0,00199)	(0,00198)	(0,00221)
Drought in 2013				−0,0172***
				(0,00297)
Dry spell in 2013				−0,0197***
				(0,00268)
Municipality- and year-related fixed effect	Yes	Yes	Yes	Yes
Socioeconomic controls	No	Yes	Yes	Yes
Child labor controls	No	No	Yes	Yes
No. of observations	7.515.059	6.481.935	6.232.230	6.232.230

Note: Standard error in parentheses. Errors clustered at the municipal level. Significance level: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. Log.: logarithm.*** $p < 0,01$. Ln: logaritmo.

In Tables 9 and 10 we see that, when restricting the dataset to the *Prova Brasil* editions that took place in the years of most severe drought – 2013 and 2015 – the estimated effects of the strong reduction in the volume of rainfall are even greater and more significant. The results of the estimates in Tables 9 and 10 suggest that a drought scenario may have an average impact of more than 4% in mathematics and 2% in Portuguese. It is important to note that all estimates were controlled for students' socioeconomic characteristics, child labor, domestic work, in addition to year- and municipality-related fixed effects.

TABLE 9: IMPACT OF DROUGHT ON 5TH-GRADE STUDENTS' MATH PERFORMANCE (2013–2015)

	Log. Mathematics	Log. Mathematics	Log. Mathematics
Drought	−0,0328***	−0,0281***	−0,0270***
	(0,00640)	(0,00587)	(0,00553)
Dry spell	−0,0491***	−0,0426***	−0,0407***
	(0,00422)	(0,00387)	(0,00365)
Municipality- and year-related fixed effect	Yes	Yes	Yes
Socioeconomic controls	No	Yes	Yes
Child labor controls	No	No	Yes
No. of observations	7.515.059	6.481.935	6.232.230

Note: Standard error in parentheses. Errors clustered at the municipal level. Significance level: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. Log.: logarithm.

TABLE 10: IMPACT OF DROUGHT ON 5TH-GRADE STUDENTS' PORTUGUESE PERFORMANCE (2013–2015)

	Log. Portuguese	Log. Portuguese	Log. Portuguese
Drought	−0,0213***	−0,0178***	−0,0178***
	(0,00639)	(0,00585)	(0,00544)
Dry spell	−0,0265***	−0,0240***	−0,0239***
	(0,00312)	(0,00303)	(0,00286)
Municipality- and year-related fixed effect	Yes	Yes	Yes
Socioeconomic controls	Yes	Yes	Yes
Child labor controls	Yes	Yes	Yes
No. of observations	7.515.059	6.481.935	6.232.230

Note: Standard error in parentheses. Errors clustered at the municipal level. Significance level: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. Log.: logarithm.

Table 11 estimates the effects of drought on the performance of individuals who were close to completing high school or who had already completed it. Practically all parameters are negative, although only a few have statistical significance. Since from the analysis of drought impacts on primary education we knew that the greater effects of drought may have occurred in 2013 – given the aforementioned reasons – another analysis was carried out, with the inclusion of an interactive dummy variable to verify the impact of rainfall volume reduction on student performance at the Enem 2013 exam.

In Table 12 as well as in the analysis of elementary education, there is evidence of a significant negative effect on the performance of Enem 2013 candidates living in municipalities that experienced reduced rainfall. The estimated effect is approximately 2% for human sciences; only for natural sciences does it come up short of exceeding 1%.

TABLE 11: IMPACT OF DROUGHT ON ENEM PERFORMANCE (2010–2018)

	Log. Mathematics	Log. Portuguese	Log. Writing	Log. Human sciences	Log. Natural sciences
Drought	−0,000554	−0,00411***	−0,00999***	−0,00472***	0,000836
	(0,00148)	(0,000845)	(0,00240)	(0,00115)	(0,00103)
Dry spell	−0,000741	−0,000671	−0,00499**	−0,000676	−0,000423
	(0,00107)	(0,000616)	(0,00204)	(0,000734)	(0,000683)
Municipality- and year-related fixed effect	Yes	Yes	Yes	Yes	Yes
Socioeconomic controls	Yes	Yes	Yes	Yes	Yes
No. of observations	12.604.020	1.275.0516	12.228.634	13.005.958	12.863.073

Note: Standard errors in parentheses. Errors clustered at the municipal level. Significance level: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. Log.: logarithm.

TABLE 12: IMPACT OF DROUGHT ON ENEM PERFORMANCE – 2013 EFFECT (2010–2018)

	Log. Mathematics	Log. Portuguese	Log. Writing	Log. Human sciences	Log. Natural sciences
Drought	0,00244	−0,000302	−0,00764***	0,0000940	0,00196*
	(0,00158)	(0,000963)	(0,00204)	(0,00131)	(0,00116)
Dry spell	−0,00161	0,0000139	−0,00388**	−0,000740	−0,000555
	(0,00103)	(0,000703)	(0,00191)	(0,000824)	(0,000744)
Drought in 2013	−0,0114***	−0,0164***	−0,0107***	−0,0197***	−0,00448***
	(0,00167)	(0,00172)	(0,00277)	(0,00156)	(0,00110)
Dry spell in 2013	0,000479	−0,00795***	−0,00793***	−0,00558***	−0,000752
	(0,00140)	(0,00170)	(0,00260)	(0,00132)	(0,000974)
Municipality- and year-related fixed effect	Yes	Yes	Yes	Yes	Yes
Socioeconomic controls	Yes	Yes	Yes	Yes	Yes
No. of observations	12.604.020	12.750.516	12.228.634	13.005.958	12.863.073

Note: Standard errors in parentheses. Errors clustered at the municipal level. Significance level: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. Log.: logarithm.

Table 13 restricts the dataset to the years in which the drought was more severe, i.e., 2012 to 2016. Consequently, there is a greater amount of public disaster decrees motivated by rainfall-volume reduction. Despite controlling for individuals' socioeconomic characteristics and for year- and municipality-related fixed effects, all the estimated parameters are negative and statistically significant. Thus, Table 13 contains clear evidence that droughts can reduce educational performance across all areas of knowledge.

For Table 14, we placed an interactive dummy between the variables of interest and the year 2013. Although all parameters remained negative, the effect on Enem performance in 2013 was, in fact, greater and more significant, with results similar to those seen in Table 12.

.TABLE 13: IMPACT OF DROUGHT ON ENEM PERFORMANCE (2010–2016)

	Log. Mathematics	Log. Portuguese	Log. Writing	Log. Human sciences	Log. Natural sciences
Drought	−0,00461***	−0,00464***	−0,00848***	−0,00641***	−0,00267***
	(0,00151)	(0,00109)	(0,00232)	(0,00130)	(0,000868)
Dry spell	−0,00334***	−0,00150***	−0,00804***	−0,00223***	−0,00138***
	(0,000866)	(0,000545)	(0,00186)	(0,000693)	(0,000477)
Municipality- and year-related fixed effect	Yes	Yes	Yes	Yes	Yes
Socioeconomic controls	Yes	Yes	Yes	Yes	Yes
No. of observations	7.551.339	7.553.495	7.305.445	7.742.910	7.741.435

Note: Standard errors in parentheses. Errors clustered at the municipal level. Significance level: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. Log.: logarithm.

TABLE 14: IMPACT OF DROUGHT ON ENEM PERFORMANCE WITH THE INCLUSION OF NEW CONTROLS (2012–2016)

	Log. Mathematics	Log. Portuguese	Log. Writing	Log. Human sciences	Log. Natural sciences
Drought	−0,00103	−0,000347	−0,00582***	−0,000921	−0,00130
	(0,00145)	(0,000936)	(0,00213)	(0,00114)	(0,000843)
Dry spell	−0,00423***	−0,000992*	−0,00822***	−0,00284***	−0,00128**
	(0,000852)	(0,000524)	(0,00182)	(0,000665)	(0,000514)
Drought in 2013	−0,0134***	−0,0177***	−0,0102***	−0,0213***	−0,00557***
	(0,00166)	(0,00168)	(0,00271)	(0,00162)	(0,00119)
Dry spell in 2013	−0,00347**	−0,0110***	−0,00431*	−0,00859***	−0,00323***
	(0,00137)	(0,00178)	(0,00240)	(0,00143)	(0,00115)
Municipality- and year-related fixed effect	Yes	Yes	Yes	Yes	Yes
Socioeconomic controls	Yes	Yes	Yes	Yes	Yes
No. of observations	7.551.339	7.553.495	7.305.445	7.742.910	7.741.435

Note: Standard errors in parentheses. Errors clustered at the municipal level. Significance level: * $p <0.10$; ** $p < 0.05$; *** $p < 0.01$. Log.: logarithm.

It is important to note that we also investigated whether droughts had an effect on the individual's probability of enrolling in or missing the Enem exam. In both cases, estimates showed that drought does not seem to have significant effects on these variables, that is, there is no reduction in the number of individuals enrolled in the test in response to a reduction in rainfall volume. Moreover, once the individual has enrolled, drought does not increase the likelihood that the individual will miss the test.

To estimate health outcomes, we applied a methodology similar to that used in the previous section. We sought to identify the possible effects of a reduction of 1 standard deviation in each municipality's volume of average rainfall on the Prova Brasil performance of 5th-year elementary school students. This exercise's results are shown in Tables 15, 16 and 17. Parameters estimated for the municipalities in the semiarid are all negative and, for the most part, significant, regardless of the exam's edition (2013, 2015 or 2017). This result corroborates the evidence found in previous years that the reduction in the volume of rainfall can have a negative impact on the educational performance of elementary school students.

The results shown in Tables 15, 16 and 17 indicate that the Portuguese performance of students living in municipalities in the semiarid region can suffer a negative impact of 4.2% to 5.5% when there is a reduction of 1 standard deviation in the rainfall volume during the month prior to the test. The reduction can be as high as 6.7% if this negative shock has occurred during the previous three months.

Regarding the math performance of students residing in the Semiarid Region, there was also a negative effect of about 3.5% when the reduction in rainfall volume occurred during the month prior to the test. This negative effect may reach up to 4.7% when the reduction has occurred in the previous three months. It is worth mentioning that, when we specifically analyzed the year 2015, no statistically significant results were found for the period of three months prior to the test, although in this case the parameter sign is also negative.

For students residing outside the semiarid region, results are barely significant. This may be evidence that the reduction in the volume of rainfall has a lesser effect in this region. The difference in effects between regions can be explained by several factors. A reasonable possibility has to do with the two regions having different socioeconomic profiles.

TABLE 15: CLIMATIC IMPACTS OF THE LAST MONTH AND THE LAST THREE MONTHS PRIOR TO *PROVA BRASIL* ON THE PORTUGUESE AND MATH PERFORMANCE OF 5TH-YEAR STUDENTS, 2013

Panel A: Semiarid				
	Log. Portuguese	Log. Portuguese	Log. Math	Log. Math
Drought in the month of test application	−0,0546***		−0,0363***	
	(0,0113)		(0,0138)	
Drought in the three months prior		−0,0600***		−0,0388*
		(0,0163)		(0,0217)
No. of observations	608.547	608.547	608.547	608.547
Panel B: outside the semiarid				
	Log. Portuguese	Log. Portuguese	Log. Math	Log. Math
Drought in the month of test application	−0,0189*		−0,00536	
	(0,0103)		(0,0115)	
Drought in the three months prior		−0,0172*		0,00423
		(0,0104)		(0,0140)
No. of observations	244.950	244.950	244.950	244.950

Note: Standard errors in parentheses. Errors clustered at the municipal level. Significance level: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

TABLE 16: CLIMATIC IMPACTS OF THE LAST MONTH AND THE LAST THREE MONTHS PRIOR TO PROVA BRASIL ON THE PORTUGUESE AND MATH PERFORMANCE OF 5TH-YEAR STUDENTS, 2015

Panel A: Semiarid				
	Log. Portuguese	Log. Portuguese	Log. Math	Log. Math
Drought in the month of test application	−0,0423***		−0,0324***	
	(0,0101)		(0,00919)	
Drought in the three months prior		−0,0279*		−0,0219
		(0,0157)		(0,0162)
No. of observations	200.168	200.168	200.168	200.168
Panel B: outside the semiarid				
	Log. Portuguese	Log. Portuguese	Log. Math	Log. Math
Drought in the month of test application	−0,00842		−0,00626	
	(0,0110)		(0,00846)	
Drought in the three months prior		−0,0122		−0,00679
		(0,0123)		(0,00944)
No. of observations	262.781	262.781	262.781	262.781

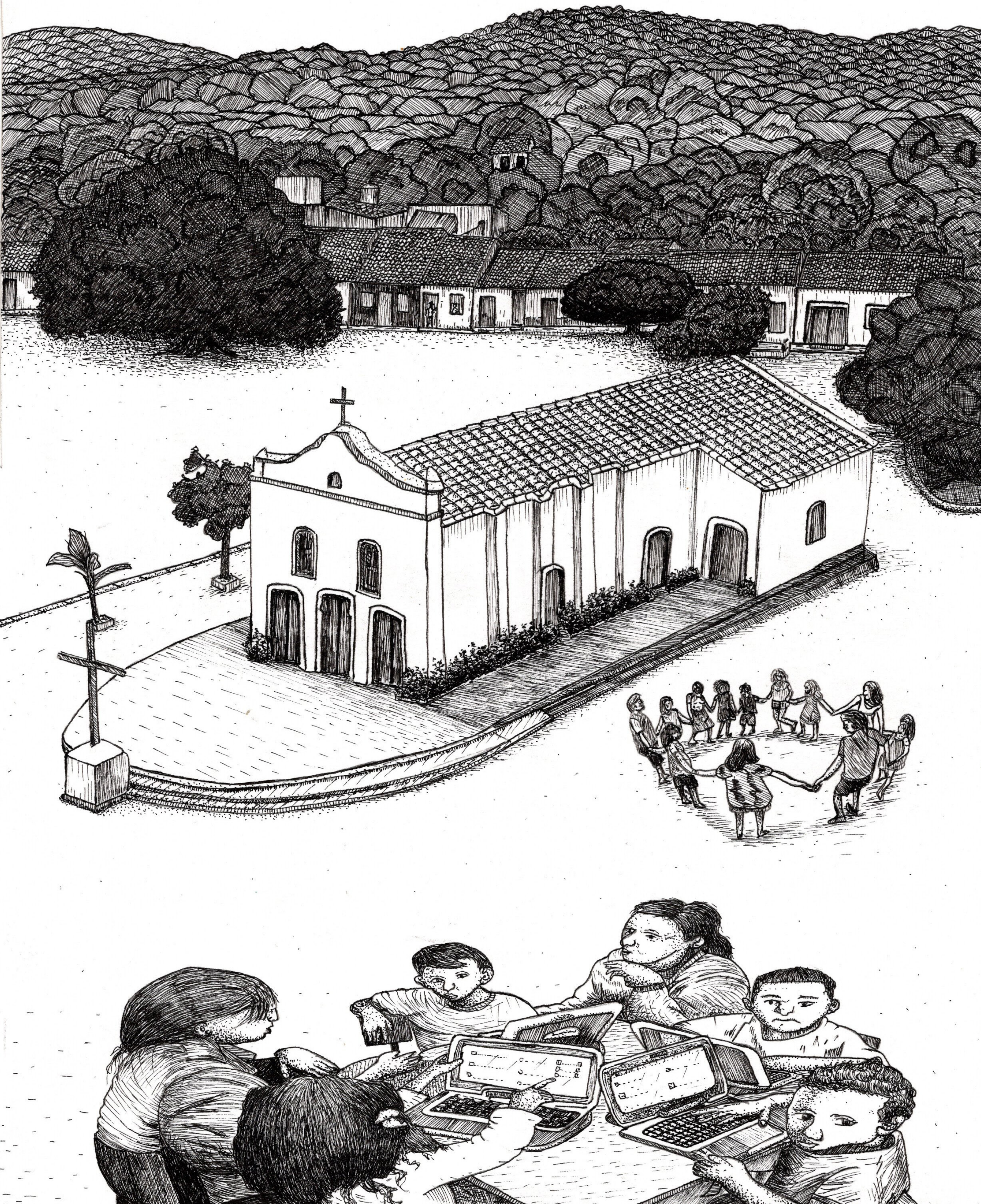
Note: Standard errors in parentheses. Errors clustered at the municipal level. Significance level: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. Log.: logarithm.

TABLE 17: CLIMATIC IMPACTS OF THE LAST MONTH AND THE LAST THREE MONTHS PRIOR TO PROVA BRASIL ON THE PORTUGUESE AND MATH PERFORMANCE OF 5TH-YEAR STUDENTS, 2017

Panel A: Semiarid				
	Log. Portuguese	Log. Portuguese	Log. Math	Log. Math
Drought in the month of test application	−0,0423***		−0,0341***	
	(0,0136)		(0,0115)	
Drought in the three months prior		−0,0668***		−0,0468**
		(0,0235)		(0,0188)
No. of observations	227.776	227.776	227.776	227.776
Panel B: outside the semiarid				
	Log. Portuguese	Log. Portuguese	Log. Math	Log. Math
Drought in the month of test application	−0,0207*		−0,0200*	
	(0,0125)		(0,0114)	
Drought in the three months prior		−0,00199		−0,00575
		(0,0104)		(0,0107)
No. of observations	284.946	284.946	284.946	284.946

Note: Standard errors in parentheses. Errors clustered at the municipal level. Significance level: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. Log.: logarithm.

In comparison to the previous century, one would expect a greater adaptation to climatic conditions in the Northeast region in contemporaneity. The available technologies and social assistance mechanisms would make this population less vulnerable than it once was. Evidently, there are still many adversities that, combined with a lower level of income and often with a low-quality public education system, can make it difficult to improve or even maintain educational performance in a difficult time such as a drought period. The years between 2012 to 2016 witnessed a long drought period; 2012, in fact, saw the greatest reduction in rainfall volume versus the historical average. Our estimates constitute evidence that this drought had negative impacts on the educational performance of children and young people who were either undergoing or had completed elementary school or high school.



5. Discussion and conclusions

The aim of this study was to analyze the impacts of extreme weather events on children, adolescents and young people. In this sense, we constructed a database encompassing rainfall, temperature, health and education data, using descriptive and econometric analyses to measure said impacts.

As we have shown, climate shocks and droughts are associated with worse health and educational indicators. More specifically, the occurrence of droughts causes an increase of 1.8 percentage points in infant mortality, 34 percentage points in prematurity, and 6.8 percentage points in the rate of underweightness at birth. Droughts can also hamper the consumption of drinking water, as well as the availability of water for hygiene and proper food handling. In fact, we found an increase of 12 percentage points in mortality from infectious diseases and 14.7 percentage points in mortality from diarrhea.

Educational performance was also significantly impacted by drought. For children in the 5th year of elementary school, the crossing of data from emergency decrees with educational data showed a −1.5% to −3% impact of droughts on math scores, and a −1% to −2% impact of droughts on Portuguese scores. When applying a methodology similar to that used when assessing health outcomes, the occurrence of drought had an impact of up to −4.7% and −6.7%, respectively, on the reduction of Prova Brasil mathematics and Portuguese scores.

These findings corroborate the national and international body of evidence on the effects of the climate and particularly of droughts on the population. It should be noted that, as we explained in this work's introduction, the effects shown here may be intensified in the coming years, with climate changes further affecting rainfall and temperature patterns worldwide. Furthermore, we were able to observe that the Northeast-region population residing in the semiarid area suffers much more deeply from climatic impacts than the rest of the population.

Lack of rainfall and drought affect children, adolescents and young people in diverse ways. First, the lack of water hinders hygiene, adequate hydration and the management and production of food. This has a direct impact on the health of pregnant women, causing problems affecting children's birth and development. Second, the lower consumption and absorption of nutrients and the lack of a balanced diet impair children's, adolescents' and young people's cognitive development, leading to learning difficulties. Third, water scarcity and high temperatures are associated with a higher prevalence of infectious and parasitic diseases. Finally, water scarcity limits families' available time, which may cause many children to be forced to help with daily work, directly impacting their health and reducing the time they dedicate to educational activities.

In this sense, to combat the impacts of drought, it is necessary to design public policies to assist the population of the most affected regions with properly collecting and storing water. This includes the provision of water trucks, the construction of cisterns and the transposition of rivers. However, these policies in themselves do not guarantee the overcoming of climate shocks. They must be accompanied by structural policies for coexistence with the Semiarid region aimed at ensuring that its population has access to basic health services, sufficient income, and quality education.

Local governments and legislators must be prepared to jointly build policies able to support capital financing, development and dissemination of technologies, collaboration and coordination of different sources of knowledge, and the strengthening of local leadership. In this way, society will be able to develop ways to mitigate the effects of droughts and climate change on health and education. Local public health officials have an essential role in increasing the population's resilience and reducing vulnerability to the health impacts of climate change and prolonged periods of drought.

5.1. HOW THESE RESULTS RELATE TO THE STUDY BY MACHADO FILHO ET AL. (2016): "CLIMATE CHANGE AND IMPACTS ON FAMILY AGRICULTURE IN THE NORTH AND NORTHEAST OF BRAZIL"

Considering this scenario, it is clear that the agricultural sector is one of the most sensitive to climatic variations, especially when it comes to family farming, which corresponds to a large part of agricultural production in Brazil. Thus, climate change can affect both national agricultural production and small farmers' food security: after all, most small farmers are in a situation of high social vulnerability, suffering strongly from climate variations.

Such factors are directly linked to the negative impacts on health and education found in this research. The reduction in family income due to climatic impacts on agricultural production has effects on food security, hygiene and basic sanitation. With all said and done, this form of vulnerability may have the greatest deleterious effects on children's and young people's mortality, malnutrition and educational performance.

Since we found evidence that both health and education are negatively impacted in periods of water stress, the prospect of greater climatic variability, more frequent droughts and higher temperatures in the coming years makes it crucial to implement measures for mitigating the likely negative effects of these climatic phenomena.

In this sense, Machado Filho et al. (2016) make some suggestions on how to contribute to increase the resilience of Northeasterners in regards to climatic variations. Among them, the authors refer to income transfer programs, improvements in the quality of the educational system, and investments in research and infrastructure, meant to increase productivity as well as access to (and efficient use of) water resources. Moreover, a more inclusive rural development plan through incentives to family farming would strengthen food security and the generation of income and employment.

5.2. RELATIONSHIP BETWEEN THIS STUDY'S RESULTS AND EARLY CHILDHOOD POLICIES

Several concepts related to child development have been construed in recent decades through independent research in areas such as economics, neuroscience and psychology. These studies' main conclusion is that the architecture of the brain and the skill-formation process are influenced by the interaction between genetics and individual experience (Heckman, 2006). More specifically, according to Unicef (2020), brain development requires good nutrition, stimuli through speech, games and activities that promote development, and parents or guardians to devote sufficient attention to their children. The importance of early childhood policies for child development was also recognized by the specialized journal The Lancet in 2016, when it published an issue focused on the theme (The Lancet, 2016).

Unicef argues that children who have undergone at least one year of pre-school are more likely to develop essential skills needed to perform well and are less likely to fail or drop out (Unicef, 2017). Because of these factors, the UN develops policies and actions focused on meeting goal 4 of the Sustainable Development Goals, namely: ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.

Thus, considering this study's findings, policies focused on early childhood become even more important in a context of high social vulnerability. The fact that children's health and education can be highly impacted by drought indicates that these policies are key to mitigate such impacts, which can be lifelong and have severe consequences on future employment and income, as studies on early childhood programs conducted in the USA (Heckman et al., 2013) and Jamaica (Gertler et al., 2014) suggest.

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List of abbreviations and acronyms

ICD	International Classification of Diseases
Cidacs	Centro de Integração de Dados em Saúde
CRED	Centre for Research on the Epidemiology of Disaster
Datasus	Unified Health System Department of Informatics
Enem	National High School Exam
IFAD	International Agricultural Development Fund
Fiocruz	Oswaldo Cruz Foundation
IBGE	Brazilian Institute of Geography and Statistics
BMI	Body mass index
Inep	National Institute for Educational Studies and Research "Anísio Teixeira"
ME	Ministry of Economy
OECD	Organization for Economic Cooperation and Development
WHO	World Health Organization
UN	United Nations
WAP	Working-age Population
Rais	Relação Anual de Informações Sociais
S2ID	Sistema Integrado de Informações sobre Desastres
Sedec	Secretaria Nacional de Proteção e Defesa Civil
SIHSUS	Hospital Information System of the Unified Health System
SIM	Mortality Information System
Sinasc	Live Birth Information System
Sisvan	Food and Nutrition Surveillance System
Sudene	Superintendency for the Development of the Northeast
SUS	Unified Health System
UFBA	Federal University of Bahia
Unesco	United Nations Educational, Scientific and Cultural Organization
Unicef	United Nations Children's Fund
UNISDR	United Nations Office for Disaster Risk Reduction
WDI	World Development Indicators
WHO	World Health Organization
WWDR	World Water Development Report

List of illustrations

FIGURES

CHARTS

TABLES