Artigo

The characteristics and behavior of the population in the face of droughts: a multivariate analysis of the municipalities in the upper valley of the sub-basin of the River Piracuruca (CE/PI)

Francílio de Amorim dos Santos
Federal Institute of Education, Science and Technology of Piauí, Piripiri, PI, Brazil
e-mail: francilio.amorim@ifpi.edu.br
0000-0002-0415-6673

Maria Lucia Brito da Cruz
Ceara State University, Fortaleza, CE, Brazil
e-mail: mlbcruz@gmail.com
0000-0002-2202-923X

p. 361-380

revista
GeoUSP
espaço e tempo
Volume 24 • nº 2 (2020)
ISSN 2179-0892

How to cite this article:
SANTOS, F. A,; CRUZ, M. L. B. The characteristics and behavior of the population in the face of droughts: a multivariate analysis of the municipalities in the upper valley of the sub-basin of the River Piracuruca (CE/PI). **Geousp – Espaço e Tempo** (On-line), v. 24, n. 2, p. 361-380, ago. 2020. ISSN 2179-0892.

Available at: https://www.revistas.usp.br/geousp/article/view/167227. doi: https://doi.org/10.11606/issn.2179-0892.geousp.2020.167227.

The characteristics and behavior of the population in the face of droughts: a multivariate analysis of the municipalities in the upper valley of the sub-basin of the River Piracuruca (CE/PI)

Abstract

This investigation analyzed the demographic variables, including age and gender structure, and education and income, by means of factor analysis and principal component analysis, in order to understand the characteristics and behavior of the populations in the upper valley municipalities in the sub-basin of the River Piracuruca, as a possibility for studying droughts. Involving a quantitative approach, this was a descriptive study that investigated the acquired information using statistical techniques, particularly linked to multivariate statistics and the use of principal component analysis. Through the methodology it was possible to extract four factors from amongst the 15 initial variables. Factor 1 (linked to monthly income, ability to read and write and age structure), and Factor 2 (associated with household income) contributed positively to reducing criticality, while Factor 3 (residents and no income) and Factor 4 (population density) contributed to increasing the level of criticality. Thus, by integrating these 4 Factors, it was identified that in 48.0% of the census tracts in the upper valley the criticality is high to very high, demonstrating the need for investments in strategic areas, in order to reduce the degree of criticality in the face of the occurrence of droughts.

Keywords: Hydrographic basin. Census tracts. Factor analysis. Droughts.

Características e comportamento da população frente às secas: estatística multivariada dos municípios do Alto Vale da Sub-bacia do Rio Piracuruca (CE/PI)

Resumo

A pesquisa analisa variáveis demográficas, de estrutura etária e de gênero, educacionais e de renda por meio de análise fatorial e de análise de componentes principais, para conhecer as características e o comportamento da população dos municípios do Alto Vale da Sub-bacia do Rio Piracuruca como possibilidade para estudar as secas. Com abordagem quantitativa, o estudo se configura como descritivo e tratou as informações recolhidas com técnicas estatísticas, sobretudo ligadas à estatística multivariada à análise de componentes principais. Essa metodologia permitiu extrair quatro fatores dentre as 15 variáveis iniciais. O Fator 1 (rendimento mensal, pessoas alfabetizadas e estrutura etária) e o Fator 2 (renda do domicílio) contribuíram positivamente para reduzir a Criticidade, enquanto o Fator 3 (pessoas residentes e sem rendimento) e o Fator 4 (densidade populacional) concorreram para aumentá-lo. Integrados, esses quatro fatores levaram à conclusão de que, em 48,0% dos setores do Alto Vale, a Criticidade é de alta a muito alta, evidenciando a necessidade de investimento em áreas estratégicas para reduzir esse grau de Criticidade frente à ocorrência de secas.

Palavras-chave: Bacia hidrográfica. Setores censitários. Análise fatorial. Secas.

Características y comportamiento de la población frente a las sequías: análisis multivariado de los municipios de Alto Vale en la subcuenca del río Piracuruca (CE/PI)

Resumen

La investigación buscó realizar análisis de variables demográficas, estructura de edad y género, educación e ingresos, a través del análisis factorial y el método de análisis de componentes principales, para comprender las características y el comportamiento de la población de los municipios del Valle Superior de la Subcuenca del Río Piracuruca, como una posibilidad para estudiar sequías. El estudio se configura como descriptivo, exhibe un enfoque cuantitativo y utiliza técnicas estadísticas para manejar la información adquirida, particularmente vinculada a estadísticas multivariadas y el uso del análisis de componentes principales. A través de la metodología, fue posible extraer 4 Factores entre las 15 variables iniciales, donde el Factor 1 (vinculado al ingreso mensual, las personas alfabetizadas y la estructura de edad) y el Factor 2 (asociado con el ingreso del hogar) contribuyeron positivamente a la reducción de la Criticalidad, mientras que El factor 3 (residente y sin ingresos) y el factor 4 (densidad de población) contribuyeron a aumentar el nivel de criticidad. Por lo tanto, cuando se integran estos 4 Factores, se identificó que en el 48.0% de los sectores de Alto Vale hay una Criticalidad de alta a muy alta, lo que demuestra la necesidad de inversiones en áreas estratégicas para reducir el grado de Crítica ante la ocurrencia de sequías.

Palabras clave: Cuenca hidrográfica. Sectores censales. Análisis factorial. Secado.

Introduction

According to Rebouças (1997), the Brazilian semiarid region exhibits the following edaphoclimatic characteristics: periodic droughts, frequent flooding of intermittent rivers, as well as sandy, shallow, saline soils, poor in nutrients essential to plant development. Within this context, Ab'Saber (2003) highlighted that the factor, which most plagues the social space, daily life and countryside families is periodic climatic irregularities, particularly in drought years.

It is important to emphasize that, from the time of the settlement process, the population of Northeastern Brazil (NEB) has been affected by drought events, which hit the low-income population more intensely. It should be noted that, according to the civil defense, a drought is defined as a prolonged period with little or no rain, long enough to cause a severe hydrologic imbalance within a given region (Brazil, 2014).

Based on this scenario, government agencies were created, and public policies have sought to mitigate the effects of periodic droughts. Initially outstanding was the creation of the Inspectorate of Works Against Drought (IOCS)[1], through Decree No. 7,619, on October 21, 1909, the main objective of which was to study the problem of droughts in the semiarid region (Brazil, 1909).

Subsequently, the IOCS changed its name to the National Department of Works Against Drought (DNOCS), on the occasion of Decree No. 8,486, on December 28, 1945, which defined its purposes as being the improvement of areas and works to protect against droughts and floods; irrigation; population settlement in irrigation communities or in special areas; providing assistance to populations affected by public disasters and cooperation with municipalities (Brasil, 1945; DNOCS, 2016).

During this initial period, from the viewpoint of combating droughts, government policy, through the DNOCS, concentrated on constructing a number of reservoirs in the semi-arid

1 The acronyms used herein for Brazilian institutions refer to the Portuguese terms used in Brazil.

region in the Northeast of Brazil. However, this reservoir policy proved to be inefficient for food production and served more as a bargaining chip used by the agrarian oligarchy to obtain votes, a fact that became known as the "drought industry" (Cabral, 2011).

Based on this, the Superintendency for the Development of the Northeast (SUDENE) was created, and covered an operational area within a region referred to as the drought polygon, which comprises the nine northeastern states, and the northern parts of the states of Minas Gerais and Espírito Santo (Araújo, 2015). This body was created through Law No. 3,692, on December 15, 1959, with the purpose of: studying and proposing guidelines for the development of the Northeast; supervising, coordinating and controlling and executing development projects under the charge of federal agencies in the region; executing projects, either directly or by means of an accord, agreement or contract, related to the development of the Northeast; coordinating technical assistance programs, national or international, for the Northeast (Brazil, 1959).

Within the scope of the semiarid region, the network known as Articulação do Semiárido Brasileiro [Linking the Brazilian Semiarid Region] (ASA) was created in 1999, which defends, propagates and puts into practice the political project for living with the semiarid region, whose members are organized into forums and networks throughout the ten states that make up the Brazilian semiarid region, and is based on the philosophy of living with its characteristics (ASA Brasil, [sd]).

Also of note is the creation of the National Semi-Arid Institute (INSA), through Law No. 10,860, on April 14, 2004, a research unit linked to the Ministry of Science, Technology, Innovations and Communications, the priority of which was to promote scientific and technological development and integrate the socioeconomic poles and strategic ecosystems of the Brazilian semiarid region (Brazil, 2004a).

Also worthy of mention is the creation of the National Action Program to Combat Desertification and Mitigate the Effects of Drought (PAN-Brazil), in 2004, which, with a view to combating drought and focusing on sustainable development, contained the general objective of establishing guidelines and legal and institutional instruments to formulate and execute public policies and private investments in areas susceptible to desertification (ASD) (Brasil, 2004b).

In view of the relevance and historical complexity of the theme, studying hydrographic basins is of extreme importance, in this case, taking as the spatial cross-section the upper course of the hydrographic sub-basin of the River Piracuruca, located between the states of Ceará and Piauí. In this area, according to Santos (2019), between 1985 and 2016, there were eight dry years, seven very dry years and two extremely dry years. This fact indicates the need to study the characteristics of the resident population as a perspective of integrating information that enables the improvement of their quality of life and enables them to expand their ability to live with semi-arid conditions. The relevance of the study, although incipient, should also be emphasized, both from the thematic and methodological viewpoints.

Thus, the research may be classified as descriptive with regard to its objective, and used multivariate statistics, with the application of principal component analysis (PCA) and factor analysis (FA) in order to select variables and to reduce data, respectively. Mingoti (2005) states that, in general, the proposal of PCA is to reduce the number of variables with which it works and assesses, so as to clarify the structure, variance and covariance of a random vector. For Rogerson (2012), when working with many variables, PCA reduces the number of data, since it enables the construction of factors that correspond proportionally to the variability of the data set. Therefore, the study was based on the methodological proposal suggested by Cunha et al. (2011), considering only the use of criticality (C) to recognize the behavior and characteristics of the population in terms of reacting to droughts.

Hence, criticality is defined as the set of characteristics and behaviors of individuals that may disrupt the system or the resources of communities to react to disasters (Mendes et al., 2011), in this study, droughts. Mendes (2018) adds that the territorial system also presents a set of resources that allows the population to face episodes of natural disasters.

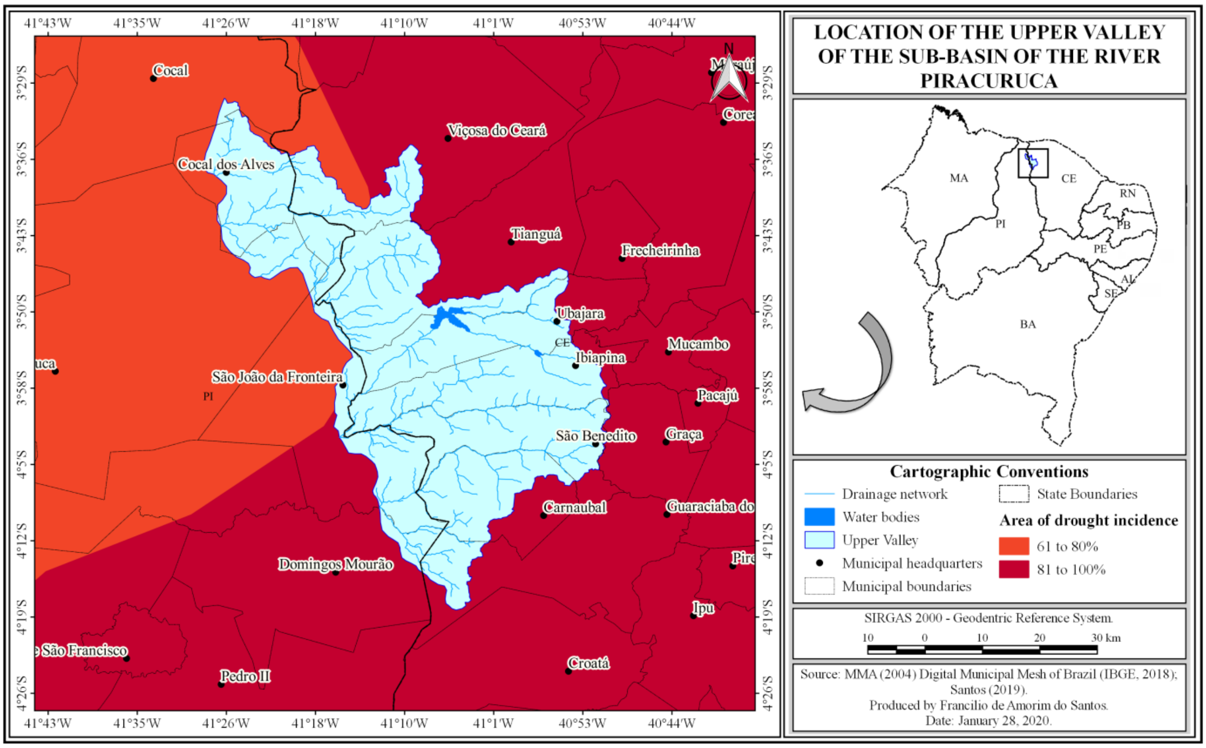
The relevance is reiterated of using statistical techniques to analyze socioeconomic information in a semi-arid region, and the study has focused on demographic variables, including education and income, age and gender structure, applying FA and PCA to identify the characteristics and behavior of the population in the municipalities of the upper valley of the sub-basin of the River Piracuruca as a possibility of studying droughts.

Material and methods

The study area

The upper valley of the hydrographic sub-basin of the River Piracuruca (AVSBHRP) is on the border of Ceará with Piauí, in a semi-arid region and subject to the incidence of droughts (Figure 1). It should be noted that, according to data from the Ministry of the Environment (MMA, 2004), in the studied section, droughts occur in a proportion of 61% to 100%.

Figure 1 - Location of the upper valley of the sub-basin of the River Piracuruca, on the border between the states of Ceará and Piauí



Sources: MMA (2004), IBGE (2018) and Santos (2019).
Organized by the authors.

The AVSBHRP is located entirely on the Ibiapaba Plateau and comprises 37.7% (2,904.4 km2) of the total area of the sub-basin of the River Piracuruca. The upper valley drains areas from seven municipalities in Ceará (Carnaubal, Guaraciaba do Norte, Ibiapina, São Benedito, Tianguá, Ubajara and Viçosa do Ceará) and five in Piauí (Cocal, Cocal dos Alves, Domingos Mourão, Piracuruca and São João da Fronteira). However, only the municipal headquarters of Cocal dos Alves, Ibiapina, São Benedito, São João da Fronteira and Ubajara are actually located within the AVSBHRP.

It is important to highlight that the upper valley is in the area of influence of the Intertropical Convergence Zone (ITCZ), which operates mainly between the months of March and April, constituting the main atmospheric system that provides rain in the north of the Northeast of Brazil (NEB). The position of the ITCZ is associated with the global phenomena El Niño – Southern Oscillation (ENSO) and the Atlantic Dipole, important in the configuration of years with normal or anomalous precipitation.

The ITCZ corresponds to a band of clouds formed by the convergence of the northeast trade winds of the subtropical high pressure system from the northern hemisphere with the southeast trade winds, originating from the high subtropical southern hemisphere (Molion; Bernardo, 2000; Varejão-Silva , 2006).

In turn, El Niño, which concerns the warming of the surface waters of the Pacific Ocean, around Ecuador, promotes the prevention of cloud formation and the descent of the ITCZ (Ferreira; Mello, 2005). Meanwhile, the positive phase of the Dipole occurs when the waters of the South Atlantic are colder than those of the North Atlantic and therefore configures an unfavorable gradient towards the occurrence of rain.

The joint or individual occurrence of El Niño and the positive phase of the Atlantic Dipole interfere with the position of the ITCZ, and thus prevents the descent of this atmospheric system to its northernmost position (Ferreira; Mello, 2005). This results in the occurrence of dry years in different proportions in the Northeast of Brazil, particularly where the upper valley of the sub-basin of the River Piracuruca is located.

Methodological Procedure

The research is classified as descriptive, since it proposes to integrate variables as a possibility of identifying the characteristics and behavior of the populations in the municipalities of the upper valley of the sub-basin of the River Piracuruca and of studying droughts. The approach is quantitative, since it employs statistical techniques to address the information obtained. The methodology proposed by Cunha et al. (2011) was adapted, because only the element of criticality (C) was used to identify the characteristics and behavior of the population to react to droughts.

Thus, data were collected on 15 variables linked to the conditions of demographics, age and gender structure, education and income (Table 1), from the 2010 Census, together with the database of the Brazilian Institute of Geography and Statistics (IBGE, 2010b, 2010c), from the 204 census tracts (127 rural tracts and 77 urban tracts) in the upper valley of the sub-basin. These variables were selected considering their impact on either mitigating or accentuating the conditions of being able to react to droughts. Thus, areas with a large population, people of extreme age (children or older people), low levels of education and low income exhibit a higher level of criticality.

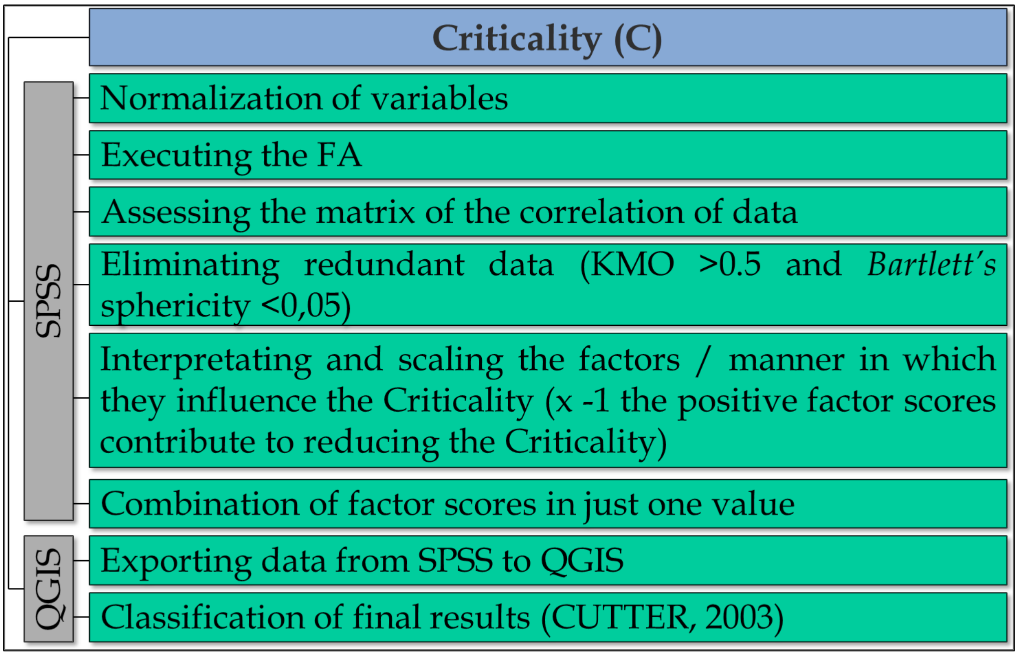
Table 1 – Variables used to analyze the characteristics and behavior of the population in the face of droughts in the upper valley municipalities in the sub-basin of the River Piracuruca

Thematic block	Code	Variable
Demographics	V01	Resident population
	V02	Density of permanent private households
	V03	Population density
Age and gender structure	V04	People aged 0 to 5 years
	V05	Resident population aged 65 years or over
	V06	Responsible females
	V07	Responsible males
Schooling	V08	People able to read and write aged 5 years or more
	V09	Responsible males able to read and write
Income	V10	Total monthly nominal income of permanent private households
	V11	Total monthly nominal income of improvised private households
	V12	Responsible people with no monthly nominal income
	V13	Responsible people with a monthly nominal income of 1/2 to 1 minimum salary
	V14	Responsible people with a monthly nominal income of 1 to 2 minimum salaries
	V15	Responsible people with a monthly nominal income of more than 5 to 10 minimum salaries

Source: Produced by the authors, 2020.

SPPS Statistics 17.0 was used for procedures related to the proposed methodology. Thus, initially, the data for the 15 previously selected variables were standardized, i.e., the initial values were converted into percentages. Afterwards, the PCA method was applied to reduce the amount of data to a manageable size (Field, 2009; Rogerson, 2012). The applied methodology comprises eight stages (Figure 2), according to the proposal by Cunha et al. (2011).

Figure 2 – Routines used for the factor analysis (FA) and principal component analysis (PCA) of the criticality (C) of the upper valley of the hydrographic sub-basin of the River Piracuruca.



Source: Adapted from Cunha et al. (2011).

The factor analysis also applied the Varimax orthogonal rotation method with Kaiser normalization to select variables with a common value ≥ 0.5. Subsequently, the following tests were carried out to validate the model: the Kaiser-Meyer-Olkin (KMO) test, which varies from 0 to 1, whereby the closer to 1 the better the model; and the Bartlett's test of sphericity, which should present a significance <0.05.

These procedures were performed in SPSS Statistics, using the Analyze tool and Dimension Reduction → Factor function. Thus, the characteristics and behavior of the population, synthesized through the criticality for each census tract in the upper valley of the sub-basin were calculated from the main factor, due to their positive or negative influence on the results obtained in this analysis according to Equation 1:

$$C = (-F1) + (-F2) + F3 + F4 \qquad \text{[Equation 1]}$$

Where:

- Fn are criticality factors resulting from FA/PCA
- n = 1 to 4

Thus, the C values for each of the census tracts inserted into the upper valley of the surveyed sub-basin were exported, in excel format (* .csv), to the work platform at QGIS, where these data were gathered with the vector file census tracts. Once completed, it was possible to classify, using the Jenks natural breaks classification method, taking into account the intervals presented in Table 2.

Table 2 – Intervals, assigned classes and criticality scores (C) of the census tracts within the limits of the upper valley of the hydrographic sub-basin of the River Piracuruca – 2010

C interval	Attributed class	Score
-8.8851 to -2.7672	Very low	1
-2.7672 to -0.4016	Low	2
-0.4016 to 1.2121	Medium	3
1.2121 to 3.9970	High	4
3.9970 ato10.0723	Very high	5

Source: Produced by the author.

Results and discussion

In the first round of tests to analyze the criticality of the upper valley of the sub-basin of the River Piracuruca, the variable z011 (total monthly nominal income of improvised private households) was eliminated, since its commonality coefficient was below 0.5, specifically 0.282. The new round resulted in satisfactory commonality values, since all variables presented values of above 0.5. Thus, the Varimax orthogonal rotation enabled the variables that best correlated with the selected factors to be selected (Table 3).

Therefore, it may be stated that the four factors listed explain 87.490% of the accumulated variance, when considering the census tracts located in the upper valley of the sub-basin of the River Piracuruca. It is reiterated that the factor loads were greater than 0.50 in all variables (the relevant factor loads are in bold), with emphasis on z03 (population density), which exhibited the greatest commonality, i.e., 99.6% of its variability is explained by the factors.

The final model, with 14 variables, was validated by the KMO test, whose value was 0.717, while the Bartlett's test of sphericity obtained significance (Sig.) At 0.00, less than 0.05 (Table 4). Thus, the model obtained was considered adequate, as well as the models presented in the studies by Mendes et al. (2011) and Bortoletto (2016), whose KMO values were greater than 0.7 and the Bartlett's test of sphericity, less than 0.05.

Table 3 – Factor loads after Varimax rotation and the obtained commonality in the factor analysis of variables for criticality (C) of the census tracts in the upper valley of the hydrographic sub-basin of the River Piracuruca.

Variable	Factor				Commonality
	1	2	3	4	
z01	0.920	0.140	0.299	-0.19	+0.955
z02	0.045	0.127	-0.069	0.986	+0.995
z03	0.053	0.113	-0.070	0.988	+0.996
z04	0.592	0.150	0.586	-0.036	+0.718
z05	0.086	-0.020	0.878	-0.066	+0.782
z06	0.573	0.318	0.379	0.170	+0.601
z07	0.925	0.131	0.171	-0.061	+0.906
z08	0.913	0.292	0.227	0.050	+0.972
z09	0.856	0.402	0.038	0.113	+0.908
z010	0.542	0.815	0.007	0.111	+0.971
z012	0.162	-0.094	0.854	-0.076	+0.771
z013	0.948	0.077	0.008	0.080	+0.911
z014	0.578	0.667	-0.032	0.187	+0.815
z015	0.088	0.962	-0.045	0.106	+0.947
eigenvalues	7.067	2.616	1.497	1.069	
% explained variance	50.481	18.683	10.691	7.635	
% cumulative variance	50.481	69.165	79.856	87.490	

Source: Produced by the authors.

This model considered the total variation of the data, and the choice of the number of factors was based on the Kaiser criteria, by which the eigenvalues must be ≥ 1, the percentage of the explained variance (Table 5) and the scree-plot graph (Figure 3).

Table 4 – The KMO and Bartlett tests used to analyze the criticality (C) of the census tracts in the upper valley of the hydrographic sub-basin of the River Piracuruca

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.717
Bartlett's Test of Sphericity	Approx. Chi-Square	5150.004
	Df	91
	Sig.	0.000

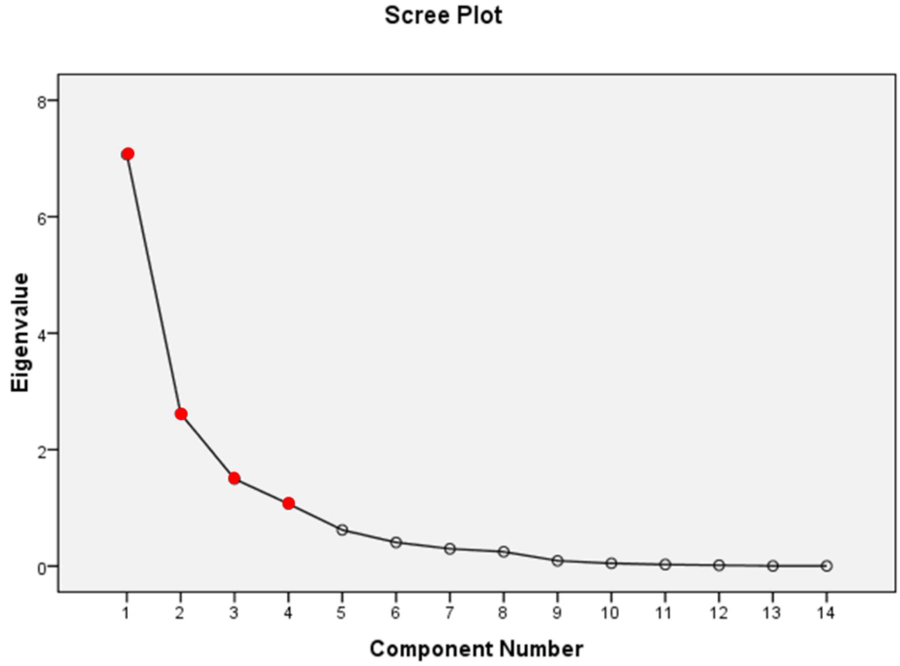
Source: Produced by the authors.

Table 5 – Total variance explained by factor, according to extraction by the FA/PCA of the criticality

Factor	Initial eigenvalue			Sum of the rotation of factor loads		
	Total	% of variance	% accumulated variance	Total	% of variance	% accumulated variance
1	7.067	50.481	50.481	5.519	39.419	39.419
2	2.616	18.683	69.165	2.486	17.758	57.178
3	1.497	10.691	79.856	2.171	15.510	72.687
4	1.069	7.635	87.490	2.072	14.803	87.490

Source: Produced by the authors.

Figure 3 – The red dots represent the retention of the four factors that make up the factor analysis of criticality (C)



Source: Produced by the authors.

The factors for the factor analysis/principal component analysis (FA/PCA) were selected from the Kaiser criteria, which consider eigenvalues greater than or equal to 1. The percentage of explained variance is demonstrated in Table 6, where it may be observed that the four factors explain 86.209% of the accumulated variance in the census tracts located in the sub-basin of the River Piracuruca.

The variables with the highest correlation for Factor 1, which integrated the criticality analysis, are presented in Table 6, where it may be observed that Factor 1 corresponds, particularly, to the variables associated with the condition of responsible people with a monthly income, responsible people able to read and write and age structure. In this Factor, the variable z013 is outstanding (responsible people with a monthly nominal income of 1/2 to 1 minimum salary), whose commonality value was +0.948, which indicates its greatest influence on this Factor and allows us to affirm that it expands the potential response when droughts occur.

Table 6 – A summary of the most correlated variables for Factor 1 in the upper valley of the hydrographic sub-basin of the River Piracuruca - 2010

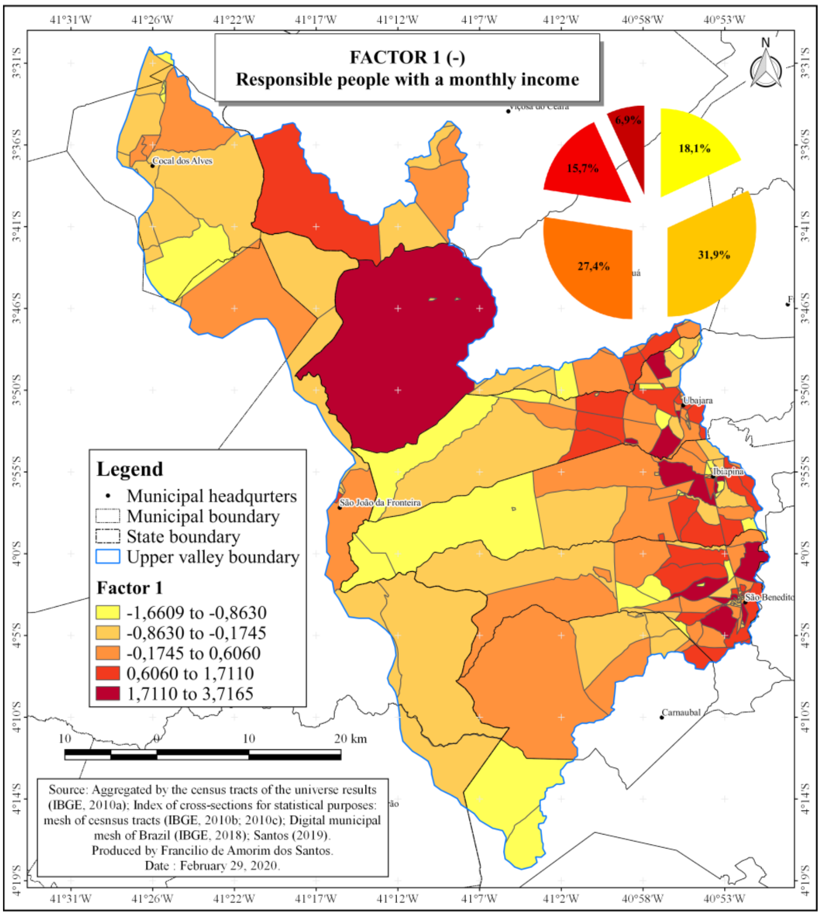
Factor (sign)	Most influential variable
1 (–) Responsible people with monthly income, able to read and write, resident population and age structure	z013 – Responsible people with a monthly nominal income of 1/2 to 1 minimum salary (+0.948)
	z07 – Responsible males (+0.925)
	z01 – Resident population (+0.920)
	z08 – People able to read and write aged 5 years of over (+0.913)
	z09 – Males able to read and write (+0.856)
	z04 – People aged 0 to 5 years (+0.592)
	z06 – Responsible females (+0.573)

Source: Produced by the authors.

The seven variables grouped in Factor 1 demonstrated a high, positive correlation, and the negative sign of this factor indicated a positive influence of the variables in reducing the criticality in the upper valley of the studied sub-basin. Thus, income and education stand out as variables that may contribute to expanding the different manners of reacting to periods of drought in the area surveyed.

Thus, the data related to the seven variables that integrated Factor 1 (-) were spatialized, as revealed in Figure 4, where a predominance may be observed of class -0.8630 to -0.1745, which occurs for 65 (31.9%) census tracts in the upper valley of sub-basin. The other classes occur as follows: -0.1745 to 0.6060, which is distributed over 56 (27.4%) tracts of the upper valley of the sub-basin; -1.6609 to -0.8630, which was frequent in 37 (18.1%) tracts; 0.6060 to 1.7110, identified in 32 (15.7%) and 1.7110 to 3.7165, present in 14 (6.9%). With regard to droughts, it may be inferred that 50% of the tracts in the upper valley present low criticality to resist the occurrence of droughts, i.e., the population that occupies these sectors presents characteristics that allow it to react to this type of disaster.

Figure 4 – Spatialization of values linked to Factor 1 by census tract in the hydrographic sub-basin of the River Piracuruca – 2010.



Source: IBGE (2010a, 2010b, 2010c, 2018) and Santos (2019).
Organized by the authors.

Table 7 presents the variables linked to Factor 2, which refers to the monthly nominal income. In Factor 2, the variable z010 (total of the monthly nominal income of permanent private households) stands out, which presented a common value of +0.854, a fact that makes it possible to improve the response of the population to the occurrence of droughts. Thus, it may be stated that the three variables linked to Factor 2 have a high, positive correlation, whose negative sign is due to the fact that the variables contribute to reducing criticality in the upper valley of the studied sub-basin.

Figure 5 presents the spatialized values of the three variables that integrated Factor 2 (-), where the predominance may be identified of class -1.1721 to -0.3526, the occurrence of which occurs in 90 (41.1%) census tracts of the upper valley in the sub-basin. In the sequence, the following classes appear: -0.3526 to 0.1878, 0.1878 to 1.2987, 1.2987 to 3.8229 and 3.8229 to 7.6624, which occurred respectively in 75 (36.8%), 20 (9.8%), 17 (8.3%) and 2 (1.0%) census tracts. This factor is directly linked to the monthly nominal income of the resident population: the higher the income of the population, the greater the potential for reacting to droughts, since it will increase their chances of acquiring food, clothing, medicines, etc.

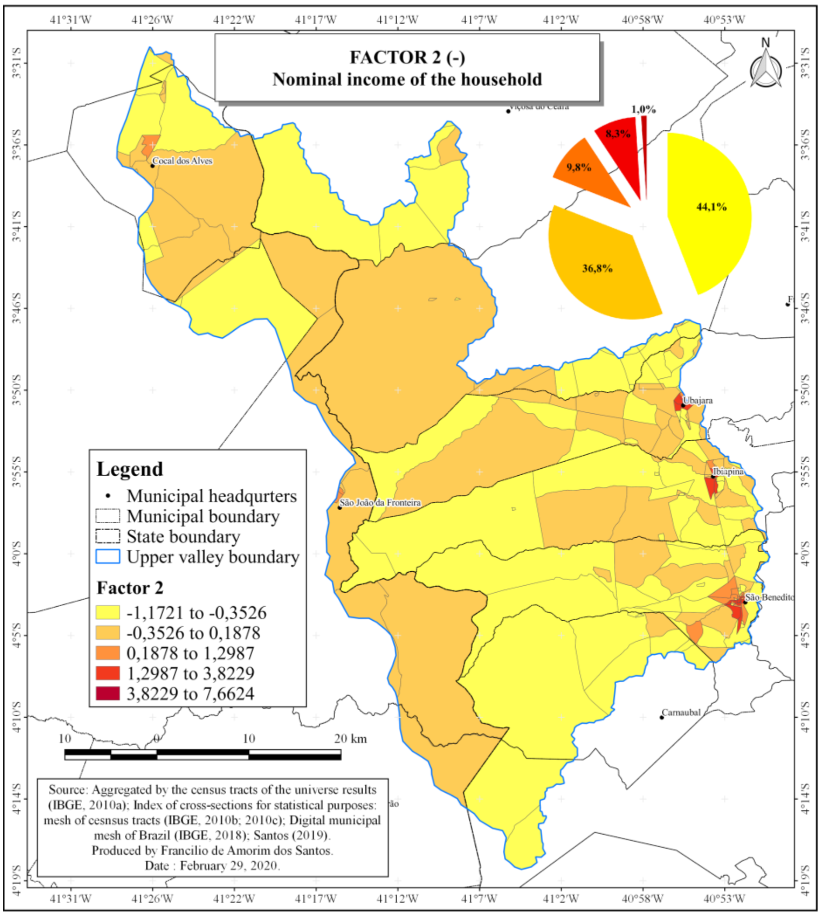
Table 7 – A summary of the variables with the highest correlation for Factor 2 in the upper valley of the hydrographic sub-basin of the River Piracuruca - 2010

Factor (sign)	Most influential variables
2 (–) nominal income of the household	z010 – Total monthly nominal income in permanent private households (+0.854)
	z014 – Responsible people with monthly nominal income of 1 to 2 minimum salaries (+0.667)
	z015 – Responsible people with monthly nominal income of more than 5 to 10 minimum salaries (+0.962)

Source: Produced by the authors.

Factor 3 integrated only two variables for the criticality analysis, which are directly related to residents and those with no income (Table 8), with the variable z05 (people aged 65 and over) prevailing, which exhibited a commonality of +0.878. The two variables of this factor demonstrated a high, positive correlation, where the positive sign is due to these variables increasing the critical potential of the upper valley of the studied sub-basin in relation to the occurrence of droughts.

Figure 5 - Spatialization of values linked to Factor 2 by census tract in the hydrographic sub-basin of the River Piracuruca – 2010



Source: IBGE (2010a, 2010b, 2010c, 2018) and Santos (2019).
Organized by the authors.

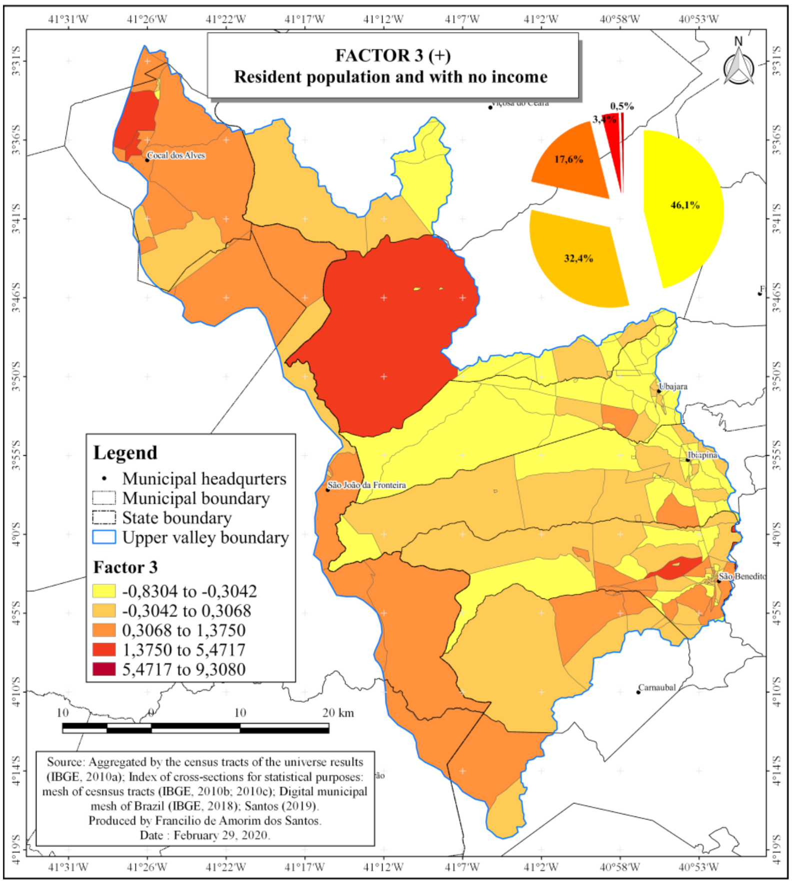
Table 8 – A summary of the variables with the highest correlation with Factor 3 in the upper valley of the hydrographic sub-basin of the River Piracuruca - 2010

Factor (sign)	Most influential variables
3 (+) Residents and with no income	z05 – Resident population aged 65 years and over (+0.878)
	z012 – Responsible people with no income (+0.854)

Source: Produced by the authors.

The values of the two variables that were grouped in Factor 3 (+) are spatialized in Figure 7, where the predominance is observed of class -0.8304 to -0.3042, which occurred in 94 (46.1%) census tracts in the upper valley of the sub-basin. It should be noted that the other classes had the following distribution: -0.3042 to 0.3068, with a frequency of 66 (32.4%) census tracts; 0.3068 to 1.3750, which occurred in 36 (17.6%) tracts of the upper valley of the sub-basin; 1.3750 to 5.4717, which was identified in 7 (3.4%) tracts; 5.4717 to 9.3080, which is present in 1 (0.5%) tract of the upper valley of the analyzed sub-basin. It is necessary to draw attention to the fact that the presence of people aged ≥ 65 years, with more limited mobility, and people with no income, with little purchasing power, in the upper valley, indicate a less agile response to the occurrence of droughts.

Figure 6 – Spatialization of values linked to Factor 3 by census tract in hydrographic sub-basin of the River Piracuruca - 2010



Sources: IBGE (2010a, 2010b, 2010c, 2018) and Santos (2019).
Organized by the authors.

The two variables that make up Factor 4 are linked to population density (Table 9), where the variable z03 (population density) stands out, whose commonality value was +0.988. The two variables that make up Factor 4 demonstrated a high, positive correlation, while their positive sign is related to the fact that these variables reduce the potential of the population to react to drought in the upper valley of the sub-basin.

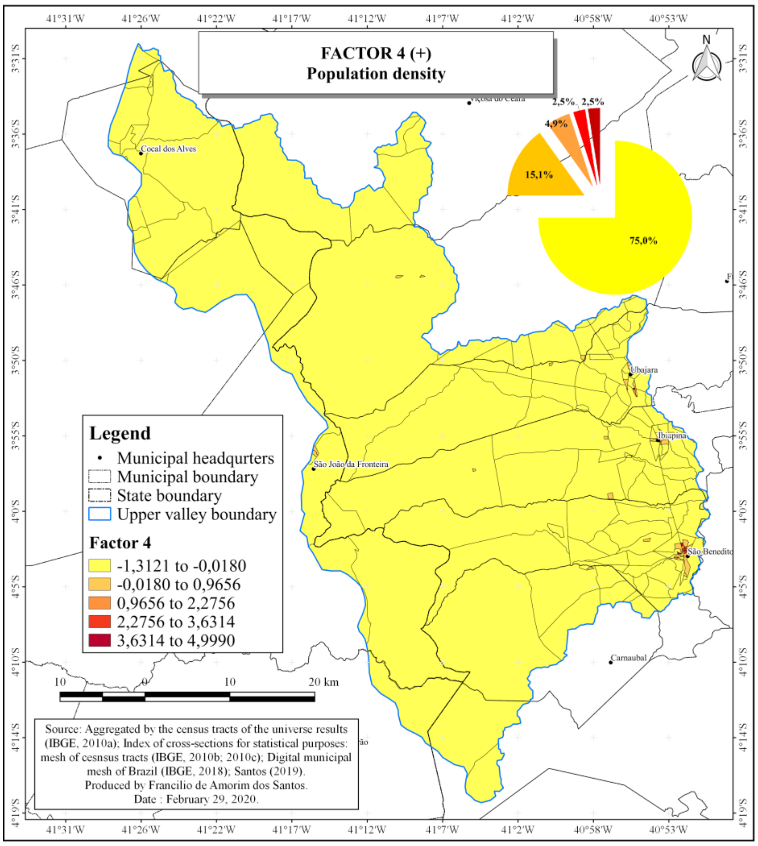
Table 9 – A summary of the most correlated variables for Factor 4 in the upper valley of the hydrographic sub-basin of the River Piracuruca – 2010

Factor (sign)	Most influential variables
4 (+) Population density	z03 – population density (+0.988)
	z02 – Density of permanent private households (+0.986)

Source: Produced by the authors.

Figure 7 presents the spatialized values of the two variables that integrated Factor 4 (+), and the prevalence of class -1.3121 to -0.0180, which occurred in 153 (75.0%) census tracts in the upper valley of the sub-basin. The other classes had the following frequencies: -0.0181 to 0.9656 in 31 (15.1%) census tracts; 0.9656 to 2.2756 in ten (4.9%) tracts; 2.2756 to 3.6314 and 3.6314 to 4.9990 together comprised ten tracts (5.0%). With regard to Factor 4, the upper valley has few tracts with a high population density, which enables this population to react better to drought situations.

Figure 7 – Spatialization of the values linked to Factor 4 by census tract in the hydrographic sub-basin of the River Piracuruca – 2010

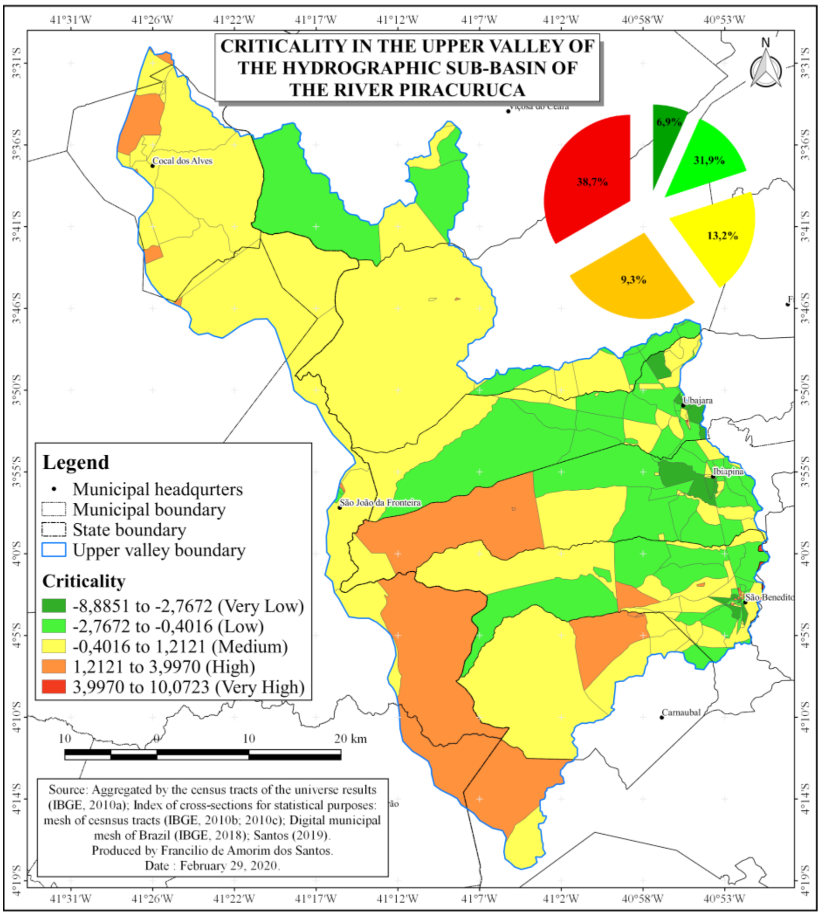


Sources: IBGE (2010a, 2010b, 2010c, 2018) and Santos (2019).
Organized by the authors.

SANTOS, F. A.; CRUZ, M. L. B.

The four factors analyzed were integrated and made it possible to estimate the criticality in the upper valley of the sub-basin of the River Piracuruca, values of which are spatialized in Figure 8, where it may be verified that the very high criticality class (3.9970 to 10.0723) predominates, which was identified in 79 (38.7%) of the census tracts. In turn, 65 (31.9%) of the census tracts were classified as having low criticality (-2.7672 to -0.4016), while the middle class (-0.0406 to 1.2121) is present in 27 (13, 2%) tracts. The classes of high (1.2121 to 3.9970) and very low (-8.8851 to -2.7672) criticality are spread across 19 (9.3%) and 14 (6.9%) of the census tracts in the upper valley, respectively.

Figure 8 – Criticality by census tract in the upper valley of the hydrographic sub-basin of the River Piracuruca – 2010



Sources: IBGE (2010a, 2010b, 2010c, 2018) and Santos (2019).
Organized by the authors.

Thus, generally speaking, there is a clear need for investment in various census tracts, and also to pay attention to elementary indicators, such as income and education, given that 98 (48.0%) of the census tracts in the upper valley present high criticality with respect to droughts. As this is a frequent phenomenon in the studied area, investments must be continuous and aimed at serving the population with the most critical characteristics, as indicated herein.

Conclusions

It should be noted that the study has achieved its objective and was of paramount importance in ratifying the applied methodology. Thus, it is confirmed that statistics and computer programs may be applied to geographic studies, particularly those related to drought, by analyzing the variables of demographics, age and gender, and education and income, and may also be applied to other areas.

It was possible to individualize four factors extracted from the 15 initial variables. Factor 1 (monthly income, people able to read and write and age structure) and Factor 2 (household income) had a positive influence in reducing criticality. Factors 3 (resident and with no income) and 4 (population density) contributed to increasing the criticality of the upper valley.

It was verified that the criticality in 48.0% of the upper valley tracts was confirmed as being high or very high, so that investments in strategic areas, such as education and income, would be a prospect for reducing the level of criticality towards the occurrence of droughts. On the other hand, the need for further studies is also emphasized for a systemic knowledge of the environmental characteristics of the upper valley, which will enable the integration of this information to support environmental planning in the area.

Finally, it is important to stress that, through the methodology employed, the intensity of social inequality and its impact on the way the population reacts to the occurrence of droughts in the upper valley of the sub-basin of the River Piracuruca may be evidenced. Thus, by considering information that is available in a free access database, with the necessary adaptations, the methodological proposal adopted may be applied to other environments, and not only to the Brazilian semiarid region.

References

AB'SABER, A. N. **Os domínios de natureza do Brasil:** potencialidades paisagísticas. São Paulo: Ateliê, 2003.

ARAÚJO, G. F. **A trajetória da Sudene, suas (re)invenções, na condução do projeto de desenvolvimento regional**. Dissertação (Mestrado em Geografia) – Universidade Federal de Sergipe, São Cristóvão, 2015.

ASA BRASIL. ARTICULAÇÃO SEMIÁRIDO BRASILEIRO. **História**. Disponível em: http://www.asabrasil.org.br. Acesso em: 6 fev. 2019.

BORTOLETTO, K. C. **Estudo das vulnerabilidades social e ambiental em áreas de riscos de desastres naturais no município de Caraguatatuba-SP**. Tese (Doutorado em Geografia) – Instituto de Geociências e Ciências Exatas, Universidade Estadual Paulista, Rio Claro, 2016.

BRASIL. Ministério da Integração Nacional. Secretaria Nacional de Defesa Civil. Centro de Nacional de Gerenciamento de Riscos e Desastres. **Anuário brasileiro de desastres naturais**: 2013. Brasília: Cenad, 2014.

BRASIL. Lei n. 10.860, de 14 de abril de 2004. Dispõe sobre a criação do Instituto Nacional do Semi-Árido – INSA, unidade de pesquisa integrante da estrutura básica do Ministério da Ciência e Tecnologia, e dá outras providências. Brasília: MCT, 2004a.

BRASIL. Ministério do Meio Ambiente. Secretaria de Recursos Hídricos. **Programa de Ação Nacional de Combate à Desertificação e Mitigação dos Efeitos da Seca – PAN-Brasil**. Brasília: MMA, 2004b.

BRASIL. Lei n. 3.692, de 15 de dezembro de 1959. Institui a Superintendência do Desenvolvimento do Nordeste e dá outras providências. Rio de Janeiro: Presidência da Casa Civil, 1959.

BRASIL. Decreto-Lei n. 8.486, de 28 de dezembro de 1945. Dispõe sobre a reorganização da Inspetoria Federal de Obras Contra as Secas (Ifocs), que passa a denominar-se Departamento Nacional de Obras Contra as Secas (Dnocs). Rio de Janeiro: Câmara dos Deputados, 1945.

BRASIL. Decreto n. 7.619, de 21 de outubro de 1909. Aprova o regulamento para organização dos serviços contra os efeitos das secas. Rio de Janeiro: Câmara dos Deputados, 1909.

CABRAL, R. 1959: das ideias à ação, a Sudene de Celso Furtado – oportunidade histórica e resistência conservadora. **Cadernos do Desenvolvimento**, Rio de Janeiro, v. 6, n. 8, p. 17-34, maio 2011.

CUNHA, L.; MENDES, J. M.; TAVARES, A.; FREIRIA, S. **Construção de modelos de avaliação de vulnerabilidade social a riscos naturais e tecnológicos:** o desafio das escalas. Coimbra, PT: Imprensa da Universidade de Coimbra, 2011.

CUTTER, S. L. The vulnerability of science and the science of vulnerability. **Annals of the Association of American Geographer**, v. 93, n. 1, p. 1-12, 2003: doi: https://doi.org/10.1111/1467-8306.93101.

DNOCS. Departamento Nacional de Obras Contras as Secas. **História**. Brasília, 2016. Disponível em: https://www2.dnocs.gov.br/historia. Acesso em: 16 jun. 2020.

FERREIRA, A. G.; MELLO, N. G. S. Principais sistemas atmosféricos atuantes sobre a região Nordeste do Brasil e a influência dos Oceanos Pacífico e Atlântico no clima da região. **Revista Brasileira de Climatologia**, Curitiba, v. 1, n. 1, p. 15-28, dez. 2005.

FIELD, A. **Descobrindo a estatística usando SPSS**. Trad. Lorí Viali. 2a ed. Porto Alegre: Artmed, 2009.

IBGE. INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. **Malha municipal digital do Brasil:** situação em 2018. Rio de Janeiro: IBGE, 2018. Disponível em: http://downloads.ibge.gov.br/downloads_geociencias.htm. Acesso em: 10 jun. 2019.

IBGE. INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. **Agregados por setores censitários dos resultados de universo**. Censo 2010a. Disponível em: https://www.ibge.gov.br/estatisticas/sociais/populacao/9662-censo-demografico-2010.html?edicao=10410&t=resultados. Acesso em: 25 jun. 2018.

IBGE. INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. **Índice de recortes para fins estatísticos:** malha de setores censitários, censo 2010, base de faces de logradouros para o CE. Censo 2010b. Disponível em: ftp://geoftp.ibge.gov.br/recortes_para_fins_estatisticos/malha_de_setores_censitarios/censo_2010/base_de_faces_de_logradouros/CE. Acesso em: 25 jun. 2018.

IBGE. INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. **Índice de recortes para fins estatísticos:** malha de setores censitários, censo 2010, base de faces de logradouros para o PI. Censo 2010c. Disponível em: ftp://geoftp.ibge.gov.br/recortes_para_fins_estatisticos/malha_de_setores_censitarios/censo_2010/base_de_faces_de_logradouros/PI. Acesso em: 25 jun. 2018.

MENDES, J. M. Risco, vulnerabilidade social e resiliência: conceitos e desafios. **Revista Gestão e Sustentabilidade Ambiental**, Florianópolis, v. 7, p. 463-492, jun. 2018. Número especial. doi: http://dx.doi.org/10.19177/rgsa.v7e02018463-492.

MENDES, J. M.; TAVARES, A. O.; CUNHA, L.; FREIRIA, S. A vulnerabilidade social aos perigos naturais e tecnológicos em Portugal. **Revista Crítica de Ciências Sociais**, Coimbra, n. 93, p. 95-128, jun. 2011. doi: https://doi.org/10.4000/rccs.90.

MINGOTI, S.A. **Análise de dados através de métodos de estatística multivariada:** uma abordagem aplicada. Belo Horizonte: Ed. UFMG, 2005.

MMA. MINISTÉRIO DO MEIO AMBIENTE DOS RECURSOS HÍDRICOS E DA AMAZÔNIA LEGAL. **Download de dados geográficos**. Brasília: MMA, 2004. Disponível em http://mapas.mma.gov.br/i3geo/datadownload.htm. Acesso em: 27 jan. 2020.

MOLION, L. C. B.; BERNARDO, S. O. Dinâmica das chuvas no Nordeste brasileiro. In: CONGRESSO BRASILEIRO DE METEOROLOGIA, 11., 2000, Rio de Janeiro. **Anais...** Rio de Janeiro: 2000. p. 1334-1342.

REBOUÇAS, A. D. Água na região Nordeste: desperdício e escassez. **Estudos Avançados**, São Paulo, v. 11, n. 29, p. 127-154, 1997. doi: https://doi.org/10.1590/S0103-40141997000100007.

ROGERSON, P. A. **Métodos estatísticos para geografia:** um guia para o estudante. Trad. téc. Paulo Fernando Braga Carvalho e José Irineu Rangel Rigotti. 3a ed. Porto Alegre: Bookman, 2012.

SANTOS, F. A. **Resiliência ambiental a secas e a inundações na Sub-bacia Hidrográfica do Rio Piracuruca (CE-PI)**. Tese (Doutorado em Geografia) – Centro de Ciência e Tecnologia, Universidade Estadual do Ceará, Fortaleza, 2019.

VAREJÃO-SILVA, M. A. **Meteorologia e climatologia**. Versão Digital 2. Recife, 2006.