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Papers

Socio-spatialvulnerability to droughts and floods in the Piracuruca river hydrographic sub-basin (Ceará-Piauí/Brazil)

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Abstract
Studies aimed at understanding socio-spatial vulnerability, with the hydrographic basin as a spatial cutout, are important to subsidize the prognosis and planning in face of the occurrence of droughts and floods.. Thus, we aimed to analyze the socio-spatial vulnerability of the Piracuruca River Hydrographic sub-basin to the occurrence of droughts and floods. The sub-basin is located between the states of Ceará and Piauí, drains an area of 7,704 sq. km and is heterogeneous, both from a biophysical and socioeconomic point of view. The multivariate statistical model, Factor Analysis (FA), and the Principal Component Analysis (PCA) estimation method were applied to the study, both considering the use of variables - demographic, infrastructure, basic sanitation, natural, economic and social population - considering the 296 (two hundred and ninety-six) census sectors of the 2010 demographic census. It is noteworthy that from this method / model and integration of the elements Criticity (characteristics and behavior of the population) and Support Capacity (infrastructure), it was possible to construct the Socio-spatial Vulnerability Index (SSVI) of the Piracuruca River Sub-basin. Thus, the variables used to know the Criticity indicated that in 87 (29.4%) sectors of the Sub-basin the upper class predomiates. In turn, it was inferred through the Support Capacity that 137 (46.3%) sectors of the Sub-basin are in the very upper class. However, the SSVI indicated the predominance of the lower class, which is distributed by 172 (58.1%) sectors of the sub-basin surveyed. However, investment is needed to improve socioeconomic indicators and reduce Criticism and maintain Support Capacity.

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INTRODUCTION

The Northeast of Brazil exhibits a geo-environmental diversity characterized by a condition of semi-aridity, in 53% of its total area, resulting in a landscape whose precipitations are concentrated in a short period of time (SALES, 2002), which generates constant droughts and periodic floods, due to the irregular rainfall distribution, and concentration in a short period.

The population who lives in the semi-arid region has sought to live with droughts and floods, since both have historically left many people displaced and/or homeless. These extreme events are classified as natural disasters and, for Marcelino (2008), they have accompanied the history of man and how he appropriates and uses the natural resources.

According to the Brazilian Yearbook of Natural Disasters (BRASIL, 2014, p.15), natural disasters are conceptualized as "[...] the result of adverse events, natural or man-made, on a vulnerable scenario, causing a serious disturbance to the functioning of a community or society [...]".

Natural disasters cause negative effects when they occur in inhabited areas. More than 130 million Latin Americans live in high-risk situations, according to the Latin American and Caribbean Economic System (SELA, 2011). In this scenario, Nunes (2015) reiterates that the negative consequences, the result of the manifestation of a natural disaster, maybe more linked to the forms of occupation of the geographic space than to the phenomenon's magnitude.

In this sense, the process of socio-spatial segregation accentuates the consequences of natural disasters. Ramos (2003) says that socio-spatial segregation is associated with the unequal way in which social classes appropriate the social, economic and cultural goods and services produced in urban space. Lima (2001) states that segregation is related to the division of the city into parts, promoting an economic, social and psychological differentiation that are reproduced spatio-temporally through the different ways of living.

Thereby, the occupation of spaces and implementation of urban equipment occurs differentiatly to serve certain social classes, with a focus on the quality of life. In this sense, socio-spatial segregation is aggregated to elements inherent to directly interconnected to socio-spatial vulnerability, especially because the segregated population is the one that has less access to institutional instruments to improve the quality of life.

Concerning vulnerability, according to Lavell (2010), the vulnerability is the predisposition or propensity to society's elements of suffering damage, loss and finding it difficult to recover and thus, as Campos-Vargas, Toscana-Aparicio and Alanís (2015) assert, vulnerability determines the occurrence and intensity of disasters. For Cunha et al. (2011), vulnerability exposes individuals and their goods to a certain degree of resistance and resilience, and communities to the occurrence of potentially harmful processes and events. Thus, vulnerability aggregates elements associated with exposure and propensity to risk (CUTTER, 2011).

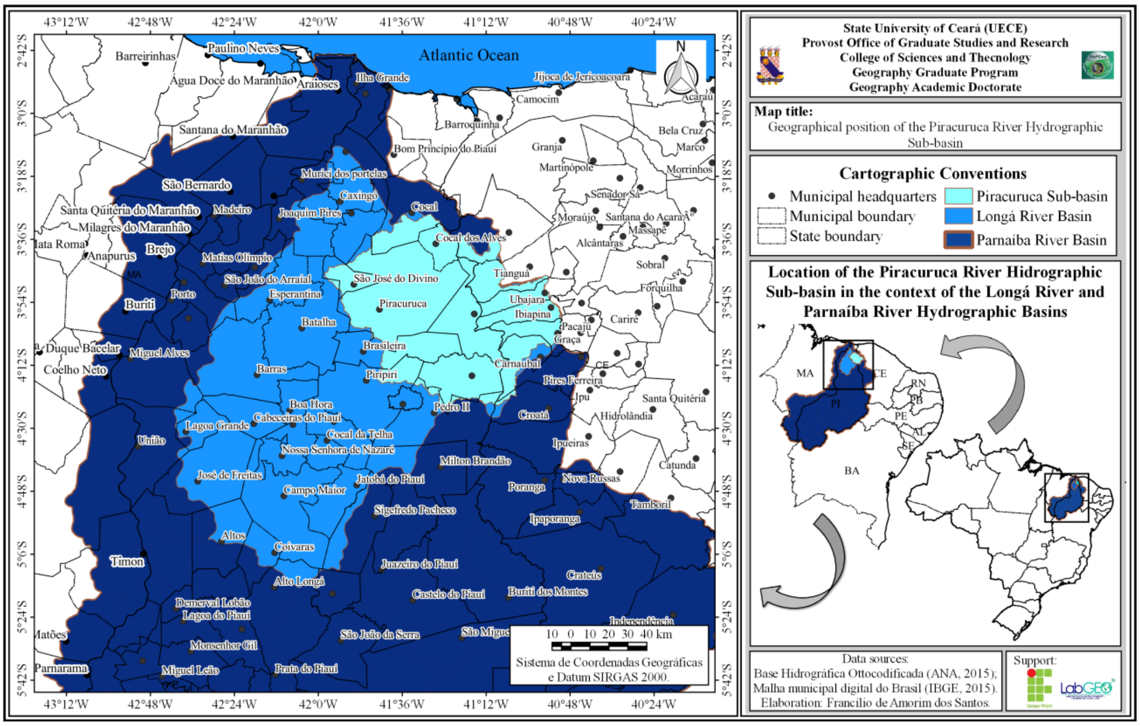
In this context, the Piracuruca River Hydrographic Sub-basin (PRHSB), which is located in Brazil between the states of Ceará and Piauí, has the Piracuruca River as its main water resource. This Sub-basin is periodically affected by extreme pluviometric events like droughts and floods, which, associated with the factors inherent to social vulnerability, converge to potentialize the natural disasters consequences.

Considering the relevance of studies aimed at the knowledge of the socioeconomic reality and, as such, the socio-spatial vulnerability in watersheds, this research aimed to analyze the socio-spatial vulnerability of the PRHSB to the occurrence of droughts and floods.

STUDY AREA LOCALIZATION AND CHARACTERIZATION

The PRHSB belongs to the Longá River Hydrographic Basin (LRHB) which, in turn, integrates the set of main affluents of the Parnaíba River Hydrographic Basin (PRHB), with flow directed to the medium/low course, as represented in Figure 1. The PRHSB is located on the eastern border of the PRHB and the northeastern sector of the LRHB, between the states of Ceará and Piauí, in Brazil, in an area considered semiarid. The PRHSB drains an area of 7,704 km² and the main sources of its main river rise in the Serra da Ibiapaba, close to the municipality of São Benedito, state of Ceará, and flows into the Longá river close to the municipality of São José do Divino, in the state of Piauí. This sub-basin drains areas of 20 municipalities, 11 of which are located in Piauí territory and 9 in Ceará state.

Figure 1. Geographical situation of the PRHSB, located between the states of Ceará and Piauí, Northeast Brazil.



Source: Authors (2019).

The PRHSB exhibits geological formations with morphostructural domain and chronology associated with Detrito-Lateritic/Cenozoic Covers and Fissural/Mesozoic Volcanism, in addition to failures in the eastern portion and predominantly in the northeast-southeast (NE-SE) direction (CPRM, 2006a; 2006b; 2006c). The Sub-basin is settled on six geological formations, namely: Serra Grande Group (Silurian Period); Pimenteiras Formation (Lower Devonian Period); Cabeças Formation (Middle Devonian Period); Sardinha Formation (Cretaceous Period); Colluvial-Eluvial Deposits (Neogene Period) (CPRM, 2006a; 2006b; 2006c).

Erosive processes of dissection and accumulation act on these formations, where eroded slopes of the Ibiapaba Plateau can be seen towards the state of Piauí, with forms that vary from strong to partially dissected, due to the consequent action of the rivers. In the sequence, the Sub-basin shows a flattened relief with the formation of extensive lowered and periodically floodable areas (SANTOS, 2019).

The precipitations in PRHSB are under the influence of the Intertropical Convergence Zone (ITCZ), Upper Level Cyclonic Vortices (ULCVs), Eastern Wave Disturbances (DOLEWDs), Instability Lines (ILs), Wave Disturbances in the Allysian (WDA). It should also be noted that the ITCZ is the main rainfall generating system in the studied area, whose movement is closely linked to the oceanic phenomena El Niño South Oscillation (ENSO) and Atlantic Dipole, a fact that generates years with normal or anomalous precipitation totals, negative or positive (SANTOS, 2019).

According to Koppen, the Piracuruca River Sub-basin has the BSh climate, characterized mainly by the irregular distribution of rainfall throughout the year, whose evaporation and perspiration exceed the total rainfall, classifying it as semi-arid dry. The area is under the influence of the Ibiapaba Plateau, due to the occurrence of orographic rains. Thus, the amount of precipitation varies from 860 mmto 1,710 mm annually, average temperatures ranging from 20 to 27°C, up to 7 dry months, potential evapotranspiration ranging from 903 mm to 1643 mm, water surplus from 100 to 1000 mm and deficits ranging from 30 to 730 mm annually (SANTOS, 2019).

The soil mosaic shows occurrence of 8 orders and 11 suborders, namely: the Neosolos (suborders: Neosols (suborders: Litholic Neosols and Quartzarenic Neosols), covered by shrubby caatinga and/or *carrasco,* type of vegetation that corresponds to a very dense and dry savannah; Argisols (suborders: Yellow and Red), covered by shrubby caatinga; Latosols (suborder: Yellow Latosol), constituting substrate for pluvio-nebular map; Planosols (suborder: Haplic Planosol), which allows the development of pluvio-nebular forest; Plinthosols (suborders: Argilluvic and Petric), which allows the occurrence of carnaubal and open shrubby caatinga; the Vertisols (suborder: Ebanic Vertisols), with shrubby caatinga; the Gleysols (suborder: Melanic), are covered with pluvio-nebular forest; the Chernosols (suborder: Argilluvic Chernosol), allowing the growth of shrubby caatinga vegetation (INDE, 2014; SANTOS, 2019).

METHODOLOGICAL PROCEDURES

The procedures used during this research were essential to spatialize the data of the variables listed to construct the Socio-spatial Vulnerability Index (SSVI), from the adaptation of the methodology of Cunha et al. (2011) and (MENDES et al., 2011), which use the concepts of Criticity (C), as the set of individual characteristics and behaviors that can break the system, and Support Capacity (SC), as the set of territorial infrastructures that allow the community to react in cases of disaster, for each PRHSB census sector.

To develop the SSVI, the *SPSS* software, *Statistics*, version 17, multivariate statistical model Factor Analysis (FA) and estimation method Principal Component Analysis (PCA) were used. These methods were obtained from the demographic, infrastructure, basic sanitation, environmental, economic and social variables of the population, through the census sector, from the 2010 demographic census. The FA/PCA represents a model/method for reducing the amount of data when one works with a large number of variables - in this study 18 variables were initially considered for C and 44 for SC (Table 1) - to a manageable size when one extracts as much information as possible (FIELD, 2009; ROGERSON, 2012).

Table 1. Set of variables used for C and SC analysis of the PRHSB.

Criticity (C)	
Code	**Variable**
C01	Density of permanent private homes.
C02	Population density.
C03	People aged 0 to 5 years.
C04	Resident people - 65 or older.
C05	Responsible people, female.
C06	Literate people aged 5 or older.
C07	Literate responsible people.
C08	Responsible people, male.
C09	Literate responsible people, male.
C10	Men responsible for the private home.
C11	Women responsible for the private home.
C12	Resident people.
C13	Total of nominal monthly income of permanent private homes.
C14	Total of nominal monthly income of improvised private homes.
C15	Responsible people with a nominal monthly income of more than 1/2 to 1 minimum wage.
C16	Responsible people with a nominal monthly income of more than 1 to 2 minimum wages.
C17	Responsible people with a nominal monthly income of more than 5 to 10 minimum wages.
C18	Responsible people without a nominal monthly income.
Support Capacity (SC)	
Code	**Variable**
SC01	Permanent private homes, house.
SC02	Permanent private homes, villa or condominium.
SC03	Permanent private homes, apartment.
SC04	Rented permanent private homes.
SC05	Permanent private homes provided by employer.
SC06	Permanent private homes in another occupancy condition (not owned, rented or provided).
SC07	Permanent private homes with water supply from the general system.
SC08	Permanent private homes with well or spring water supply on the property.

SC09	Permanent private homes with rainwater supply stored in cistern.
SC10	Permanent private homes with another form of water supply.
SC11	Permanent private homes with bathrooms for the residents' exclusive use or toilets and sanitary sewage via general sewage or rainwater system.
SC12	Permanent private homes with bathrooms for the residents' exclusive use or toilets and sanitary sewage via septic tank.
SC13	Permanent private homes with bathrooms for the residents' exclusive or toilets and sanitary sewage via a rudimentary septic tank.
SC14	Permanent private homes with bathrooms for the exclusive use of the residents or toilet and sanitary sewage via river, lake or sea.
SC15	Permanent private homes with garbage collected.
SC16	Permanent private homes with garbage burned on the property.
SC17	Permanent private homes with garbage thrown in the river, lake or sea.
SC18	Permanent private homes with electric power.
SC19	Permanent private homes without electric power.
SC20	Permanent private homes with 1 resident.
SC21	Permanent private homes with 2 to 4 residents.
SC22	Permanent private homes with 5 to 9 residents.
SC23	Permanent private homes with 10 or more residents.
SC24	Own permanent private homes - There is public lighting.
SC25	Rented permanent private homes - There is public lighting.
SC26	Provided permanent private homes - There is public lighting.
SC27	Own permanent private homes - There is paving.
SC28	Rented permanent private homes - There is paving.
SC29	Provided permanent private homes - There is paving.
SC30	Own permanent private homes - There is manhole/storm drain.
SC31	Rented permanent private homes - There is manhole/storm drain.
SC32	Provided permanent private homes - There is manhole/storm drain.
SC33	Own permanent private homes - There is wheelchair ramp.
SC34	Rented permanent private homes - There is wheelchair ramp.
SC35	Provided permanent private homes - There is wheelchair ramp.
SC36	Own permanent private homes - There is forestation.
SC37	Rented permanent private homes - There is forestation.
SC38	Provided permanent private homes - There is forestation.
SC39	Own permanent private homes - There is open sewage.
SC40	Rented permanent private homes - There is open sewage.
SC41	Provided permanent private homes - There is open sewage.
SC42	Own permanent private homes - There is garbage accumulated in the patios.
SC43	Rented permanent private homes - There is garbage accumulated in the patios.
SC44	Provided permanent private homes - There is garbage accumulated in the patios.

Source: Santos (2019).

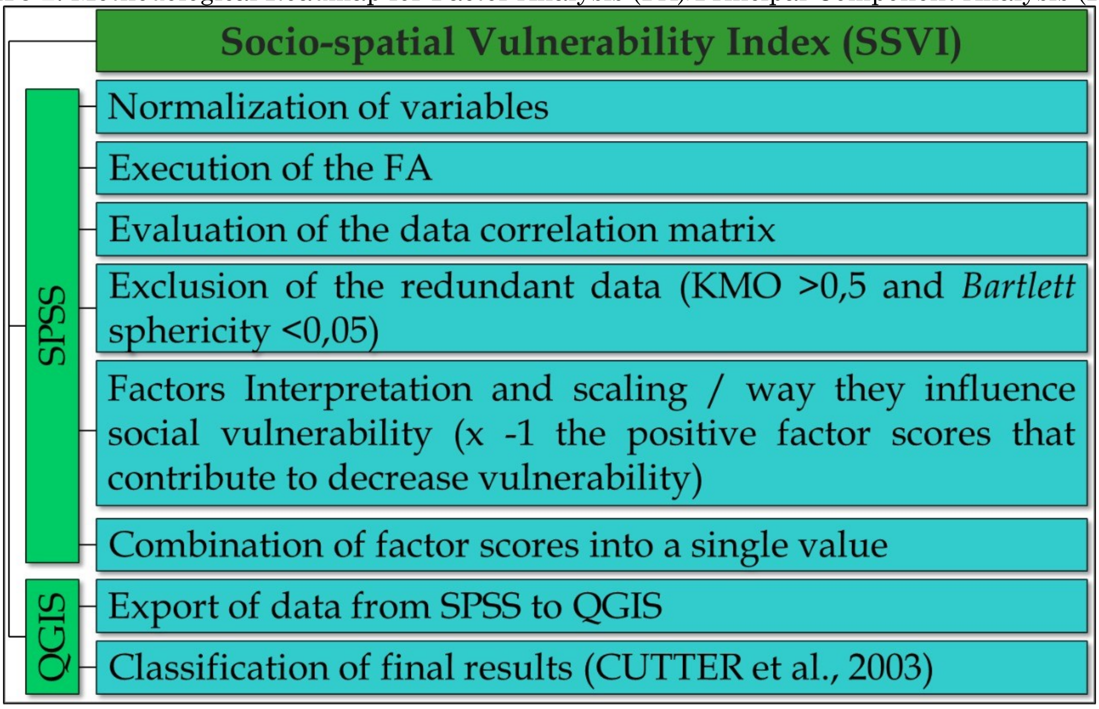
Thus, to produce the results linked to the SSVI, the following files were acquired: vector, related to the census sectors used for the 2010 Census, by the Brazilian Institute of Geography and Statistics (IBGE); alphanumeric, which refers to the spreadsheets of data - demographic, infrastructure, basic sanitation, environmental, economic and social population - by census sectors, obtained from the microdata of the universe of the 2010 Demographic Census (IBGE, 2018). The limits of the Piracuruca River Sub-basin cover 296 (two hundred and ninety-six) census sectors, being 186 rural and 110 urban sectors.

For the identification of the main C and CS components, such as the evaluation of the SSVI of PRHSB, the Varimax orthogonal rotation method with Kaiser normalization was used for the integration of IBGE census data for 2010. This method aims to aggregate a smaller number of variables for each factor (FIELD, 2009). It is worth mentioning that two tests were applied for FA/PCA validation: Kaiser-Meyer-Olkin (KMO), which varies between 0 and 1, being equal to or above 0.7 is considered median (MALHOTRA, 2001, *apud* BAKKE; LEITE; SILVA, 2008); and

Bartlett's sphericity test, which tests the null hypothesis that the original correlation matrix(R) is an identity matrix, considering that the R matrix has all the correlation coefficients equal to 0, and must have a significance value < 0.05 (FIELD, 2009).

The reduction of the number of variables happened through the identification of their communalities and their correlations. The similar variables, the level of similarity and the degree of explanation that the factors provide to the created model have the scores as a product (MARTINEZ; FERREIRA, 2010). One can reiterate that FA/PCA was considered as a model/method to reduce the number of redundant variables and enable the grouping of the remaining variables into factors, considering the realization of 8 (eight) steps, as suggested by Cunha et al. (2011) (Figure 2).

Figure 2. Methodological Roadmap for Factor Analysis (FA)/Principal Component Analysis (PCA).



Source: Cunha et al. (2011).

To obtain the results for C and for SC the weighted sum was used, based on adjustments to the methodological proposal of Cunha et al. (2011), who works with FA related to C and SC, for knowledge of Vulnerability. To obtain the value of C and SC for each census sector, the product sum of the communality of each variable by its standardized value was considered.

Thus, for the C analysis, we initially worked with a set of 18 variables that, after the execution of the FA, had only one variable excluded. When the first round to obtain the factors was made, one of the variables showed communality coefficient below 0.5, therefore, it was not being well represented in the modeling and it was disregarded. Once this procedure was carried out we calculated the C for the PRHSB census sectors based on the main factor and use of Equation 1:

$$C = (-F_1) + (-F_2) + F_3 + F_4 \quad (1)$$

Where: C = Criticity; Fn = Criticity factors resulting from FA/ACP; n = 1 to 4.

The C values for each census sector, considering Equation 1, were exported from the excel (*.csv) format to the work platform in the QGIS, where the classification of these data was made using the natural breaks method (jenks) in the referred GIS (Geographic Information System), resulting in 5 classes of C (Chart 1).

Chart 1. Intervals, Assigned Classes and Criticity Scores (C) for the 296 census sectors of the PRHSB for the year of 2010.

C intervals:	Assigned classes:	Scores
-28,05840740 a -11,93914040	Very low	1
-11,93914040 a -4,44841431	Low	2
-4,44841431 a 0,69792666	Medium	3
0,69792666 a 4,84258660	High	4
4,84258660 a 11,44525901	Very high	5

Source: Authors (2019).

In turn, for knowledge of the SC a group of 44 (forty-four) variables were considered, which after executing 4 tests of factor analysis it resulted in the exclusion of 14 (fourteen) variables, since they presented communiality higher than 0.5. Then, Equation 2 could be applied to obtain the SC for the census sectors of the Subbasin studied, considering the main factor and its positive or negative influence on the results achieved.

$$SC = (-F_1) + (-F_2) + (-F_3) + F_4 + F_5 + (-F_6) + F_7 \quad (2)$$

Where: SC = Support Capacity; Fn = Support Capacity Factors resulting from FA/ACP; n = 1 to 7.

The values resulting from the application of Equation 2 made the identification of the SC by census sector of the PRHSB possible. These values were exported from the excel format (*.csv) for handling in the QGIS. In this GIS the classification of the data, mentioned, was made through the graduated option and natural break method (jenks), where 5 classes of SC were generated (Chart 2).

Chart 2. Intervals, Assigned Classes and Support Capacity (SC) scores for the 296 census sectors of the PRHSB for the year of 2010.

SC intervals	Assigned classes:	Scores
-66,42206630 a -29,59488850	Very low	5
-29,59488850 a -12,85094580	Low	4
-12,85094580 a -1,80323566	Medium	3
-1,80323566 a 5,66628248	High	2
5,66628248 a 17,74679925	Very high	1

Source: Authors (2019).

Once the steps to obtain the C and SC values have been completed, the calculation to obtain the SSVI by census sector can be done, considering the year of 2010, as expressed in Equation 3:

$$SSVI = CxSC \quad (3)$$

Where: SSVI = Socio-spatial Vulnerability Index; C = Criticity; SC = Support Capacity.

The spatialization of the classes previously defined for Cand SC subsidized the delimitation of classes for the SSVI of the PRSB (Chart 3).

Chart 3. Intervals, assigned classes and scores of the SSVIof the PRHSB.

IVSE intervals	Assigned classes	Scores
1 a 3	Very low	1
4 a 6	Low	2
8 a 10	Medium	3
12 a 16	High	4
20 a 25	Very high	5

Support Capacity \ Criticity	1	2	3	4	5
1	1	2	3	4	5
2	2	4	6	8	10
3	3	6	9	12	15
4	4	8	12	16	20
5	5	10	15	20	25

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

RESULTS AND DISCUSSION

Initially, the tests KMO and Bartlett's sphericity showed, respectively, a value of 0.813 and significance (Sig.) equal to 0.00, considered appropriate. Thus, the 4 (four) extracted factors represent 86.209% of the accumulated variance related to the variables listed for Criticity analysis. So, the accumulated variance rotated for the Factor 1 was 55.215%, 69.866% for Factor 2, 79.168% for Factor 3 and for Factor 4 it was equal to 86.209%. Therefore, Factor 1 can explain 55.215% of the original data variance, while Factors 1, 2 and 3 together explain 30.995%.

Table 2 presents the exploratory factor analysis, with the dominant variables in the Criticity Factors that most influenced during the analysis. Factor 1 presented high and positive correlation and promotes the reduction of socio-spatial vulnerability; the second Factor showed high and positive correlation and allows the reduction of vulnerability; in Factor 3, there was a high and positive correlation and it increases vulnerability; Factor 4 has a positive and very high correlation, contributing to increase the vulnerability in the studied Sub-basin.

The integration and spatialization of the factors with greater influence for C construction regarding the 296 census sectors of the PRHSB allowed the elaboration of Figure 3, which shows the predominance of the upper class occurring in 87 (29.4%) sectors of the Sub-basin at issue. Then there is the middle class that is distributed among 83 (28.0%) sectors. In turn, the upper-upper, low and very lower classes are located in 67 (22.6%), 43 (14.5%) and 16 (5.4%) sectors of the surveyed Sub-basin, respectively.

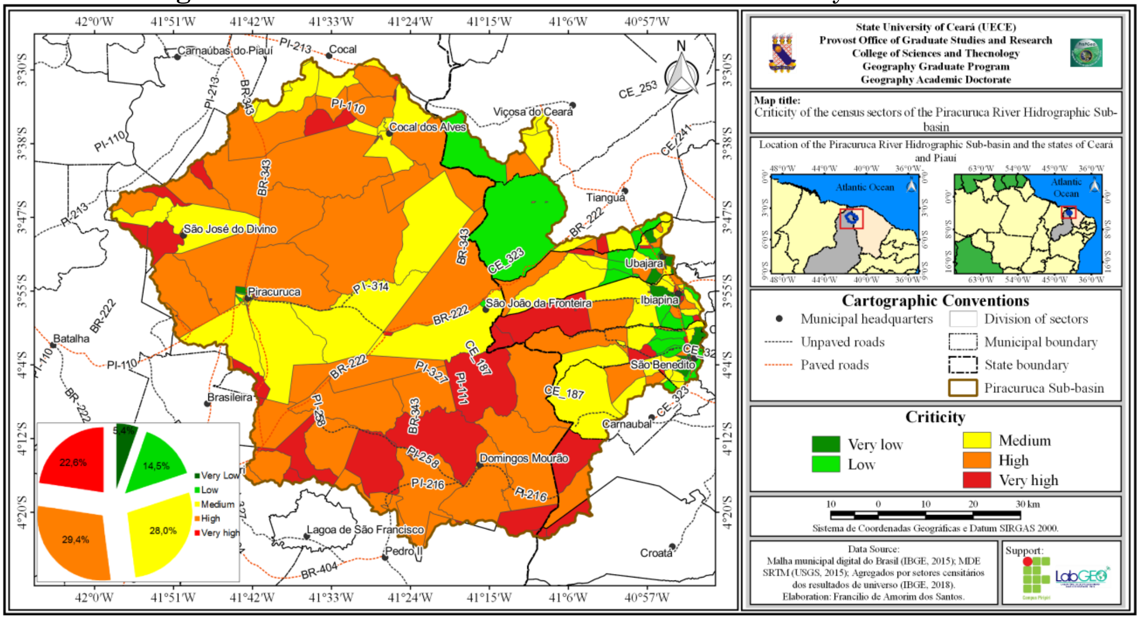
The upper and upper-upper classes in the studied Sub-basin disperse, mainly, in the rural census sectors of the cities from Piauí state. There are a higher number of people with 0 to 5 years old and 65 or older in these places, requiring more attention and care related to the manifestation of extreme pluviometric events, due to difficulties in locomotion. The presence of women responsible for home income and the occurrence of responsible people without income or with income up to 1 minimum wage contributes to increasing socio-spatial vulnerability.

Table2. Synthesis of the variables with the highest correlation of the C for the PRHSB, for the year of 2010.

Factor (Signal)	Variables of highest influence
1 (-) Literate Responsible People, Gender, Resident, Income and Age Structure	C08 - Responsible people, male.(+0,949)
	C15 - Responsible people with a nominal monthly income of more than 1/2 to 1 minimum wage.(+0,891)
	C12 - Resident people.(+0,885)
	C06 - Literate people aged 5 or older.(+0,878)
	C09 –Literate responsible people, male.(+0,870)
	C11 - Women responsible for the private home.(+0,866)
	C07 - Literate responsible people.(+0,751)
	C03 - People aged 0 to 5 years.(+0,683)
2 (-) Home Nominal Income	C17 - Responsible people with a nominal monthly income of more than 5 to 10 minimum wages. (+0,911)
	C13 - Total of nominal monthly income of permanent private homes.(+0,813)
	C16 - Responsible people with a nominal monthly income of more than 1 to 2 minimum wages. (+0,686)
3 (+) Responsible People by gender and Age Structure	C04 - Resident people - 65 or older.(+0,785)
	C10 - Men responsible for the private home.(+0,774)
	C18 - Responsible people without a nominal monthly income.(+0,704)
	C05 - Responsible people, female.(+0,692)
4 (+) Population Density and Private Homes	C02 - Population density.(+0,982)
	C01 - Density of permanent private homes.(+0,980)

Source: Authors (2019).

Figure 3. C of the census sectors of the PRHSB for the year of 2010.



Source: Authors (2019).

In this sense, Fragoso, Gehlen and Silva (2012) point out that although there is an unequal division of resources among the various economic groups in society, it is the woman in most cases, as well as the others who do not have claiming power, who holds the exclusion of any direct benefits that this may bring. This fact corrobrates that women become more vulnerable than men, not for behavioral characteristics, but for the social exclusion that she suffers.

Factor 1 shows high and strong correlation and contributes to vulnerability reduction; Factor 2 has high correlation and its contribution reduces vulnerability; the third Factor shows high correlation and allows the reduction of flood occurrence; Factor 4 demonstrates high correlation and decreases the conditions of support to natural disasters in the Sub-basin; Factor 5 has high correlation and negative influence on SC; In the sixth Factor, there is a strong correlation and a contribution to increasing the SC of the PRHSB population; while in Factor 7, there is a relevant contribution to reduce the SC of the PRHSB population to natural events, since a larger population living in the same residence demands a larger amount of services, such as the need for medication, food, clothing, etc (Table 3).

These data allowed the integration of the Factors and the spatialization of the SC of the 296 census sectors of PRHSB (Figure 4). In this one, it is observed the predominance of the upper-upper class, distributed by 137 (46.3%) sectors of the Sub-basin. The upper class was the second most representative, being identified in 69 (23.3%) sectors. In turn, the middle, low and very low classes were identified in 44 (14.9%), 36 (12.2%) and 10 (3.4%) of the Sub-basin sectors.

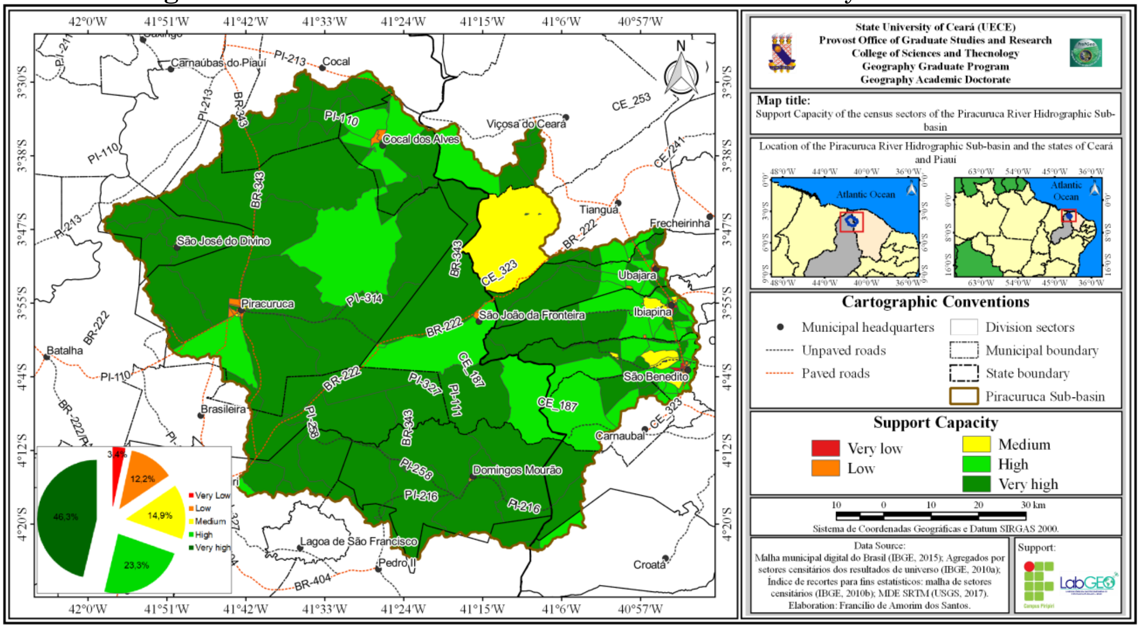
Although the PRHSB presents preponderantly high to very high its capacity to withstand periodic droughts and floods, its sectors exhibit distinct SC and demand improvements in environmental quality from the elaboration of adequate planning. Thus, investments for improvement of environmental indicators as a fundamental condition for reducing vulnerability should be considered.

Table 3. Synthesis of the variables with the highest correlation of the SC for the PRHSB, for the year of 2010.

Factor (Signal)	Variables of highest influence
1 (-) Home infrastructure (water supply from the general system, garbage collection, lighting, paving and forestation).	SC26 - Provided permanent private homes - There is public lighting.(+0,884)
	SC27 - Own permanent private homes - There is paving.(+0,879)
	SC29 - Provided permanent private homes - There is paving.(+0,873)
	SC38 - Provided permanent private homes - There is forestation. (+0,873)
	SC36 - Own permanent private homes - There is forestation. (+0,865)
	SC24 - Own permanent private homes - There is public lighting.(+0,853)
	SC25 - Rented permanent private homes - There is public lighting.(+0,841)
	SC15 - Permanent private homes with garbage collected.(+0,836)
	SC04 - Rented permanent private homes.(+0,831)
	SC37 - Rented permanent private homes - There is forestation.(+0,824)
	SC28 - Rented permanent private homes - There is paving.(+0,817)
	SC07 - Permanent private homes with water supply from the general system.(+0,698)
	SC16 - Permanent private homes with garbage burned on the property.(-0,612)
2 (-) Type and quantity of residents per home and infrastructure (presence of electric power and type of bathroom).	SC01 - Permanent private homes, house.(+0,938)
	SC18 - Permanent private homes with electric power.(+0,913)
	SC21 - Permanent private homes with 2 to 4 residents.(+0,875)
	SC13 - Permanent private homes with bathrooms for the residents' exclusive or toilets and sanitary sewage via a rudimentary septic tank.(+0,835)
	SC20 - Permanent private homes with 1 resident.(+0,728)
3 (-) Home infrastructure (type of manhole).	SC32 - Provided permanent private homes - There is manhole/storm drain.(+0,917)
	SC30 - Own permanent private homes - There is manhole/storm drain.(+0,909)
	SC31 - Rented permanent private homes - There is manhole/storm drain.(+0,856)
4 (+) Home infrastructure (type of sewage).	SC39 - Own permanent private homes - There is open sewage.(+0,837)
	SC41 - Provided permanent private homes - There is open sewage.(+0,789)
	SC40 - Rented permanent private homes - There is open sewage.(+0,760)
5 (+) Home infrastructure (accumulation of garbage in the patios).	SC43 - Rented permanent private homes - There is garbage accumulated in the patios.(+0,880)
	SC44 - Provided permanent private homes - There is garbage accumulated in the patios.(+0,868)
	SC42 - Own permanent private homes - There is garbage accumulated in the patios.(+0,857)
6 (-) Infrastructure (accessibility).	SC33 - Own permanent private homes - There is a wheelchair ramp.(+0,880)
	SC35 - Provided permanent private homes - There is a wheelchair ramp. (+0,866)
	SC34 - Rented permanent private homes - There is a wheelchair ramp.(+0,705)
7 (+) Quantity of residents per home.	SC22 - Permanent private homes with 5 to 9 residents. (+0,632)

Source: Authors (2019).

Figure 4. SC of the census sectors of the PRHSB for the year of 2010.

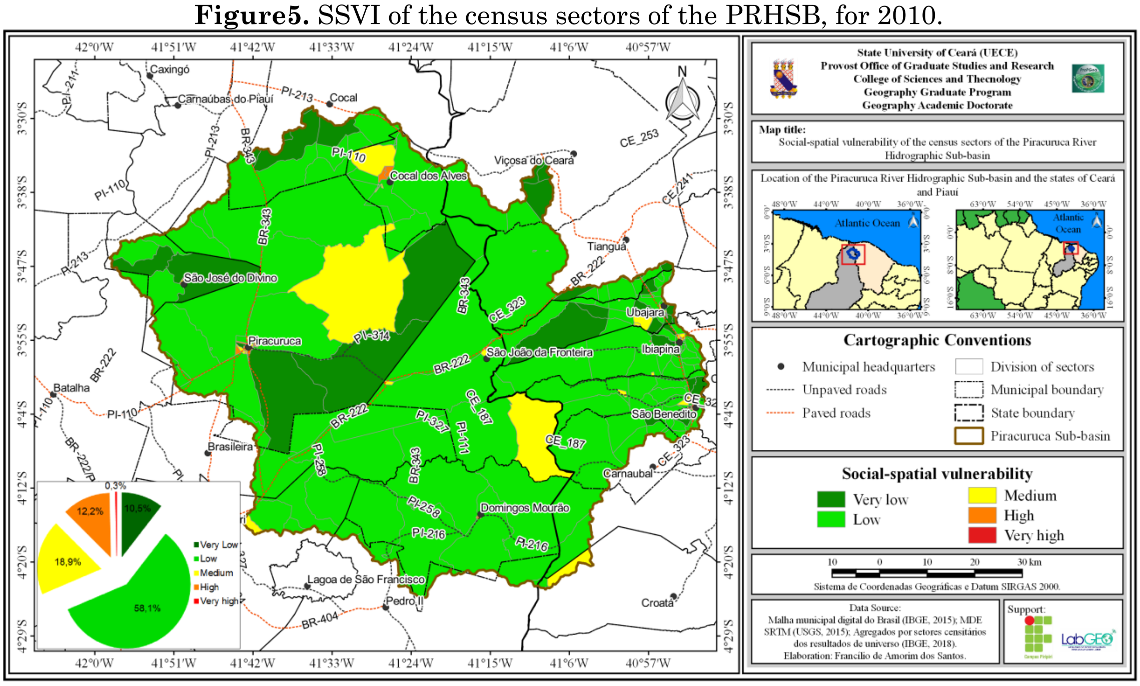


Source: Authors (2019).

When integrated, the variables related to C and CS were able to create the SSVI. In this index, there is the preponderance of the low vulnerability class (Figure 5), whose distribution was given by 172 (58.1%) sectors of the surveyed Sub-basin. This class is followed by the middle vulnerability, which occurs in 56 (18.9%) sectors of the PRHSB. The other classes have occasional occurrence, where the upper class was identified in 36 (12.2%) sectors, mainly in the municipalities of Cocal dos Alves, Piracuruca and São Benedito; while the very low class occurred in 31 (10.5%) sectors; the upper-upper class appeared in only 1 (0.3%), which is located in the municipality of São Benedito.

Thus, the diversity of the sub-basin sectors concerning the SSVI demands investments in those sectors with more C and less CS, which will reduce the vulnerability of the population to the occurrence of natural disasters, particularly droughts and floods.

Figure5. SSVI of the census sectors of the PRHSB, for 2010.



Source: Authors (2019).

FINAL CONSIDERATIONS

The methodology applied was relevant for the use of the statistical model FA and PCA as a perspective for the grouping of demographic, infrastructure, basic sanitation, environmental, economic and social variables of the population. This grouping resulted in an index that may contribute for the knowledge of the socio-spatial vulnerability of the PRHSB.

Thus, the predominance of the upper class of C, frequent in 87 (29.4%) of the Sub-basin, suggests the need for investments to improve the quality of life, particularly *per capita* income, the opening of new jobs and strategies for the literacy of residents. Since they are essential to increase the population's capacity to resist droughts and floods episodes.

The preponderance of the upper-upper class of SC, which occurs in 137 (46.3%) sectors, makes it possible to infer that the Sub-basin provides an appropriate infrastructure to the population to deal with droughts and floods. However, government efforts must be made to expand environmental quality, based on adequate planning and improvement of environmental indicators, as an elementary condition to equip the population with tools to face eventual droughts and floods.

As a synthesis of C and SC, the SSVI showed the prevalence of the middle class, which is distributed in 56 (18.9%) sectors of the Sub-basin. This fact demands attention and should be taken as a starting point for the improvement of quantitative indicators referring to the most vulnerable population, as a way to reduce C and increase the SC for droughts and floods in the surveyed area.

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