The Quantile Statistical Technique as a Method to Determine Dry and Rainy Seasons in Sobral, Ce

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Abstract

Climate change and related topics are presenting themselves as issues discussed in various sectors of society in recent decades. In this scenario, the extreme events of rain contribute to the outbreak of natural disasters in Brazil, with material and human damages that affect the most vulnerable populations. However, several factors and variables – such as social affairs – make it hard to define the term extreme event. Thus, this research aims to determine the rainfall levels in Sobral based on the use of the quantile statistical technique for thirty years (from 1989 to 2018). Five delimitation categories in this paper characterize the rainfall behavior (yearly accumulation): very dry, dry, normal, rainy, and very rainy. The collection of information on the climate regime of the area, especially in the extreme groups (very dry and very rainy), serves as a tool for further studies related to the topic. Besides, it represents the authors' belief that the delimitation of the events is the first step towards the correct adoption of preventive measures.

Keywords: Extreme events. Social-Natural disasters. Quantile.

1. Introduction

It is becoming more and more evident, at least to most scholars, that climate change has a strong relationship with the way man exploits the ground. In this scenario, the increase in extreme climate is gaining notoriety in the media and various sectors of society. Cities are growing in a disorderly form and without urban planning, which causes problems for the population. In Brazil, more than 80% of people live in urban areas (EMBRAPA, 2017).

Climate change has caused a relevant increase in the occurrence of extreme events, which are usually heavy rainfall or its absence. According to WMO (2018), the number of floods and other hydrological events has quadrupled since 1980 and doubled since 2004, affecting 35 million people worldwide. This situation has happened principally because of urbanization processes in areas occupied by people in vulnerable conditions. On the other hand, the drought affects around 1.8 billion people, making it the most important category when it comes to natural disasters. The economic losses caused by droughts and floods together correspond to more than $40 billion per year in all sectors (UN, 2018).

Sobral represents perfectly an area that occurs drought and flood. Because of its location – semi-arid northeastern region and northwestern Ceará –,there is an irregular incidence of rainfall that, depending on the period, causes disasters triggered by both drought and flood.

Thus, this research[3]aims to define extreme rainfall values for the city of Sobral through the use of the quantile statistical technique, which allows a reliable analysis to establish such values. The relevance resides in the fact that it serves as a support for further preventive actions organized either by public agencies or even by the own population. Besides that, it serves as a basis for academic manuscripts as an initial step to understand and learn how to deal with natural disasters.

2. Understanding the Extreme Event and the Context Involving Sobral

The term extreme event usually relates to precipitation, both for the maximum and for the inexpressive or absent accumulation, that is, considering drought and flood incidences. According to civil defense, an extreme event is a not-so-often disaster capable of causing real damage (CASTRO, 2009).

Due to the Brazilian territorial extension, the rainfall levels are different according to each geographic region. Even when such events occur in overpopulated places, they cause real problems. In this case, exposure and vulnerability are significant components in the analysis of the damage associated with the event, evidencing a more social and integral conception to understand the situation.

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[3] This investigation is part of a larger research project, which aims to analyze the occurrence of social disasters associated with extreme rainfall events in northwestern Ceará.

After all, if an accumulation of 150 mm/24h occurs in a portion of a densely urbanized and inhabited territory, it will bring much more damage than a more interior and practically uninhabited location.

However, such a more social/integral conception has traces of subjectivity that make it difficult to define what would be extreme. Thus, aiming at a more coherent and operational definition, it is necessary to consider the rainfall level in a specific place during an established period (space-time analysis), which allows a better interpretation of these events.

The high volume, intensity, and frequency of rainfall bring countless problems when in areas inhabited by vulnerable populations. People usually relate these maximum extreme events of precipitation to a divine manifestation, as if it were a punishment from God. They do not consider that overpopulation causes segregation, in which the most vulnerable people settle in vulnerable places from a physical-natural point of view (river banks, lakes, hillsides).These facts contribute to the consolidation of the ideal scenario for disasters to happen.

Similarly, in places often impacted by droughts, such socially vulnerable populations living in these areas find it more difficult to respond positively to a situation of social disaster.

Different parts of the country have suffered negative impacts, whether by intense rainfall or the lack of it. Consequently, it has caused damage to the population, such as death, homelessness, material losses, among others. The impacts are usually natural disasters, depending on their magnitude and spatial extent (BRANDÃO, 2001). The various emergency decrees published by different Brazilian municipalities make this situation more evident.

In Brazil, the most common disasters relate to floods, landslides, drought, and erosion (SILVA; PINTO; FREITAS, 2016). In Ceará, the most frequenteventsinvolve floods and drought.

Most of the time, the term extreme event refers to phenomena arising from rainfall, from those that consider a minimum accumulation (low incidence) to those maximum events of precipitation (high level). They receive attention through electronic and printed media due to the high power of the deflagration of various impacts in the environment in which they occur (MONTEIRO: ZANELLA, 2017. p. 139).

The rainfall incidences from February to May usually relates to the Intertropical Convergence Zone (ITCZ), considered to be one of the principal causes of rain in the State of Ceará. The ITCZ is an unsteady zone that oscillates between North and South, always close to the equatorial belt. It is the result of the confluence of trade winds near the surface. The ITCZ position/action has a strong relationship with the difference in the temperature of the oceanic waters of the North and South Atlantic, as well as by the interference of a phenomenon that occurs remotely – El Niño – Southern Oscillation (ENSO).

According to Bezerra (2002), besides having high temperatures and solar incidence that cause high rates of evaporation, the annual average rainfall in the Northeast region is low and irregular. Thus, it is necessary to understand the rainfall behavior and distribution in the region to predict possible disasters.

The municipality of Sobral is in the Mid North sertão, which presents a semi-arid environment, irregular rainfall, and water deficit. Besides that, the shallow soil is susceptible to erosion on a crystalline lithotype base with a low capacity of underground water storage. A spaced and deciduous vegetation (arboreal-arbustive caatinga) covers the soil, forming landscapes vulnerable to degradation (BIRTH; SOUZA; CRUZ, 2007). However, this scenario may change due to the performance of some atmospheric systems.

According to data from the Instituto de Pesquisa e Estratégia Econômica do Ceará (Institute for Research and Economic Strategy from Ceará, IPECE), the usual climate in the area is the semi-arid warm tropical, with average temperatures ranging from 26°C to 28°C, according to the Fundação Cearense de Meteorologia e Recursos Hídricos (Meteorology and Water Resources Foundation from Ceará, FUNCEME). From January to June, the highest rainfall rates of the year are concentrated, reaching around 800 mm, while a significant part of the northeastern sertão experiences drought in the other months with a notorious water deficit and high evaporation rates.

It is from this contrast that some extremes are noticeable in each period (maximum accumulated rainfall in the four rainy months and minimum in the second semester). However, there is great difficulty among researchers in determining such values. After all, how to establish a reliable threshold for regions with various climatic characteristics?

Although components such as vulnerability and susceptibility are relevant in understanding the phenomenon, measuring them involves subjectivity. However, when viewing it from a physical point of view or the event is rare in a specific place or season, it is possible to establish extreme intervals objectively.

3 Materials and Method

Some steps were necessary to achieve the objective, such as literature review on concepts related to the subject discussed, data collection taken from the

FUNCEME website regarding rainfall in Sobral from 1989 to 2018 and, application of the quantile statistical technique. The last step took place according to the methodology of Pinkayan (1966) and Xavier (2007), which was essential to establish the extreme values for rainfall in Sobral.

Quantiles are separation measures for probability distributions or for their samples. A p quantile (set to $0<p<1$) is a numerical value that slices the distribution into two parts, with probabilities p (to the left of this theoretical quantile) and $1 - p$ (to the right). In sample terms, one can divide a sample in two masses of numerical observations, with $100 * p\%$ of the elements located to the left of the sample quantile and the other $100 * (1 - p)\%$ to the right. [...] The quantiles until 5% include the lower extreme values, whereas the quantiles between 95% and 100% include the upper ones. Other levels characterize even rarer events as well, such as the less (15% and 85%) and more (1% and 99%) strict (XAVIER, 2007, p.3).

The researcher himself decides the number of quantiles, which may vary according to the objective of the research (MONTEIRO; ROCHA E ZANELLA, 2012). If the intention is to set extreme rainfall values for the studied region, one can use quantiles between 5% and 95%, the lower and upper values. According to the accumulated total from each one of the 30 years, ordered from the lowest to the highest value, 5% of them will be below Q(0.05) representing lower extreme values of rainfall.

However, at the other end of the table, the values above Q(0.95) represent the high rainfall rates. Thus, one can conclude that it is possible to obtain the extreme values of accumulated rainfall only in one or two years of this period, for low (extremely dry years) and for high (extremely rainy years) rainfall rates (MONTEIRO; ROCHA, ZANELLA, 2012, p. 238).

In this paper, the division followed the one that Pinkayan (1966) had used in his work, namely very dry, dry, normal, rainy, and very rainy. The quantile intervals that represent these categories are Q(0,15), Q(0,35), Q(0,65) and Q(0,85). Furthermore, the interval below Q(0,15) indicates very dry accumulations, whereas the one above Q(0,85) indicates very rainy accumulations.

The category considered extreme – very dry and very rainy – presents a relatively smaller interval of only 15% and offers a more reliable mathematical calculation that considers the normal distribution. The normal category, in turn, presents an interval of 30%. To facilitate the understanding of this distribution using the quantile over 30 years, figure 01 below goes from the very dry to very rainy years.

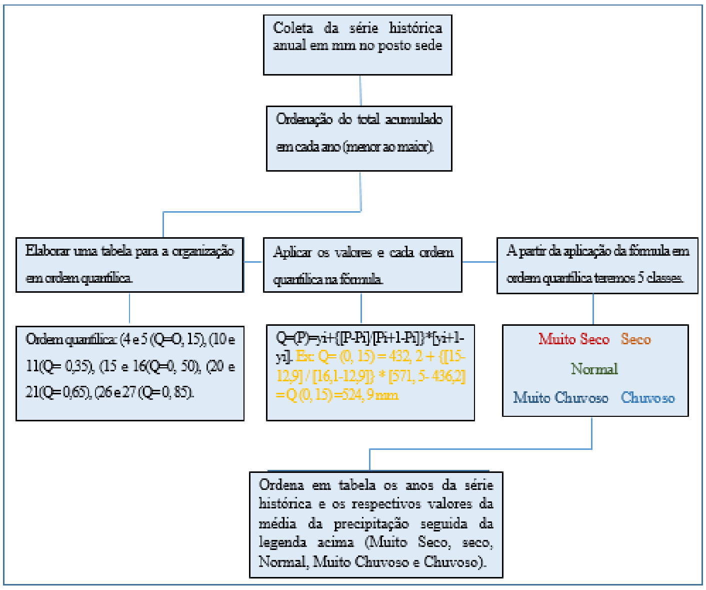
Figure 1 –Distribution of rainfall accumulations over 30 years from the lowest to the highest rainfall accumulation

Anos	Total acumulados em mm anual (Menor ao maior)
Anos muito secos (15%)	
2012	395 mm
1993	407,6 mm
1997	413 mm
1998	436, 2 mm
Anos secos (20%)	
2016	571, 5 mm
1992	576,8 mm
2010	585, 4 mm
2014	612, 5 mm
2015	656 mm
2005	674 mm
Anos normais (30%)	
1990	715, 2 mm
1991	721, 5 mm
2011	821,9 mm
2013	823 mm
2006	841, 5 mm
2017	856 mm
2001	871, 6 mm
1996	891, 2 mm
2002	892, 8 mm
2018	914, 4 mm
Anos chuvosos (20%)	
2007	922, 2 mm
1995	923 mm
2000	1039, 4 mm
1989	1142, 6 mm
2003	1156 mm
2008	1196 mm
Anos muito chuvosos (15%)	
1994	1231, 5 mm
1999	1240, 8 mm
2009	1266, 5 mm
2004	1270 mm

Source: SILVA (2020), based on Monteiro; Rocha and Zanella (2012)

To obtain this result, it was necessary to establish the quantiles Q(0.15), Q(0.35), Q(0.50), Q(0.65), Q(0.85), according to the qualified information present in the considered places. They underwent an analysis process to compose the table and perform the statistical calculations. In this study, the consideration of only one place for 30 years (from 1989 to 2018) identifies the extreme years (very dry and very rainy). Figure 02 presents the application of the quantile technique.

Figure 2– Flowchart with the application steps of the quantile technique to obtain the thresholds for the rainfall categories.



Source: SILVA (2019).

4 Results and Discussion

By analyzing the data from Sobral, it is possible to verify that the rainfall takes place during four months (from February to May). This seasonality is related to the occurrence of atmospheric systems strongly influenced by oceanic temperatures. It acts in low latitudes, presenting atmospheric steadiness in winter/spring and unsteadiness in summer/fall.

The accumulated values during thirty years in the station are in ascending order, according to figure 3, for subsequent application of the quantile technique. They are Q(0.15), Q(0.35), Q(0.50), Q(0.65) and Q(0.85).
Figure 3 - Tables with values ordered for the application of the quantile technique in Sobral
Source: SILVA (2020)

i	y (mm)	Pi = i/(N+1)	
1	395	1/31	0.032
2	407,6	2/31	0.064
3	413	3/31	0.096
4	436,2	4/31	0.129
5	571,5	5/31	0.161
6	576,8	6/31	0.193
7	585,4	7/31	0.225
8	612,5	8/31	0.258
9	656	9/31	0.290
10	675	10/31	0.322

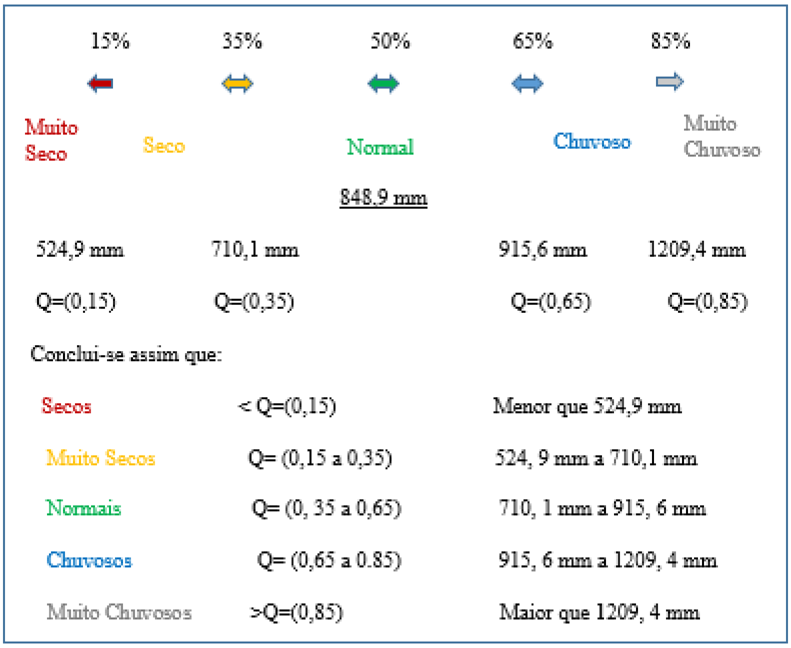
i	y (mm)	Pi = i/(N+1)	
11	715,2	11/31	0.354
12	721,5	12/31	0.387
13	821,9	13/31	0.419
14	823	14/31	0.451
15	841,5	15/31	0.483
16	856	16/31	0.516
17	871,6	17/31	0.548
18	891,2	18/31	0.580
19	892,8	19/31	0.612
20	914,4	20/31	0.645

i	y (mm)	Pi = i/(N+1)	
21	922,2	21/31	0.677
22	923	22/31	0.709
23	1039,4	23/31	0.741
24	1142,6	24/31	0.774
25	1156	25/31	0.806
26	1196	26/31	0.838
27	1231,9	27/31	0.870
28	1240,8	28/31	0.903
29	1266,5	29/31	0.935
30	1270	30/31	0.967

Source: SILVA (2020)

After the application of the quantile statistical technique, values in (mm) estimated for the due quantiles Q(0.15), Q(0.35), Q(0.50), Q(0.65) and Q(0.85) were obtained and arranged in the five categories, according to the schematic model below (Figure 4).So, 15% and 85% represent the extreme categories (very dry and very rainy).

Figure 4 – Established values for eachquantile



Source: SILVA (2020), based on Monteiro, Rocha and Zanella (2012)

To obtain the results above, there was a mathematical calculation for each quantile (figure 5).

Figure 5 – Calculation to obtain the quantiles

Q= (0,15) = 436,2+(15-12,9/16,1-12,9) *(571,5-436,2) =524,9 mm

Q= (0,35) = 675,0+(35-32/35,4-32,2) *(715,2-675,0) = 710,1mm

Q= (0,50) = 841,5+ (50-48,3/51,6-48,3) *(856-841,5) =848,9 mm

Q= (0,65) = 914,4+(65-64,5/67,7-64,5) * (922,2-914,4) = 915,6mm

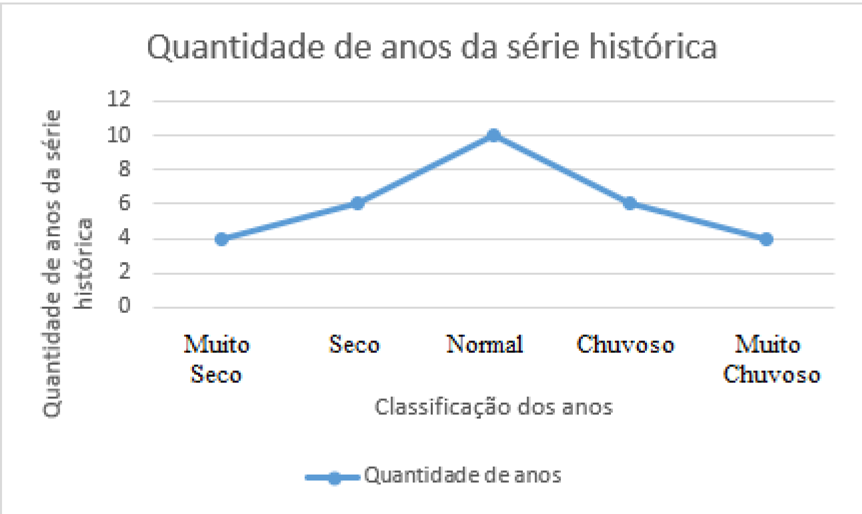
Q = 0,85) = 1196 (85-83,8/87,0-83,8) * 9 1231,9-1196) =1209,4mm

Source: SILVA (2020)

Through the results obtained, it was possible to observe that the city of Sobral has an average accumulation that revolves around 848.9 mm annually. The intervals established in (mm) for each extreme category indicate that accumulations below 524.9 mm are very dry years, while accumulations of 1209.4 mm are very rainy years.

According to the application of the quantile technique for 30years, it was possible to observe that four years (1993, 1997, 1998, 2012) were very dry, with emphasis on the years 2012 with 395 mm and 1993 with 407.6 mm.In those years, a declared public calamity lasted 90 days. On the other hand, the years considered very rainy were also four (1994, 1999, 2009, 2004), with emphasis on the years2004 with 1270 mm and 2009 with 1266.5 mm.

Figure 6 – Number of years classified according to each quantile category



Source: SILVA (2020)

Six years were dry (2016, 1992, 2010, 2014, 2015, 2005), corresponding to 20% of the observations. The years considered normal were ten (1990, 1991, 2011, 2013, 2006, 2017, 2001, 1996, 2002, 2018), corresponding to 30% of the observations. Rainy years were six (2007, 1995, 2000, 1989, 2003, 2008), corresponding to 20% of the observations. In other words, there is a normal distribution from the statistical point of view.

5 Final Considerations

The studies of extreme events are gradually consolidating due to the serious consequences triggered when they occur, such as disease, death, and material and human losses, which strike harder the most vulnerable populations.

Adopting prevention and response strategies for such events becomes a hard task. However, identifying the event is already a significant step. In this sense, statistical techniques can be important allies in this process, since they allow one to understand the rainfall behavior in a specific place, a fact verified in this research.

The use of the quantile technique demonstrated for the city of Sobral the importance of methodology when studying geographic climatology in the characterization of dry and rainy years in a historical series of thirty years (from 1989 to 2018). It supports discussions involving regional and urban planning, as well as for other works and research projects. Such methodology ends up indicating a prognosis for extreme climates in the semiarid region, since it takes into consideration the rainfall behavior in a certain location, the characteristics of the region's climate, accurately indicating the extreme values of rainfall for the area.

In a city in the semi-arid northeastern region, such as Sobral, the upper extreme events of rainfall is not so significant when compared to those that occur in cities from the south eastern region, where there are more significant accumulations. On the other hand, drought is quite common and leads to a continuous and silent socio-natural disaster that causes material and human damage.

Whether maximum or minimum precipitation, such events gain notoriety in a scenario that points to a global climate crisis. Extreme events are problems to be explored, studied, understood, and overcome in their most different aspects.

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