IJSRM
INTERNATIONAL JOURNAL OF SCIENCE AND RESEARCH METHODOLOGY
An Official Publication of Human Journals

Human Journals
Research Article
August 2020 Vol.:16, Issue:2

Statistical Study in Pluviometric Series of the Highrographic Basin of the High Course of Rio Paraíba/PB, Brazil

IJSRM
INTERNATIONAL JOURNAL OF SCIENCE AND RESEARCH METHODOLOGY
An Official Publication of Human Journals

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Submission: 25 July 2020
Accepted: 01 August 2020
Published: 30 August 2020

HUMAN JOURNALS

www.ijsrm.humanjournals.com

Keywords: Sustainability; Climatic Characterization; Climate Variability, Statistical Application, Pluviometry

ABSTRACT

Precipitation is of extreme importance for the management of water resources since it is a question of degraded areas and with deforestation for deforestation and the withdrawal of firewood. Frequency analysis was performed on annual rainfall totals using the graphs. The scale proposed by Meis *et al.* (1981), and by the meteorological and CPTEC/INPE nuclei, and provided by Xavier *et al.* (2005), the annual values that approached the mean value were characterized as intermediaries, and in the scale of annual precipitation values, those that moved away 25% in relation to the average were considered as very rainy years, and below 25%, as dry years. The application of the Student's t-test of significance pointed out that the precipitation data in general are 99% significant. The results showed a tendency of reductions in the rainfall indices, with oscillations of precipitations throughout the series 1962 to 2019 and evidenced the recurrence of maximum values of annual precipitation in the range of 17, 13 and 9 years. It is suggested a study with a series of larger years in order to verify the fluctuations and the contributions of the El Niño phenomena in the studied area.

INTRODUCTION

Precipitation is considered a relevant factor in the provision of various socioeconomic and environmental activities, in which hydroelectric plants, industries, agriculture and cattle raising and the increase of reservoir levels for human supply purposes stand out. For Kulkarni *et al*. (2013) rains are highly important, especially in tropical regions and are considered the main point of convective processes that occur in the atmosphere.

The analysis of trends in historical precipitation series is important to verify the inter-annual and ten-year climate variability so that they can be identified as the climatic changes can modulate these temporal patterns of variability.

Investigations on variability and climate change consider variations in rainfall as an index for detecting climate change because it has a reasonably long observational record and is easy to estimate. The analysis of the behavior of the rains in the Northeast Region of Brazil (NEB) is of great relevance, mainly due to its irregularity, since the climatic variables are very important not only under the climatic approach, but also due to the social and economic consequences. economical. According to Zanella (2006), several phenomena linked to the new climatic conditions in the cities, in the last decades, such as the temperature increase, an atmospheric pressure, such as more intense rains, among others, become part of the daily life of the population, vulnerable to countless problems of theirs needed.

Medeiros *et al*. (2015) carried out an analysis of the climate and availability of surface and underground water resources in the municipality of São João do Cariri, state of Paraíba and found that in terms of climate, water resources and the real water needs for the main activities of economic importance, viewed through of the water balance the municipality needs rainwater storage since the groundwater is not sufficient and also does not present satisfactory quality for domestic use and for other purposes.

Different authors have evaluated the trend in precipitation observed in NEB during the 20th century. For example, Haylock *et al*. (2006) carried out an analysis of precipitation over South America and observed an upward trend in the annual total rainfall over NEB. The study by Santos *et al*. (2007), using indexes of climatic extremes and correlating them with sea surface temperature anomalies (TSM), also shows a tendency to increase the total annual precipitation in the States of Paraíba and Rio Grande do Norte. Still according to Santos *et al*. (2007) showed trends of increased precipitation for the State of Ceará.

Second Marengo (2012), the NEB region is naturally characterized with high potential for water evaporation due to the great availability of solar energy and high temperatures. Temperature increases associated with climate change resulting from global warming, regardless of what may happen with the rains, would be enough to cause greater evaporation of lakes, weirs and reservoirs and greater evaporative demand from plants. That is, unless there is an increase in rainfall, water will become a much scarcer commodity, with serious consequences for the sustainability of regional development.

With the objective of analyzing the climate changes on the NEB and aiming at the importance of conceptualizing the processes that influence the pattern of rainfall distributions, both spatial and temporal. It was observed that the relevant factor to be highlighted is the irregularity of the distributions of the pluviometric indexes, associated with the high interannual variability of precipitation in the tropical region, with dry and rainy years. Different factors contribute to explain the variability of precipitation over the NEB, among which can be mentioned the fluctuation in the TSM's values of the South Tropical Pacific Ocean and the South Atlantic. In general, the values of TSM's anomalies, of the Tropical Pacific and Atlantic are associated with changes in the general circulation pattern of the atmosphere and consequent variations in NEB precipitation according Araújo (2009).

On the other hand, the importance of research involving the study of the climate in the search for the construction of new knowledge parameters and consequent application in the various human activities (agriculture, water impounding, agriculture, economy, commerce, leisure, irrigation, hydrology and other sciences) that depend on increasingly concise data and information on rainfall, temporal droughts and extreme events, in short, medium and long term information generated with a high degree of accuracy (VIEIRA, 2010).

Precipitation is a climatic element with greater temporal space variability. For this reason, the study of extreme events of maximum daily precipitation is related to severe damage to human activities in all regions of the world, due to its potential to cause water saturation of the soil, runoff and erosion in accordance with IPCC (2007); Tammets *et al.* (2013).

Monitoring of the region's rainfall regime in recent years has shown that scarcity of water resources accentuates socioeconomic problems, particularly at the end of each year, with rainfall totals around or below the region's average according Marengo *et al*. (2006).

Water planning is the basis for dimensioning any form of integrated management of water resources, thus, the water balance allows knowledge of the need and availability of water in the soil over time. The water balance as a management unit allows to classify the climate of a region, perform the agroclimatic and environmental zoning, the period of availability and water need in the soil, in addition to favoring the integrated management of water resources (Lima, 2009).

The climate has a great influence on the operating environment as a factor of interactions between (a) biotic components. The climate located in the different latitudes of the globe does not present the same characteristics in each year, according to Soriano (1997). In a region with a climate of contrasting areas (rainy and semi-arid side) such as the NEB and especially the state of Paraíba, monitoring of precipitation, especially during the rainy season, is important for making decisions that bring benefits to the population. According to Santana *et al*. (2007), due to this, the seasonality of precipitation concentrates almost all of its volume during the five to six months in the rainy period, according to Silva (2004).

The climatic variability of a given region has an important influence on the various socioeconomic, agricultural and hydrological activities. Since the climate is made up of a set of integrated elements, determinant for human survival, it acquires relevance, since its configuration can facilitate or hinder the fixation of man and the development of his activities in the different regions of the planet. Among the climatic elements, precipitation plays a major role in the development of human activities, producing results in the economy according to Sleiman (2008).

Sant'anna Neto (2008) studied the climate and its impacts, in a geographical perspective, must reach two levels: the socioeconomic dimension and the environmental dimension. In the socioeconomic dimension, it understands the influence of atmospheric phenomena and climatic patterns in the structuring of the territory and in society's daily life, a territory that can be modified due to the variability resulting from climate changes.

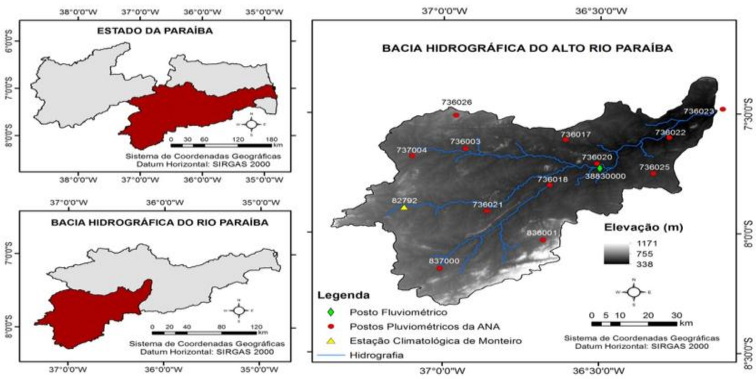
According Tucci (2002), the definitions used in the literature on climate change differ according to the inclusion of anthropic effects in the identification of variability. The Intergovernmental Panel on Climate Change (IPCC, 2007) defines climate change as temporal changes in climate due to natural variability and / or results of human activities. Other authors, such as Ferola (2003), Ichikawa (2004) and Sturm et al. (2005) adopt, for the same term, the definition of changes associated (in) directly with human activities that alter the natural climatic variability observed in a period.

According Meis et al. (1981), precipitations over time can be analyzed in different ways, making it possible to recognize their general behavior, their habitual and extreme patterns.

The distribution of precipitation in northeastern Brazil is quite uneven in time and space, in addition, the rainy season occurs differently, in quantity, duration and distribution. The objective of the hydrographic basin of the upper course of the Parnaíba River - PB, Brazil is to analyze the rainfall variation in the period from 1962 to 2019. This study is relevant, since the studied area is characterized by having variability in the rainfall indexes and a diversity in the patterns of land occupation, where the impacts of precipitation have a great influence on the studied area, extreme events affect the socioeconomic and agricultural issues and water impoundment.

MATERIAL AND METHODS

The Paraíba River Upper Course Basin (BHACRP), with an area of 20,071.83 km2, comprised between latitudes 6º51'31 "and 8º26'21" South and longitudes 34º48'35 "; and 37º2'15"; West of Greenwich, it is the second largest hydrographic basin in the State of Paraíba, as it covers 38% of its territory, housing 1,828,178 inhabitants which correspond to 52% of its total population. Considered one of the most important basins in the northeastern semi-arid region, it comprises the sub-basin of the Taperoá River and the Upper Course of the Paraíba River, the Middle Course of the Paraíba River and the Low Course of the Paraíba River. In addition to the high population density, the basin includes the cities of João Pessoa, capital of Paraíba and Campina Grande, its second largest urban center (Figure 1).



Source: Silva et al. (2016).

Figure No. 1: Location of the Upper Course of the Paraíba River hydrographic basin. Source: Silva *et al*. (2016).

The basin is made up of regions afflicted by local, regional and large-scale synoptic events causing rain, such as the Intertropical Convergence Zone (ZCIT) and the contributions of the High Level Cyclonic Vortexes (VCANs) when operating on the NEB, in addition to the effects of the northeast trade winds in conjunction with the effects of sea breeze, aided by the formation of the South Atlantic Cyclonic vortices (VCAS) and the formation of the Instability Lines (IL), the Dipole Pattern (PD) in the Ocean Tropical Atlantic and wave disturbances in the field of trade winds, providing events for droughts, floods, floods, floods, overflowing rivers, dams, muds, ponds, lakes and streams; in most cases, the flow of rivers at the headwaters is temporary due to poor rainfall distribution. In the region of Paraiba, the rainy season with the increase in rainfall levels causes a significant increase in runoff in which the majority are dammed in large and medium dams and their excess after the damming flows slowly into the ocean due to the relief and its basic courses of the waters in accordance with Medeiros (2016).

The relief is generally quite diversified, consisting of different forms of relief worked and by different processes, acting under different climates and on rocks that are little or very different. Regarding geomorphology, there are three groups formed by the most significant climatic types: humid, sub-humid and semi-arid. Current use and vegetation cover are characterized by forest formations defined as open tree shrubbery, closed tree shrubbery, closed treehouse, coastal board, mangroves, wetland, semi-deciduous forest, Atlantic forest and sandbank.

It used series of monthly and annual precipitation data collected by the Northeast Development Superintendence (SUDENE, 1990) and provided by the Executive Water Management Agency of the State of Paraíba (AESA, 2019), for the twelve municipalities that bypass The Paraíba River Upper Course Watershed (BHACRP) represented in table 1.

Table No. 1: Location of municipalities and their geographic coordinates, with the period of monthly and annual rainfall observations.

Municipalities/months	Latitude	Longitude	Altitude	Period
Barra S. Miguel	-7,45	-36,19	520	1962-2019
Cabaceiras	-7,29	-36,17	338	1926-2019
Camalaú	-7,53	-36,49	565	1962-2019
Caraúbas	-7,43	-36,29	460	1931-2019
Congo	-7,47	-36,39	500	1962-2019
Coxixola	-7,37	-36,36	465	1962-2019
Monteiro	-7,53	-37,07	590	1911-2019
Prata	-7,41	-37,04	600	1962-2019
São João do Tigre	-8,04	-36,5	616	1934-2019
São José Cordeiros	-7,23	-36,48	600	1963-2019
São Sebastião Umbuzeiro	-8,09	-37	600	1962-2019
Serra Branca	-7,28	-36,39	450	1962-2019

Source: Medeiros (2020).

The use of electronic spreadsheets for graphing with the annual variability of rainfall, rainfall anomalies, historical precipitation and percentage deviation. The rain data were made of fault filling, homogenization and consistency in order to provide consistent information.

Frequency analysis of the distributions of annual rainfall totals was carried out by means of graphs. The scale proposed by Meis *et al*. (1981), made available by Xavier *et al*. (2005), defined as follows: the annual values that came closest to the average value, were characterized as intermediate, and the annual precipitation values that deviated from the average were considered as representative for the driest and most humid years. A scale of variation of 25% was used in relation to the average for the intermediate months; values above the scale were characterized as very rainy years, and those below 25%, dry years in accordance with Xavier *et al*. (2005).

Table No. 2: Classification criteria used to classify municipalities according to classes of the monthly and annual percentage deviation for the upper Paraíba watershed area.

Classification Criteria	
Percent Deviation	Classification
± 0,0 A 25,0%	Normal
±25,1 A 45,0%	Dry / Rainy
± 45,1 A 70,0%	Very dry / Very rainy
± 70,1 >100,0%	Extremely Dry / Extremely Rainy

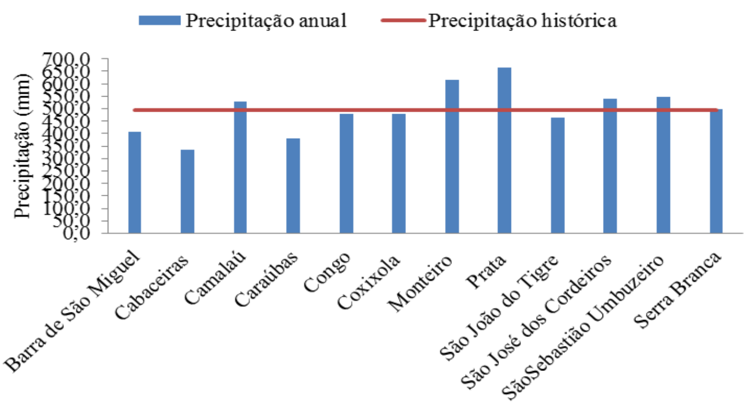
Source: CPTEC / INPE / meteorology nuclei (2010).

RESULTS AND DISCUSSION

The Diagnosis of the variability of rainfall indexes in the studied area indicates a slight downward trend in these annual totals over 52 years, with a decrease of 0.2 mm.year-1, totaling 75 mm in the whole series. However, it is not possible to affirm that this is about some climatic change, because, as already mentioned, the rainfall variability may alter this trend in the years to come. Similar results were observed by Holanda *et al*. (2016) showing the decadal rainfall fluctuations for Recife - PE where in the rainy season there are positive trends and negative trends were recorded in the dry period.

As the sample series is a period of data with great significance, having a period of 52 years, it is necessary to expand the data series during the second decade of the 21st century, for a more accurate future evaluation; thus, it is suggested that these analyzes continue in subsequent years. Similar results were obtained by Medeiros *et al*. (2013) for the area of the hydrographic basin of Rio Uruçuí Preto - PI.

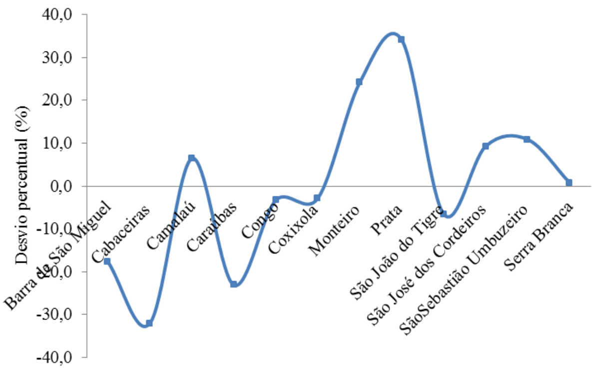
The oscillations of the rain are established in main characteristics of the pluviometric regime in the area of the hydrographic basin of the upper course of the Parnaíba river. As it is an area where two climatic types are distinguished, “As” and “Bsh”. The climatic types were determined by the method of Köppen (1928) and reviewed in the studies by Alvares *et al*. (2014). Having an irregular rainfall, with its magnitude changing intermunicipalities. Figure 2 shows the distribution of annual rainfall between the years 1962 to 2014, where the historical annual average was 495.3 mm. Precipitation rates range from 664.3 to 336.4 mm occurred among the twelve cities studied. The locations with the highest rainfall were Camalaú, Monteiro, Prata São José dos Tigre and São Sebastião do Umbuzeiro.



Source: Medeiros (2020).

Figure No. 2: Temporal distribution of annual rainfall and historical average in the area of the hydrographic basin of the upper course of the Paraíba River.

The significant rainfall variability that occurs in the study area results in observable annual deviations. As can be seen in Figure 3, during the 57 years, the highest annual index was those places: Camalaú, Monteiro, Prata, São José dos Cordeiros, São Sebastião do Umbuzeiro and Serra Branca resulting in positive variation in relation to normal higher than 35%. The droughts recorded throughout the series were: Barra de São Miguel, Cabaceiras, Caraúbas, Congo, Coxixola and São José do Tigre. The El Niño phenomenon influences the considerable reduction in rainfall, since, in El Niño years, there is a reduction in rainfall totals in the Northeast region and especially in the study region, causing severe droughts in some municipalities.



Source: Medeiros (2020).

Figure No. 3: Annual percentage deviation of precipitation in relation to the historical average for the area of the hydrographic basin of the upper course of the Paraíba River.

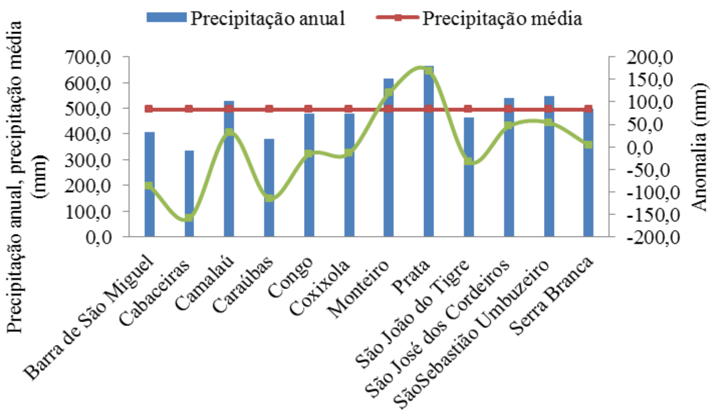
Table 2 presents the classification criteria used to classify the municipalities according to classes of the monthly and annual percentage deviation for the upper Paraíba watershed area. Table 3 shows the names of the municipalities, annual precipitation values, historical averages, percentage deviation, precipitation anomaly and their respective classifications for the period from 1962 to 2019. The variability was also expressed in the characterization of the normal, dry year, rainy, very dry, very rainy, extremely dry and extremely rainy according to the deviation from the average, as seen in Table 3. In the total of the 12 municipalities observed, it is clear that 10 sites were classified as normal rains, one like dry and rainy. The analysis of the distribution of rainfall in the study area showed a slight tendency to reduce these annual totals over the 57 years studied, according to table 3.

Table No. 3: Municipalities, annual rainfall; historical precipitation; percentage deviation, precipitation anomaly and annual classification of the period (1962 - 2019), according to the method proposed by Meis *et al*. (1981) and CPTEC / INPE / meteorology centers (2010). For the hydrographic basin area of the upper Paraíba River course.

Counties	Annual Precipitation (mm)	Historical Precipitation (mm)	Percent Deviation (mm)	Anomaly Precipitation (mm)	Classification
Barra São Miguel	407,6	495,3	-17,7	-87,6	Normal
Cabaceiras	336,4	495,3	-32,1	-158,9	Seco
Camalaú	527,1	495,3	6,4	31,8	Normal
Caraúbas	380,7	495,3	-23,1	-114,6	Normal
Congo	478,8	495,3	-3,3	-16,4	Normal
Coxixola	481,0	495,3	-2,9	-14,3	Normal
Monteiro	615,0	495,3	24,2	119,7	Normal
Prata	664,3	495,3	34,1	169,1	Chuvoso
São JoséTigre	462,7	495,3	-6,6	-32,6	Normal
São J. Cordeiros	541,3	495,3	9,3	46,0	Normal
S. S. Umbuzeiro	549,2	495,3	10,9	53,9	Normal
Serra Branca	499,2	495,3	0,8	3,9	Normal

Source: Medeiros (2020).

Regarding anomalies, there was a predominance of negative anomalies in relation to normal. Negative anomalies in the period were found in six municipalities, and positive anomalies in five municipalities and the presence of a neutral municipality. As for the analysis carried out, these allow the identification of rainy, dry and neutral municipalities, also presenting the most variable locations and, therefore, difficult to forecast as well as the probability of recurrence over time. (Figure 4).



Source: Medeiros (2020).

Figure No. 4: Distribution of annual precipitation, historical average and rainfall anomaly for the area of the hydrographic basin of the upper course of the Paraíba River.

CONCLUSIONS

The application of Student's T-test of statistical significance, highlighted that precipitation data in general are 99% significant.

The desired results make visible the tendency of decreases in the pluviometric indexes, with oscillations of the precipitations along the sampling series, which comprised the (1962 to 2019); there was a recurrence of maximum annual precipitation values within a range of 17, 13 and 9 years.

It is suggested a study with a series of older years to verify the fluctuations and contributions of the phenomena El Niño and La Niña in the studied area.

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