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TRENDS AND ANNUAL VARIABILITY OF RAINFALL IN NATAL, NORTHEASTERN BRAZIL

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Abstract: *This work proposes to carry out an analysis of trends in annual precipitation in the municipality of Natal, state of Rio Grande do Norte, northeast Brazil. We analyzed the frequency of dry and rainy years over a period of 90 years (1931-2020). The precipitation data were organized into dataframes in Software R, from which Mann-Kendall trend calculations and the quantile technique were applied to categorize wet years. As a result, it was found that the years considered extremely dry and dry were concentrated in the first 30 years of the period, and that, although no significant statistical trend was calculated, 92% of the extremely wet and wet years were concentrated in the last 30 years.*

Keywords: *Annual variability, climate change, Rio Grande do Norte, precipitation.*

Résumé : ***Tendances et variabilité annuelle des précipitations au Natal, au nord-est du Brésil.*** *Ce travail propose de réaliser une analyse des tendances des précipitations annuelles dans la municipalité de Natal, état du Rio Grande do Norte, nord-est du Brésil. Nous avons analysé la fréquence des années sèches et pluvieuses sur une période de 90 ans (1931-2020). Les données sur les précipitations ont été organisées en blocs de données dans le logiciel R, à partir desquels les calculs de tendance de Mann-Kendall et la technique des quantiles ont été appliqués pour catégoriser les années humides. En conséquence, il a été constaté que les années considérées comme extrêmement sèches et sèches étaient concentrées dans les 30 premières années de la période, et que, bien qu'aucune tendance statistique significative n'ait été calculée, 92 % des années extrêmement humides et humides étaient concentrées dans les 30 premières années de la période*

Mots clés : *Variabilité annuelle, changement climatique, Rio Grande do Norte, précipitation.*

Introduction

Among the meteorological variables most affected by climate change scenarios, rainfall is one of the most relevant parameters. Its study in climatology has a strong relevance due to the repercussions in the social, environmental, and economic spheres of a given location. Concerning the city of Natal (Figure 1), its rainfall distribution regime is heterogeneous, evidenced by its contrasts between rainy years and periods with little precipitation (Rocha and Studart, 2014).

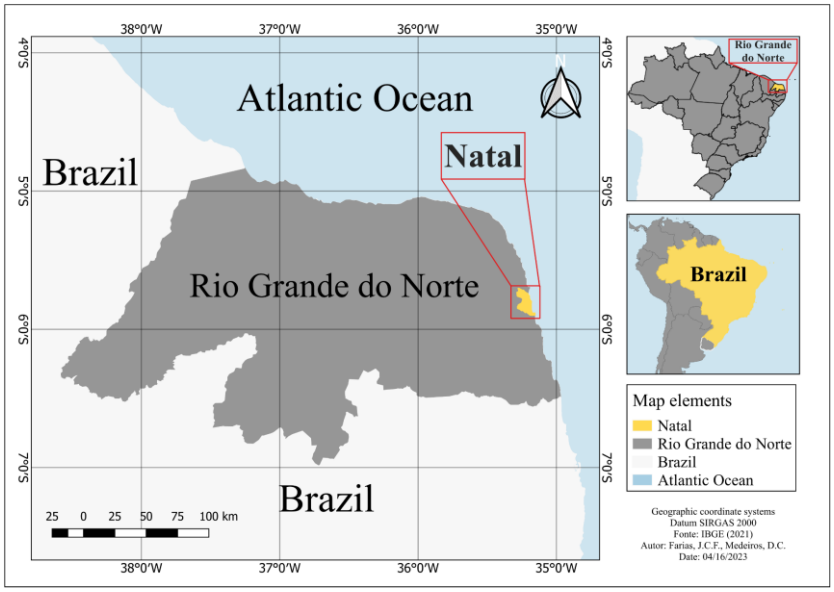

Figure 1. Localization of Natal, Rio Grande do Norte, Northeast Brazil

The present study proposes to perform a categorization of annual precipitation and an analysis of annual precipitation trends in the municipality of Natal, Rio Grande do Norte for a period of 90 years (1931-2020).

The municipality has a territorial area of 167,401 km², and an estimated population of almost 897,000 inhabitants (IBGE,2021), 100% of which are in urban areas. In the meantime, the city's urbanization process occurred quickly and in a disorderly manner, factors that resulted in poor land use and the ineffectiveness of the urban rainwater drainage system.

Factors such as these, added to the increase in the frequency of extreme events linked to heavy rainfall, have caused precariousness in the city's urban scenario, making it necessary that analyses of rainfall records, their intensities and frequencies are carried out, increasing the existing knowledge of climate trends and potential scenarios for the municipality (Rocha and Studart, 2014).

1. Data and methods

For this study, we used monthly precipitation data for the period from 1931 to 2020. They were collected through the database of the National Institute of Meteorology (INMET) and the Superintendence of Northeast Development (SUDENE), referring to the meteorological station of Natal.

It is worth mentioning that some years of the time series were not considered due to the significant incompleteness of data. However, in years with gaps of up to four months, the missing value was replaced by the average of the respective month in the interval between 1931-2020; finally, the value was added to the other months to integrate the annual average reliably.

The annual totals were organized in data frames in the R Software and, from that, submitted to the Mann-Kendall trend calculations and to the quantile technique to define the classification intervals by percentiles, being later categorized following the representations proposed by Xavier (1999) and Silvestre et al (2015). Thus, for each year we distributed precipitation into five categories concerning their totals: Extreme dry season (< 15th percentile), dry season (15th - 35th percentile), usual season (35th - 65th percentile), wet season (65th percentile - 85) and extreme wet season (>85th percentile). Table 1 reveals the ranges of rainfall values for each category and season, respectively.

Table 1. Categories of precipitation (mm) in Natal, Rio Grande do Norte, Brazil (1931-2020)

Annual Precipitation	EXTREME DRY	DRY	USUAL	WET	EXTREME WET
	< 1127.1	1127.1 to 1353.5	1353.5 to 1752.1	1752.1 to 2088.8	> 2088.8

2. Results

The average precipitation in the municipality of Natal for the 90 years studied reached the amount of 1609.4mm/year, but different values were obtained between the three normal ones. Between 1931 and 1960, an average value of only 1361 mm/year was reached, close to the threshold of one year considered to be dry and about 15% lower than the general average.

From 1961 to 1990 the rainfall indexes reached an average of 1831.8mm/year, which would be considered a year tending to rain, in addition to corresponding to an increase of approximately 35% concerning the average of the first normal year. As for the years between 1990 and 2020, the average reached 1682.1 mm/year, a value for a year considered normal. Table 2 illustrates the categories of annual precipitation in the city of Natal separated into the three climatological normals (INMET, 2021).

In context, in the second half of the 20th century, Rio Grande do Norte began its process of industrial and tourist growth, influencing the population of Natal, which grew from 160,000 inhabitants in 1960 to approximately 869,000 in 2015 (Rocha and Studart, 2014). Thus, it is pointed out that the urban extension is directly associated with a higher rate of precipitation in the municipality.

In this regard, a study showed a positive difference of 26% between the mean annual rainfall at the rainfall station in Natal and that of the Canguaretama station, a city located in a naturally wetter area south of the east coast of the state and with a population 25 times smaller than Natal (Rocha and Studart, 2014, Diniz et al, 2018). In agreement with the results displayed, the present study found an increase of 470.8 mm and 321.1 mm in the average rainfall of the second and third normals, respectively, with the average obtained in the first normal (1361 mm).

As can be seen in Table 2, considering the 90 years, the first normal shows a total of eight of the 12 dry years (67%) and nine of the 17 years tending to dry (53%), in addition, there is the occurrence of only one of the 13 wet years (8%). Furthermore, the period presented an uninterrupted drought that lasted 10 years (1946-1955), starting with three years considered to be dry, followed by seven dry years, with a minimum precipitation of 530.1 mm in 1954. The longest period without wet years can be observed in the first normal, which lasted from 1932 to 1962.

Analyzing the second normal, present in Table 2, only two out of the 12 dry years (17%) and three out of the 17 years tending to dry (18%) are noted; moreover, the presence of expressive six out of the 13 years classified as rainy (46%). Furthermore, the interval presented a rainy period of five consecutive years (1963-1967), started by two rainy years followed by three years tending to rain. It is also noticed that between the years 1961 to 1990 there is no sequence of dry and dry years.

Table 2. Annual precipitation (mm) and their categories in Natal, Rio Grande do Norte, Brazil (1931-2020)

Normal 1931-1960:									
1931	1932	1933	1934	1935	1936	1937	1938	1939	1940
2096.5	1238.2	1286.6	1601.7	2079.3	1503.1	1699.5	1517.2	1658.2	2058.0
1941	1942	1943	1944	1945	1946	1947	1948	1949	1950
1140.7	1255.8	1367.4	1249.0	1844.6	1345.1	1353.4	1329.4	1126.9	883.5
1951	1952	1953	1954	1955	1956	1957	1958	1959	1960
906.4	948.2	651.1	530.1	1106.5	1424.1	1138.5	833.7	1669.4	1990.5
Normal 1961-1990:									
1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
1761.3	1555.9	2126.7	2827.1	2014.6	1990.2	1941.2	1174.2	2067.6	1503.6
1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
1837.4	1127.4	3510.9	2461.6	1380.5	1635.6	1575.8	988.5	NA	NA
1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
NA	NA	NA	2028.9	NA	2530.3	1496.2	2136.1	1065.1	1226.4
Normal 1991-2020:									
1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1364.2	1527.3	849	2171.8	1743.6	1584.7	1193.4	1655	1105	2246.1
2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1266.6	2018.1	1463.8	2447	1988.4	1536.2	1761.7	2485.1	2340.4	1183.4
2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
2188.5	1241.2	1877.1	1756	1412.1	1165	1654.6	1803.6	1752.6	NA

Legend:					
Incomplete Data	NA	Usual			
Extreme Dry		Wet			
Dry		Extreme Wet			

Furthermore, about the third normal, also illustrated in Table 2, six of the 13 rainy years (46%) and seven of the 17 years tending to be rainy (41%) are present in this period, in addition to the presence of only two of the 12 dry years (17%).

In this regard, throughout all the years between 1990 and 2020, there were no sequences of dry years and tending to dry years. It is also noteworthy that in the last 20 years of the normal (from 2000 to 2020) there were no dry years registered.

The occurrence of these extreme events is linked to the occurrence of the atmospheric-ocean phenomenon El Niño, considered a condition for periods of drought in the northeast region of Brazil (Lucena et al, 2014). Such information converges with the information made explicit in the results, in which periods of scarcity of rain are observed throughout the first normal, concentrating 67% of dry years and 53% of dry years, in addition to the minimum recorded in the entire series, which was 530.1 mm in the year 1954.

From this perspective, the trend of increasing rainfall in Natal has increased in recent decades, noting an increase of approximately 10% in average annual rainfall between the periods 1986 to 1995 and 2006 to 2015. Recent studies also revealed the role of urbanization as a strong influence on the local and regional atmospheric circulation system, mainly on issues related to precipitation.

Thus, there is a tendency for the average to reach 1800mm/year in the climatological station of Natal between 2015 and 2025 (Diniz et al, 2018). Analogously, the results of this research show the concentration of rainy and rainy years in the period from 1961 to 1990 and 1991 to 2020, in addition to the occurrence of only two dry years for each of the normal. Important to notice, however, that the Mann-Kendall tests did reveal a low-significant trends for the 90-year time series of precipitation.

The results presented a tau value of 0.129, but a p-value of 0.08 which can be assumed as a low significant value.

Conclusion

Through this study, it was possible to identify the trends of rainfall in the city of Natal by analyzing the standard years referring to the interval from 1931 to 2020. Thus, considering the concentration of rainy years and those tending to rain in the second and third normal and, still, of dry years and tending to dry in the first normal, it is concluded that there is a perspective of increasing rainfall in the municipality.

The literature on the climatological area brings a perspective of the attenuation of the rains in the northeast region of Brazil. However, studies on the increase in precipitation as a result of urbanization in the large cities of the northeastern coast, as well as the analysis of rainfall trends in the city of Natal, corroborated the establishment of a relationship between urban growth and the increase in average rainfall.

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