Available online at http://www.journalijdr.com

IJDR

International Journal of Development Research
Vol. 12, Issue, 07, pp. 57537-57541, July, 2022
https://doi.org/10.37118/ijdr.24966.07.2022

ISSN: 2230-9926

RESEARCH ARTICLE   OPEN ACCESS

PROBABLE RAIN REGIME FOR SÃO BENTO DO UNA-PERNAMBUCO, BRAZIL

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ARTICLE INFO

Article History:
Received 11th April, 2022
Received in revised form
16th May, 2022
Accepted 03rd June, 2022
Published online 28th July, 2022

Key Words:

Climatic and Extreme Events; Probability Density; Climate Changes.

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ABSTRACT

Studies on rainfall classification help in planning the amount of water available for the expansion of human, animal, plant, industrial, agricultural and hydrological activities. To analyze which, among the three probability distributions, best fits the historical series of probable maximum monthly precipitation data in the city of São Bento do Una Pernambuco, Brazil between 1921-2020. The maximum annual precipitation for São Bento do Una - PE was analyzed from 1921 to 2020, with data from the Weather and Climate Agency of the State of Pernambuco. Estimates of probable monthly rainfall were determined for levels of 5, 10, 20, 30, 40, 50, 60, 70, 75, 80, 90 and 95% probability using the probabilistic Gamma model, as described by Thom (1958). The maximum precipitation data fit the log-normal, gamma, and Weibull probability distribution functions and best fit the gamma probability distribution function. São Bento do Uma - Pernambuco needs to adopt strategies to coexist with drought, aiming at the economic growth of the municipality.

Citation: ***Raimundo Mainar Medeiros et al.*** "Probable rain regime for são bento do una-pernambuco, Brazil*", International Journal of Development Research*, 12, (07), 57537-57541.

INTRODUCTION

In recent decades, extremes of precipitation in urban environments have occurred frequently, causing socioeconomic losses and deaths (IPCC, 2018; OLIVEIRA JÚNIOR *et al*., 2021). The relationship between rainfall and its spatio-temporal variability has been widely studied in large urban centers (SOBRAL *et al*., 2020; LIMA *et al*., 2021) and in megacities (BAKLANOV *et al*., 2016). It is known that the dynamics of rain interfere in the daily life of the population and in the various socioeconomic activities (IPCC, 2018). The economic and sustainable development of any region depends on several factors, mainly water, as a source of life, supply and hydroelectricity (BORETTI *et al*., 2019; IBGE, 2020). According to the IPCC (2014) "extreme climatic variability and events are, since ancient times, important for decision-making contexts", highlighting that the risks associated with climate are more frequent and with high intensities, causing changes in socioeconomic development. local, regional and national. Extreme weather events, in the Brazilian case, whether positive or negative, have been occurring mainly as floods and prolonged droughts (MARENGO *et al*., 2010; MEDEIROS *et al*., 2014).

Marengo *et al*. (2009) highlighted that rainfall rates showed an increase in the frequency and intensity of rainfall in the South and Southeast of Brazil and, to a lesser extent, in the West of the Amazon and in the coastal area of the East of the Amazon and in the North of the Northeast region. They warned of reduced rainfall along the east coast of Northeast Brazil, extending from Rio Grande do Norte to Espírito Santo. Rainfall is the basic component of the hydrological cycle, as it represents the largest entry of water into hydrographic basins. When there is an increase in these indices, critical situations occur, called extreme events. Since a rainfall event is considered intense, when it presents values greater than the 95% percentile of occurrence of a data series, while the rainfall event is extreme, when values greater than the 99% percentile of the said series occur. The analysis of the impacts generated by the rains is of paramount importance for society, as it determines areas of risk for housing and the agricultural sector, determining works and strategies for hydro-agricultural management (MELLO *et al*., 2013). MELLO *et al*. (2007) showed the importance of analyzing intense rainfall for the planning of hydraulic works to control floods and floods, for urban and soil drainage, damming and urban and/or rural water supply. Excess and scarcity of rainfall can cause adverse events impacting different economic sectors at local, state and federal levels (ALVARENGA, 2012). Scholars from different scientific areas have been using the statistical tool to characterize certain phenomena, in the case of rainfall in a region, probabilistic distribution models that best represent the analyzed data set are sought (VIEIRA *et al*., 2010; DOURADO NETO *et al*., 2014, MAZUCHELI *et al*., 2019). Rainfall events in the Northeast region of Brazil result from the performance of meteorological and/or synoptic systems operating on different spatial and temporal scales, and are responsible for marked interannual oscillations, with extremely dry and rainy years (MEDEIROS *et al*., 2018). The seasonal fluctuations of rainfall in São Bento do Una - PE are dependent on climatic factors such as the Intertropical Convergence Zone (ITCZ), High Level Cyclonic Vortices (HCV), South Atlantic Convergence Zone (ZCAS), Convective Systems of Mesoscale (SCM), Eastern Wave Disturbances (DOL), Instability Line (LI), Latent heat exchange for sensible and local and regional synoptic aids (MEDEIROS 2020; GOMES *et al*., 2019; FEDOROVA *et al*., 2016; REBOITA *et al*., 2015). Movements in the physical organisms that control dynamic and synoptic systems produce fluctuations in the spatial and temporal distribution of rainfall. Knowledge of these fluctuations in a given area provides strategic advantages for managing water resources, planning productive, agricultural and livestock activities, water impoundment, as well as implementing systems to respond to extreme events such as droughts (MEDEIROS *et al*., 2020; Medeiros 2020), in addition to floods and landslides (RIBEIRO *et al*., 2021). In solving the probability of occurrence of rainfall indices of high magnitude to those contained in a series of rains, or events with a return period longer than the years of data for the series studied, it is necessary to obtain the complete pattern of rainfall fluctuations by using complex statistical treatments than the analysis of frequencies, as is the case of the theoretical functions of probability distribution (NAGHETTINI *et al*., 2007). The objective is to study and analyze which, among three probability distributions, would best fit the historical series of monthly rainfall data for the city of São Bento do Una Pernambuco, Brazil, between 1921 and 2020.

MATERIAL AND METHODS

São Bento do Una is located in the Agreste mesoregion and in the Ipojuca Valley Microregion of the State of Pernambuco, limited to the north by Belo Jardim, to the south by Jucati, Jupi and Lajedo, to the east by Cachoeirinha, and to the west by Capoeiras. , Sanharó and Fisheries. The municipal seat has an average altitude of 614 meters and geographical coordinates of 08° 31’ 22” south latitude and 36° 06’ 40” west longitude.

Source: Medeiros (2022).

Figure 1. Positioning of the municipality of São Bento do Una

According to the climate classification (KÖPPEN 1928; KÖPPEN *et al*., 1931) São Bento do Una has an “As” climate, Tropical Rainy, with dry summer (ALVARES *et al*., 2014; MEDEIROS *et al*. 2018).
With the aid of computer technologies, multiple models of probability distribution functions (FDP) and methods to estimate their parameters were proposed, the most common being in intense rainfall studies, highlighting the Gamma, Generalized Extreme Values, Generalized Pareto, Gumbel, Log Normal, Pearson 5 and Weibull (SANTOS *et al*., 2016; ALVES *et al*., 2013; QUADROS *et al*., 2011; SANSIGOLO, 2008; RODRIGUES *et al*., 2008; BACK, 2006; SILVA *et al*., 2002;). However, before adopting a PDF model to explain an event, it is necessary to verify the adherence of the distribution to the data set under analysis by means of statistical tests, such as the Cramer-Von Mises and Anderson-Darling tests, which evaluate the deviations between the sample and the theoretical distribution (BACK, 2001). The annual precipitation for São Bento do Una - PE was analyzed from 1921 to 2020, with data from the Weather and Climate Agency of the State of Pernambuco (APAC, 2021). Gamma Distribution (X ~ Gamma (a, b)) - if X is a continuous random variable, such that ($0 < x < \infty$), with parameters $a > 0$ and $b > 0$, then its probability density function can be defined by equation 1.

$$f(x) = \frac{1}{\beta^{\alpha}\tau(\alpha)} X^{\alpha-1} e^{\frac{X}{\beta}} \quad (1)$$

On what,

β - scale parameter (mm);
α - shape parameter (dimensionless);
e - base of the neperian logarithm;
X - Precipitation (mm);
Γ(α) - Gamma function.

The adjustment elements of the Gamma distribution, α and β, were estimated with the polynomial approximation, for the shape parameter, proposed by Greenwood *et al*. (1960) apud Wilks (2006), equation 2 and/or 3;

$$,\hat{\alpha} = \frac{0,5000876+0,1648852A-0,0544274A^2}{A}, \quad 0 \leq A \leq 0,5772; \text{ ou} \quad (2)$$

$$\hat{\alpha} = \frac{8,898919+9,05995A+0,9775373A^2}{17,79728A+11,968477A^2+A^3}, \quad 0,5772 \leq A \leq 17,0. \quad (3)$$

Calculating A by equation 6.

$$A = ln(\overline{X}) - \frac{1}{n}\sum_{j=1}^{n} ln\,(Xj) \quad (4)$$

X = observed values

$\overline{X}$ = Average of observed values
And beta (β) givenbyequation 5.

$$\hat{\beta} = \frac{\overline{X}}{\hat{\alpha}} \quad (5)$$

The estimate of probable monthly rainfall was determined for levels of 5, 10, 20, 30, 40, 50, 60, 70, 75, 80, 90 and 95% of probability using the Gamma probabilistic model, as described by Thom (1958). The density function of the two-parameter and three-parameter Log-normal distribution is represented by the following equation (RIBEIRO *et al*. 2007):

$$F(x) = \frac{1}{(x-a)\delta\sqrt{2\pi}} e\left(\frac{-[ln(x-a)-\mu]^2}{2\delta^2}\right) \quad (6)$$

Where,

F(x) - probability density function of the variable,
e - base of the neperian logarithm,
x - value of the random variable,
μ - mean of the logarithms of the variable x,
∂- standard deviation of the logarithms of the variable x,
a - lower limit of the sample.

Weibull distribution - its probability density function is most commonly presented as follows (Catalunha *et al*., 2002):

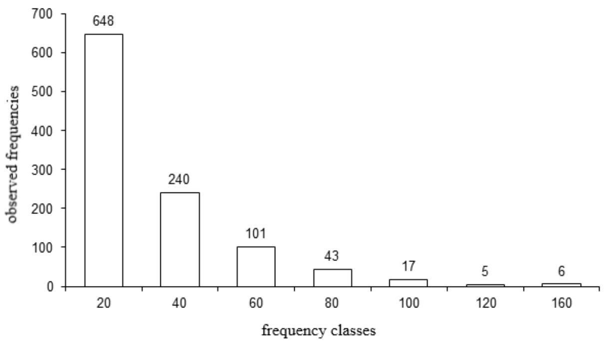
$$F(x) = \frac{\gamma}{\beta}\left(\frac{x-\alpha}{\beta}\right)^{(\gamma-1)} exp\left[-\left(\frac{x-\alpha}{\beta}\right)^{\gamma}\right] \quad (7)$$

For $x>=\alpha$
Where,
F(x) = 0 for other intervals,
x - random variable,
$\alpha \geq 0$, $\beta > 0$, $\gamma > 0$ the distribution parameters.

The data were analyzed individually for each month of each year that presented precipitation greater than 0.1 mm, being adjusted to the different probability distributions, through the maximum likelihood method, to determine the parameters referring to each distribution, due to its efficiency. and consistency (Junqueira Júnior *et al*., 2007). Log-normal, Gamma and Weibull probability distributions were applied, and their adherence tested with Cramer-von Mises and Anderson-Darling statistics, at a 5% significance level. The choice of the most recommended fit model was based on the Akaike information criterion (AIC) and on the Bayesian or Schwarz information criterion (BIC), using the R program (Rcore Team, 2021), the integrated development environment Rstudio (Rstudio Team, 2021), the fitdistrplus packages (Delignette-Muller *et al*., 2015), distributionfitR (GEIER, 2020), GOFTEST (FARAWAY *et al*., 2019).

RESULTS AND DISCUSSION

Figure 1 shows thehistogramofthe distribution of rainfall data for São Bento do Una-PE between 1921-2020. The rainfall classes were distributed like this for the study period, from 0 to 20 mm, 648 events were observed; from 20 to 40 mm we had 240 events; from 40 to 60 mm we had 101 occurrences; from 60 to 80 mm was observed with 43 occurrences; from 80 to 100 mm we had 17 events; from 100 to 120 mm, 5 events were observed; from 120 to 160 mm there were 6 events. When the occurrence of events was less than 5, it was added to the immediately preceding class. Low precipitation rates are observed in the locality, characteristic of the Brazilian semi-arid region. The study by Medeiros *et al*., (2021) corroborates the discussion presented.



Source: Medeiros (2022).

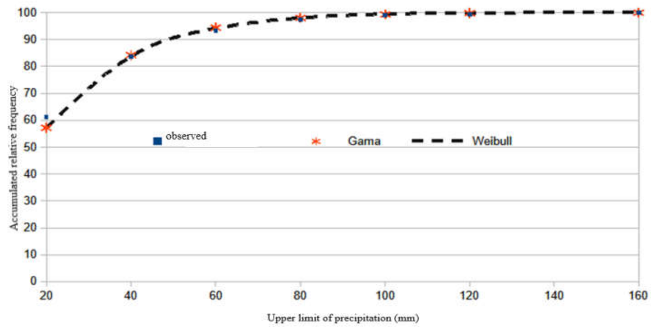
Figure 1. Histogramofthedistribution of precipitation data for São Bento do Una-PEbetween 1921-2020

Table 1 shows the probable precipitation values (mm/year) according to the probability level (%) for São Bento do Una - PE. Probability levels were computed from 5% to 5% allowing a better range of rainfall values. Between the probability levels of 5% to 50%, the maximum rainfall values do not exceed 17 mm/year. Between the levels of 55% to 95%, these values are significant, especially if they occur in a short period of time, due to the possibility of floods, inundations, floods and inundations causing socioeconomic and agricultural losses. Studies by (MARENGO *et al*., 2010; MEDEIROS *et al*., 2014; IPCC 2018) corroborate the results discussed. In these situations, knowing the periods in which rainfall fluctuations occurred more frequently is an important tool for adopting practices that minimize damage in different economic sectors, in addition to providing concise information to the hydroelectric and hydrological sector. Table 1 – Probability level (%) and probable maximum precipitation (mm/year) for São Bento do Una – PE between 1921-2020. For Medeiros *et al*. (2018) rainfall fluctuations can impact socioeconomic indicators, since the survival, permanence of the population and agricultural development fundamentally depend on the demand for rainwater.

Table 1. Probability level (%) and probable maximum precipitation (mm/year) for São Bento do Una – PE between 1921-2020

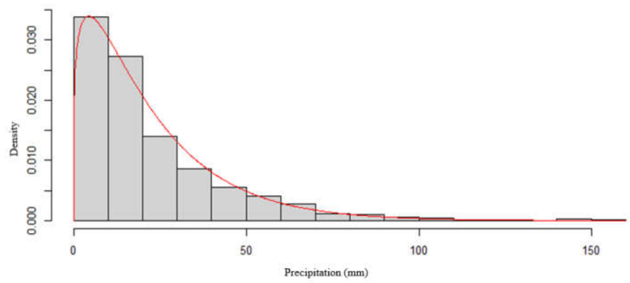
Probability	Maximum probable precipitation (mm/year)	Probability	Maximum probable precipitation (mm/year)
5%	1,87	55%	18,97
10%	3,39	60%	21,40
15%	4,86	65%	24,13
20%	6,35	70%	27,25
25%	7,87	75%	30,90
30%	9,45	80%	35,33
35%	11,11	85%	40,97
40%	12,86	90%	48,84
45%	14,74	95%	62,14
50%	16,76	-	-

Source: Medeiros (2022).



Source: Medeiros (2022).

Figure 2. Cumulative distribution as a function of precipitation (mm/year)



Source: Medeiros (2022).

Figure 3. Frequency density of the empirical and theoretical distribution of gamma probability, for São Bento do Una - PE from 1921 to 2020

In addition, works such as water reservoirs have their capacity intensely influenced by these variability. This statement corroborates the results discussed. The rainfall data follow a continuous distribution, and the gamma distribution is the most suitable fit for the representativeness of the data in relation to the Weibull and LogNormal distribution, being chosen because of the lowest values referring to the AIC and BIC criteria (Table 2). Figure 2 shows the accumulated distributions as a function of precipitation (mm/year), taking into account the observed and probable rains using the Gamma and Weibull distributions. It is observed that the behavior of the Gamma and Weibull distributions and the observed rainfall are close, but that due to the analysis of the AIC index, the gamma distribution is the most recommended. The gammadistributionshowed Cramer-Von Mises and Anderson-Darling coefficients, as shown in Table 3, higher than the reference values at the 5% significance level, making it possible to conclude that the data adequately fit the selected

Table 2- Shapefactor, scale factor, log mean, log standard deviation, Akaike criterion (AIC) and Bayesian or Schwarz information criterion (BIC) for different types of probability distribution, relative to monthly rainfall (mm) of São Bento do Una - PE, from 1921 to 2020

Distribution	factorof		Average	Standard deviation	Criterion	
	Form	Scale	log	log	AIC	BIC
Weibull	1,105125	23,298	-	-	8696,6	8706,5
Lnorm	-	-	2,655862	1,035650	8716,8	8726,7
Gama	1,244656	17,989	-	-	8684,6	8694,5

Caption: (-) withoutmodel information Source: Medeiros (2022).

Table 3. Coefficientsof adherence tests for different types of probability distribution, related to monthly rainfall (mm) in São Bento do Una-PE, between 1921 to 2020.

Distribution	Statisticaltest			
	Cramer-Von Mises		Anderson-Darling	
	Calculated	p-value	Calculated	p-value
Weibull	0,60343	0,509	2,5507	0,7956
Lnorm	0,88991	0,1277	3,6083	0,3671
Gama	0,61213	0,4912	2,4714	0,8263

Source: Medeiros (2022).

probability distribution. Table 3- Coefficientsof adherence tests for different types of probability distribution, related to monthly rainfall (mm) in São Bento do Una-PE, between 1921 to 2020. In theadjustmentof extreme precipitation events, for Mato Grosso, the studies by Mossini Júnior *et al*., (2016); Ramos *et al*., (2015); Batistão *et al*., (2014); Pizzato *et al*., (2012); Martins *et al*., (2010); corroborating the results obtained. The frequency density of the empirical and theoretical distribution of gamma probability, for São Bento do Una - PE from 1921 to 2020 is represented in Figure 3. The distribution has rainfall reduction systematically well distributed by its density and gradually homogeneous of right asymmetry with long extension. It is highlighted in the figure that indices above 100 mm tend to be practically zero, that is, of very low occurrence of extreme events. The information on these variations in a given area makes it possible to adopt strategies for managing water resources, planning production activities, as well as implementing systems for responding to crises resulting from extreme events such as droughts (MEDEIROS *et al*., 2020), in addition to floods and landslides (RIBEIRO *et al*., 2021). These statements corroborate the results discussed and the cases of events with possible maximum probabilities for the study area.

CONCLUSION

The maximum precipitation data fit the functions of log-normal, gamma and Weibull probability distributions, presenting a better fit to the gamma probability distribution function. São Bento do Una - PE needs to adopt strategies to cope with drought, aiming at the economic growth of the municipality.

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