



PROBABLE RAINFALL OF DIVINÓPOLIS CITY, MINAS GERAIS STATE, BRAZIL

Felipe Rodolfo Vieira¹ , Michael Silveira Thebaldi² , Bruno Gonçalves Silveira³  & Virgílio Henrique Barros Nogueira⁴ 

1 - Environmental and Sanitary Engineer, UNIFOR – MG, felipe.rodolfo@calmaster.com.br

2 - Agricultural Engineer, Associated Professor, UFLA, michael.thebaldi@ufla.br

3 - Civil Engineer, UNIFOR – MG, bsilveira132@gmail.com

4 - Agricultural Engineer, Master Science degree in Water Resources in Agriculture Systems, UFLA, virgiliohbn@yahoo.com.br

Keywords:

Water Resource Management
Statistical Hydrology
Temporal Variability of Rainfall

ABSTRACT

The aim of this paper was to analyze the behavior of non-parametric statistical distributions on the prediction of probable monthly and total annual rainfall as well as to determine the monthly and annual probable rainfall with different levels of probability for Divinópolis, Minas Gerais State, Brazil. The analysis consisted in adjusting the theoretical probability distribution to a data series of 66 years of monthly and annual rainfall. The data were obtained from the Hidroweb service, controlled by the National Water Agency (ANA, in Portuguese). The frequency distributions of Gumbel for Maximus, Fréchet and Gamma were adjusted to the observed series, where the adherence of these models to the data were tested by the Kolmogorov-Smirnov and Chi-Squared test, both with 5% of probability. The model that best represented, in most cases, the frequency distributions of the series of total monthly precipitation was Gumbel for Maximus, while the Fréchet model had the worst result, not fitting to the data of the historical series for both tests performed in the study. The probable monthly maximum precipitation for Divinópolis is 527 mm, associated with a probability of 5% and for January, while the lowest one is 0.0042 mm, with probability of 95% in July.

Palavras-chave:

gestão dos recursos hídricos
hidrologia estatística
variabilidade temporal da
chuva

PRECIPITAÇÃO PROVÁVEL DO MUNICÍPIO DE DIVINÓPOLIS, MINAS GERAIS, BRASIL

RESUMO

Objetivou-se, com o presente estudo analisar o comportamento de distribuições estatísticas não paramétricas na predição das precipitações prováveis mensais e anual totais, além de determinar as precipitações pluviométricas mensais e anual prováveis para o município de Divinópolis – Minas Gerais com diferentes níveis de probabilidade. A análise consistiu no ajuste de distribuições de probabilidade teóricas a uma série de dados de 66 anos de precipitações mensais e anual, sendo os dados obtidos no serviço Hidroweb, controlado pela Agência Nacional das Águas (ANA). Foram ajustadas, às séries observadas as distribuições de frequência Gumbel para Máximos, Fréchet e Gama, sendo as aderências destes modelos aos dados testadas pelos testes de Kolmogorov-Smirnov e Qui-Quadrado, ambos a 5% de probabilidade. Foi identificado que o modelo que melhor representou, na maioria dos casos, as distribuições de frequência das séries de precipitação mensal total foi a Gumbel para Máximos, enquanto o modelo Fréchet apresentou o pior resultado, não aderindo aos dados da série histórica, para ambos os testes de aderência realizados. A precipitação provável mensal máxima para Divinópolis é 527 mm, associada a uma probabilidade de 5% e referente ao mês de janeiro, enquanto a menor é 0,0042 mm, com probabilidade 95% no mês de julho.

INTRODUCTION

Given the importance of precipitation, different studies sought to analyze the relationship between rainfall levels and different agricultural crops. Thus, excessive or irregular rainfall may compromise the development of several crops, resulting in the shortage of specific agricultural products which will increase their price in the markets (BORK, 2015).

According to Frizzone *et al.* (2005) and Ávila *et al.* (2009), the probable precipitation is the lowest expected rainfall in a particular period of the year considering a certain level of probability. Additionally, authors such as Oliveira and Carvalho (2003), Sampaio *et al.* (2006) and Soccol *et al.* (2010), recommend that when performing hydraulic structure design, the probable precipitation should be used as reference, since the use of average values may result in oversizing.

The estimate of the probable rainfall can help the irrigation management as, in most projects, the water depth to be applied is calculated in relation to the crops total water needs, not considering the average rainfall of the region (ALMEIDA *et al.*, 2015). Additionally, according to Calgaro *et al.* (2009), the knowledge of probable precipitation may be useful for economic analysis of the implementation of an irrigation system. Uliana *et al.* (2013) also state that for irrigation management, the probability of 75% to 80% is usually used.

In addition to the importance of irrigation projects, the study of probable rainfall is also necessary for construction, tourism and transportation activities (ULIANA *et al.*, 2013). The knowledge of maximum rainfall is of importance for water and urban works whose objective is to design the structure in such a way they withstand extreme precipitation occurrences (ALVES *et al.*, 2013).

Thus, the objective of this work was to analyze the behavior of nonparametric statistical distributions in the prediction of the probable monthly and annual total rainfall and to determine the probable monthly and annual rainfall for the municipality of Divinópolis, state of Minas Gerais with different probability levels.

MATERIAL AND METHODS

The municipality of Divinópolis is located in western Minas Gerais state and consists of the Cerrado and Atlantic Forest biomes. The municipality, located between coordinates 20°8'33" S, 44°53'25" W for the WGS 84 datum. It has an area of 708,115 km² and an estimated population of 213,016 inhabitants, according to the last demographic census published in 2010 (IBGE, 2017).

According to the Köppen climate classification, the municipality fits in with the Cwa climate (ALVARES *et al.*, 2013), that is, it has a tropical climate, where winter has less rainfall than summer and its average temperature is 21.5°C.

Data of monthly and annual rainfall was collected through data provided by the Hidroweb service of the National Water Agency (ANA, in portuguese). The period defined for sampling was from 1942 to 2016. However, the years 1951, 1952, 1953, 1954, 1955, 1956, 1957, 1958 and 1965 were not used because they did not have complete series. Thus, 66 years were considered for the study.

The monthly and annual precipitated depths were allocated in decreasing order to obtain the frequency of exceedance. Therefore, the Cumulative Probability Functions Gumbel for Maximum, Gamma and Frechét model were adjusted. The Gumbel distribution for maxima has its Function Probability Density (FDP) represented by Equation 1.

$$f(x) = \frac{1}{\alpha} \cdot e^{\left[\frac{-(x-\mu)}{\alpha} - e^{-\frac{-(x-\mu)}{\alpha}} \right]} \quad (1)$$

where:

α and μ = distribution parameters; and
 x = rainfall value (mm).

Its cumulative probability function is given by Equation 2. For this study, x is the maximum annual daily rainfall, and x_i is any value of the same variable.

$$P(x \geq x_i) = 1 - e^{-e^{-\alpha(x-\mu)}} \quad (2)$$

The α and μ parameters given by the Method of Moments are evidenced in Equations 3 and 4, and

obtained from the sample mean (\bar{X}) and sample standard deviation (S^2).

$$\alpha = \frac{1.2826}{S^2} \quad (3)$$

$$\mu = \bar{X} - 0.451 \cdot S^2 \quad (4)$$

On the other hand, the Cumulative Probability Function of the Gamma distribution is given by Equation 5.

$$CPF = \frac{1}{\beta^v \cdot \Gamma(v)} \int_0^x u^{(v-1)} e^{-\frac{u}{\beta}} du \quad (5)$$

Gama distribution parameters are given by Equations 6 and 7.

$$\beta = \frac{S^2}{\bar{X}} \quad (6)$$

$$v = \frac{(\bar{X})^2}{S^2} \quad (7)$$

Fréchet Exponential Distribution is also known as extreme value distribution. It is a particular form of the Type II extreme value distribution. The probability density and probability cumulative functions of this distribution are represented by Equations 8 and 9, respectively.

$$FDP = f(x) = \frac{\theta}{\lambda} \cdot \left(\frac{\lambda}{x}\right)^{\theta+1} \cdot \exp\left[-\left(\frac{\lambda}{x}\right)^\theta\right] \quad (8)$$

$$P(X \geq xi) = 1 - \exp\left[-\left(\frac{\lambda}{x}\right)^\theta\right] \quad (9)$$

for $x > 0$; $\theta, \lambda > 0$.

Where:

θ = parameters of the distribution associated with the mean; and

λ = parameter of distribution associated with the variance.

Parameters of Fréchet distribution were obtained by using Equation 10 first, with the coefficient of variation (CV). Then, parameter λ was calculated using Equations 11 and 12, based on the mean adjustment.

$$CV = \sqrt{\frac{\Gamma\left(1 - \frac{2}{\theta}\right)}{\Gamma^2\left(1 - \frac{1}{\theta}\right)} - 1} \quad (10)$$

$$E(x) = \bar{X} = \lambda \cdot \Gamma\left(1 - \frac{1}{\theta}\right) \text{ for } \theta > 0 \quad (11)$$

$$Var(x) = s^2 = \lambda^2 \cdot \left[\Gamma\left(1 - \frac{2}{\theta}\right) - \Gamma^2\left(1 - \frac{1}{\theta}\right)\right] \quad (12)$$

Where $\theta > 2$.

in which:

Γ = Gama function.

Using equation 10, the distribution parameters are reached with the coefficient of variation, estimating θ , and then with the variance of the historical series, the parameter λ calculated by equation 13. The estimate of an X value, linked to a TR, is given by:

$$x_{TR} = \lambda \cdot \left[\ln\left(\frac{TR}{TR - 1}\right)\right]^{\frac{-1}{\theta}} \quad (13)$$

Overall, the statistical distribution that would best represent the historical series of total monthly precipitation for each of the months analyzed or total annual was chosen based on the adherence tests in which the selected distribution was that significant at 5% probability for Kolmogorov-Smirnov and Chi-Square tests (MELLO and SILVA, 2013) and which had the lowest calculated Chi-Square value.

In cases where the Chi-square test was not significant for any distribution applied to the historical series of total monthly precipitation, the decision parameter for choosing the distribution was the one that was significant by the Kolmogorov-Smirnov test and had the calculated Chi-Square value closest to the Tabulated Chi-Square significance at 5% probability.

For the cases where perhaps the Kolmogorov-Smirnov test was not significant for any applied distribution, the historical series of total monthly precipitation was considered as the statistical

distribution that would best represent the series, the one significant to the Chi-square test, with the lowest Chi-square value calculated. For historical series where no distribution had significant adherence to 5% probability in both tests, selection was obtained based on the distribution with the lowest calculated Chi-Square, even if one could not rely on the representation of the series through distribution.

Based on those definitions, the probable monthly precipitations were calculated from the 95, 90, 80, 70, 75, 60, 50, 40, 30, 20, 15, 10 and 5% exceedance frequencies equivalent to return periods of 1.05; 1.11; 1.25; 1.33; 1.43; 1.67; 2.00; 2.50; 3.33; 5.00, 6.67; 10.00 and 20.00 years.

RESULTS AND DISCUSSION

The values obtained from the statistics of the Kolmogorov - Smirnov and Chi-square fit tests from January to April are shown in Table 1.

From the results found in the adhesion tests and by analyzing Table 1, the distribution that best represents the historical series of total precipitation for the months from January to April is the Gumbel for maximums.

Additionally, the values obtained from the Kolmogorov - Smirnov and Chi-Square adherence

tests statistics, in the evaluation of the adjustment of the functions to the historical series of monthly precipitation of the municipality of Divinópolis - MG, between May and August, are shown in Table 2.

The analysis of Table 2 shows that between May and August, the Gamma frequency distribution best represents the historical series of monthly precipitation. Among those months, no distribution was considered significant at 5% probability by the Chi-square test and from June ahead, none were significant.

Nevertheless, Table 3 shows the values obtained from the statistics of the Kolmogorov - Smirnov and Chi-Square adherence tests in the evaluation of the adjustment of the functions to the historical series of monthly precipitation in the city of Divinópolis -MG, from September to December and total.

For September, November, December and annual, the Gama distribution best represented the historical series of total monthly precipitation, while for October, it was the Gumbel maximum distribution that best adhered to the historical series of monthly precipitation. Coan *et al.* (2014) reported in their study on the monthly and annual probable precipitation that the Gamma distribution was the most appropriate for determining the total annual precipitation.

Table 1. Kolmogorov - Smirnov and Chi-Square adherence tests statistics, between January and April for Divinópolis City – MG.

Month	Distribution	Maximum calculated ΔF	Calculated λ^2
January	Gumbel for Maximus	0.083*	3.163*
	Fréchet	0.205 ^{ns}	49.242 ^{ns}
	Gama	0.073*	49.530 ^{ns}
February	Gumbel for the maximums	0.059*	4.959*
	Fréchet	0.202 ^{ns}	49.143 ^{ns}
	Gama	0.067*	6.,079 ^{ns}
March	Gumbel for the Maximus	0.083*	4.706*
	Fréchet	0.237 ^{ns}	49.526 ^{ns}
	Gama	0.087*	49.827 ^{ns}
April	Gumbel for the Maximus	0.101*	9.819 ^{ns}
	Fréchet	0.294 ^{ns}	49.452 ^{ns}
	Gama	0.099*	49.550 ^{ns}

Where: * - Significant, ns – Not Significant

Table 2. Kolmogorov - Smirnov and Chi-Square adherence tests statistics, from May to August for Divinópolis City - MG.

Month	Distribution	Maximum calculated ΔF	Calculated λ^2
May	Gumbel for the Maximus	0.118*	62.313 ^{ns}
	Fréchet	0.304 ^{ns}	49.678 ^{ns}
	Gama	0.121*	49.665 ^{ns}
June	Gumbel for the Maximus	0.2165 ^{ns}	58.299 ^{ns}
	Fréchet	0.419 ^{ns}	49.792 ^{ns}
	Gama	0.223 ^{ns}	49.621 ^{ns}
July	Gumbel for the Maximus	0.2861 ^{ns}	53.625 ^{ns}
	Fréchet	0.6413 ^{ns}	49.529 ^{ns}
	Gama	0.389 ^{ns}	48.745 ^{ns}
August	Gumbel for the Maximus	0.274 ^{ns}	55.809 ^{ns}
	Fréchet	0.5679 ^{ns}	49.861 ^{ns}
	Gama	0.447 ^{ns}	49.2447 ^{ns}

Where: * - Significant, ns – Not-significant

Table 3. Kolmogorov - Smirnov and Qui-Square adherence tests statistics, from September to December and annual for Divinópolis City – MG.

Month	Distribution	Maximum Calculated ΔF	Calculated λ^2
September	Gumbel for the Maximus	0.1326*	62.968 ^{ns}
	Fréchet	0.312 ^{ns}	49.607 ^{ns}
	Gama	0.196 ^{ns}	49.587 ^{ns}
October	Gumbel for the Maximus	0.069*	64.622 ^{ns}
	Fréchet	0.255 ^{ns}	49.125 ^{ns}
	Gama	0.065*	49.224 ^{ns}
November	Gumbel for the Maximus	0.0509*	65.860 ^{ns}
	Fréchet	0.174 ^s	49.640 ^{ns}
	Gama	0.063*	49.951 ^{ns}
December	Gumbel for the Maximus	0.0986*	65.408 ^{ns}
	Fréchet	0.249 ^{ns}	44.215 ^{ns}
	Gama	0.0833*	49.676 ^{ns}
Annual	Gumbel for the Maximus	0.042*	65.415 ^{ns}
	Fréchet	0.2263 ^{ns}	49.436 ^{ns}
	Gama	0.0306*	49.740 ^{ns}

Where: * - Significant, ns – Not significant

It could have been observed through the analysis of Tables 1, 2 and 3, that the Gumbel distribution for maximums had significant adherence at 5% of statistical probability in 75% of months for the Kolmogorov-Smirnov test and 25% for Chi-square. At the evaluation of adherence by the Kolmogorov – Smirnov and Chi-Square method, it was observed that the Fréchet distribution did

not adjust in either month. However, the Gamma distribution adhered significantly in 66.66% of the months by the Kolmogorov - Smirnov test and in none of the months when assessing the adherence through the Chi-square method.

In their work, Silva *et al.* (2013b) conducted a study of the probable precipitation for monthly and annual rainfall in the Center-South region in

the state of Ceará, and their results corroborated with those found in this study as the cumulative probability functions (Gumbel for maximums and Gamma) adhered to data from historical series through the Kolmogorov - Smirnov test. Also, as for Divinópolis, the best fit was for Gumbel for the Maximum, with the highest number of adjustments in the series.

Alvarenga *et al.* (2018) found in their study regarding probable precipitation for Formiga, state of Minas Gerais that the cumulative probability functions that best fit the studied months were the Gamma and Gumbel functions for Maximum Values by the Kolmogorov-Smirnov test.

Still when studying the probable precipitation in São Mateus, state of Espírito Santo, Passos *et al.* (2017) observed that for the series of total and annual monthly precipitation, the Gamma distribution presented adequacy in all months analyzed on the basis of Kolmogorov -Smirnov test, which did not occur in this study, which had better results for the Gumbel distribution for maximum.

Additionally, Ribeiro *et al.* (2007) conducted a study of the probable precipitation for monthly

and annual rainfall in the city of Barbacena, state of Minas Gerais, and found the best fit when using the Gama distribution, unlike that observed in Divinópolis, state of Minas Gerais.

It was found that the Fréchet statistical distribution did not adjust significantly in any of the generated historical series of the monthly precipitation, when assessing the adherence by both tests. In their work, Alvarenga *et al.* (2018) stated that the Fréchet distribution had the worst fit among the studied functions. This fact is caused by the better performance of the distribution when representing series of maximum precipitations (MELLO and SILVA, 2013), not showing the same performance for total data.

The adjusted distribution parameters applied to the historical series of monthly rainfall from January to April in the city of Divinópolis, state of Minas Gerais, are shown in Table 4.

The adjusted distribution parameters applied to the historical series of monthly rainfall, from May to August in Divinópolis, state of Minas Gerais are shown in Table 5.

Table 4. Fitting parameters of the evaluated models with data from the historical series of monthly rainfall of Divinópolis City - MG, from January to April.

Series	Gumbel for the Maximus	Fréchet	Gama
January	μ : 211.5375	λ : 215.6111	β : 68.04652
	α : 0.009413	θ : 3.588655	ν : 4.009824
February	μ : 118.1901	λ : 127.763	β : 49.52056
	α : 0.0145	θ : 3.422939	ν : 3.190472
March	μ : 110.6773	λ : 119.4947	β : 45.43486
	α : 0.015667	θ : 3.441121	ν : 3.246806
April	μ : 36.59804	λ : 41.45972	β : 30.62591
	α : 0.031228	θ : 2.908724	ν : 1.798487

Table 5. Fitting parameters of the evaluated models with data from the historical series of monthly rainfall of Divinópolis City – MG, from May to August.

Series	Gumbel for Maximus	Fréchet	Gama
May	μ : 13.78482	λ : 17.39973	β : 25.22639
	α : 0.050961	θ : 2.546451	ν : 0.995411
June	μ : 7.428928	λ : 12.22451	β : 33.17634
	α : 0.051617	θ : 2.332558	ν : 0.56096
July	μ : 2.551036	λ : 10.00000	β : 30.40789
	α : 0.071278	θ : 2.213311	ν : 0.35019
August	μ : 3.030645	λ : 7.009705	β : 28.94797
	α : 0.071566	θ : 2.232175	ν : 0.38329

However, Table 6 shows the values obtained from the adjustment parameters of the functions evaluated using data from the historical series of monthly precipitation between September and December, in addition to the annual precipitation in the city of Divinópolis – MG.

Using only the distribution that best represents the historical series of total monthly rainfall for each month, allowed obtaining the probable precipitation in the city of Divinópolis - MG, considering frequencies of exceedance of 95%, 90%, 80%, 75%, 70%, 60%, 50%, 40%, 30%, 20%, 15%, 10% and 5%. Thus, the monthly probable rainfall with frequencies of exceedance of 95%, 90%, 80% and 75% for the city of Divinópolis - MG can be analyzed in Figure 1.

For a 95% frequency of exceedance, the highest probable precipitation obtained was 110.69 mm, while the smallest was 0.004 mm. By considering 90% of probability, the maximum monthly rainfall is 135.52 mm and the lowest, 0.03 mm. At a frequency of exceedance level of 80%, the maximum monthly probable rainfall was 170.58 mm, and the lowest, 0.22 mm. For the 75% exceedance frequency, the probable maximum precipitation is 185.40 mm while the probable minimum is 0.42 mm. All probable maximum and minimum rainfall for these frequencies of exceedance were obtained for December and July, respectively.

The monthly probable rainfall with frequencies of exceedance of 70%, 60%, 50% and 40%, for the city of Divinópolis - MG can be analyzed in Figure 2.

Table 6. Fitting parameters of the evaluated models using data from the historical series of annual and monthly precipitation from September to December of Divinópolis City – MG.

Series	Gumbel for the Maximus	Fréchet	Gama
September	μ : 26.39614	λ : 31.84343	β : 39.5208
	α : 0.030255	θ : 2.613158	ν : 1.150603
October	μ : 74.46016	λ : 81.4406	β : 40.21149
	α : 0.019882	θ : 3.206051	ν : 2.573628
November	μ : 157.9812	λ : 169.978	β : 36.84626
	α : 0.015083	θ : 4.094324	ν : 5.326103
December	μ : 218.1489	λ : 234.7333	β : 50.91264
	α : 0.010919	θ : 4.093629	ν : 5.322992
Annual	μ : 985.2993	λ : 1064.434	β : 408.494
	α : 0.00175	θ : 3.432323	ν : 3.219457

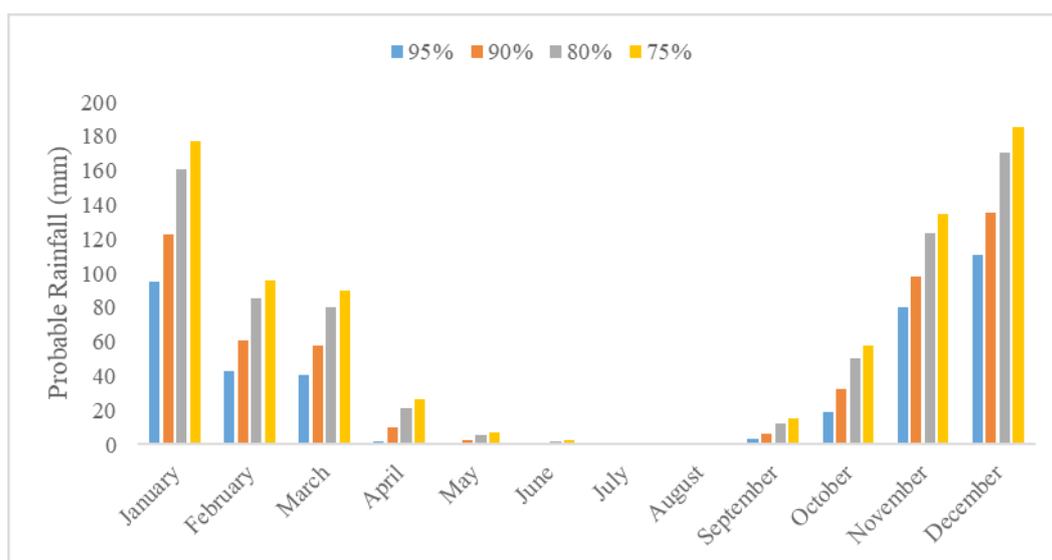


Figure 1. Monthly probable rainfall with frequencies of exceedance of 95%, 90%, 80% and 75% for the city of Divinópolis-MG.

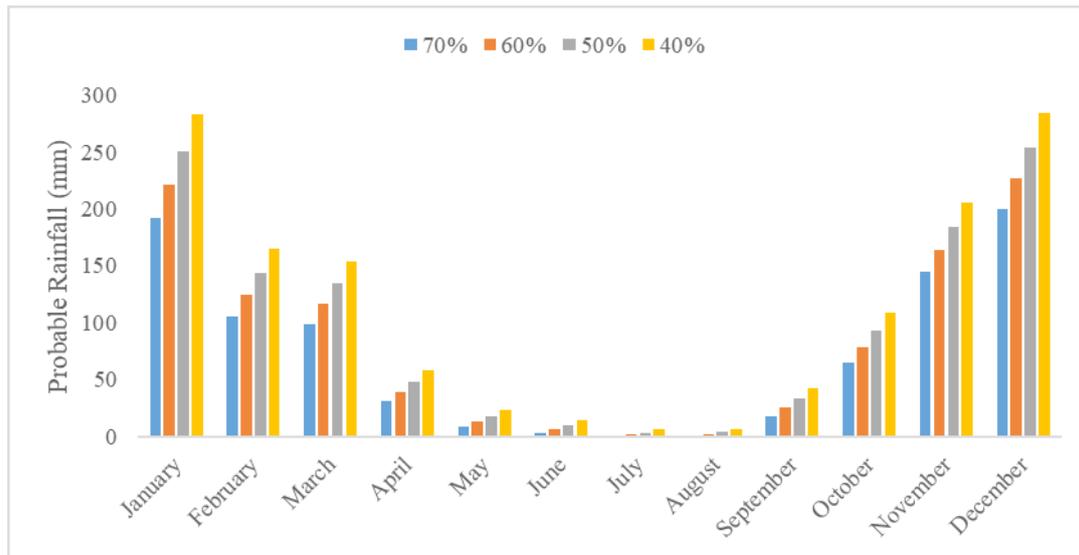


Figure 2. Monthly probable rainfall with frequencies of exceedance of 70%, 60%, 50% and 40% for the city of Divinópolis-MG.

When evaluating the probabilities for a frequency of exceedance of 70%, the highest probable precipitation obtained was 199.46 mm, while the lowest was 0.71 mm. Considering 60% probability, the maximum monthly probable rainfall is 226.65 mm, and the lowest, 1.66 mm. For a frequency of exceedance level of 50%, the maximum monthly probable precipitation was 254.24 mm, and the lowest 3.26 mm. For a 40% frequency of exceedance, the maximum probable precipitation is 283.99 mm while the minimum is 5.84 mm. The maximum probable precipitations were all obtained for December, while the minimum in July.

The monthly probable rainfall with frequencies of exceedance of 30%, 20%, 15%, 10% and 5%, for the city of Divinópolis - MG can be analyzed in Figure 3.

Considering the probabilities of exceedance 30%, 20%, 15%, 10% and 5%, the maximum probable precipitations (321.06; 370.88; 404.56; 450.61 mm, respectively) were all obtained for January, while the minimums (9.94; 16.86; 22.36; 30.74; 46.29 mm, respectively) in July.

According to the results obtained in the study, it is found that July is the driest month for the city of Divinópolis, while December and January are those with the highest rainfall, depending on the

probability expected for rain quantification.

In contrast, Passos et al. (2017), when determining the probable monthly and annual rainfall of the municipality of São Mateus, state of Espírito Santo, at different levels of occurrence, obtained the value 36.9 mm, where the exceedance probability is 90%, and 268.7 mm considering 10% for January, respectively, while in this paper, 122.93 mm was obtained for Divinópolis - MG, where the exceedance probability is 90%, and 450.61 mm considering 10% for the month of January. This difference is due to the fact that the region of Divinópolis has a higher occurrence of precipitation.

Finally, the probable annual rainfall with frequencies of exceedance of 95%, 90%, 80%, 75%, 70%, 60%, 50%, 40%, 30%, 20%, 15%, 10% and 5% for the city of Divinópolis - MG, can be analyzed in Figure 4.

Considering the probabilities of exceedance for total annual probable precipitation in the municipality of Divinópolis - MG, for frequencies of exceedance of 95%, 90%, 80%, 75%, 70%, 60%, 50%, 40%, 30%, 20%, 15%, 10% and 5%, it was obtained the annual precipitation of 381; 506; 694; 777; 857; 1,016; 1,182; 1,365; 1,581; 1,860; 2,047; 2,298 and 2,705 mm, respectively.

The average annual rainfall found for the

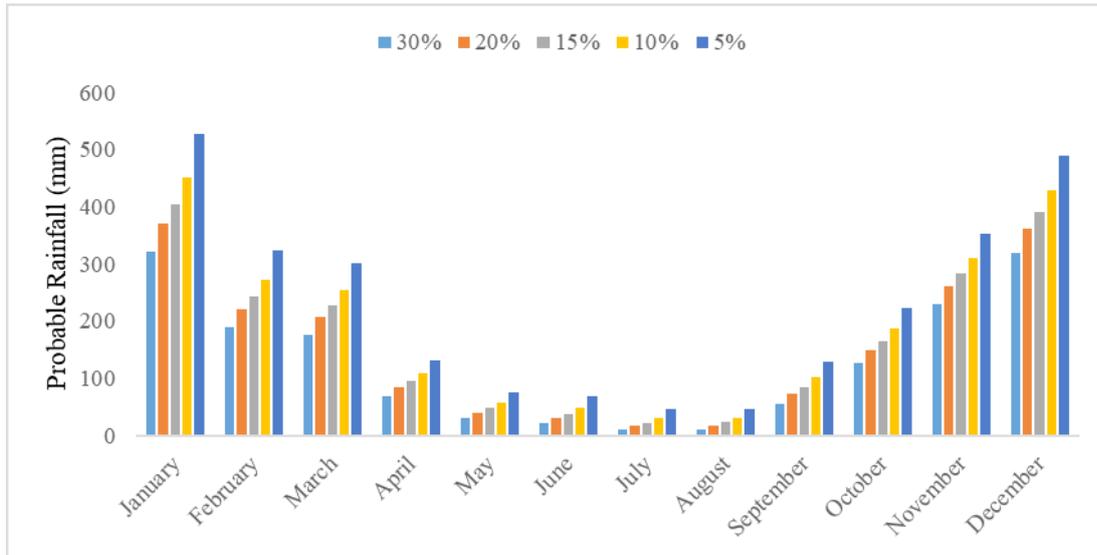


Figure 3. Monthly probable rainfall with exceedance frequencies of 30%, 20%, 15%, 10% and 5%, for the city of Divinópolis-MG.

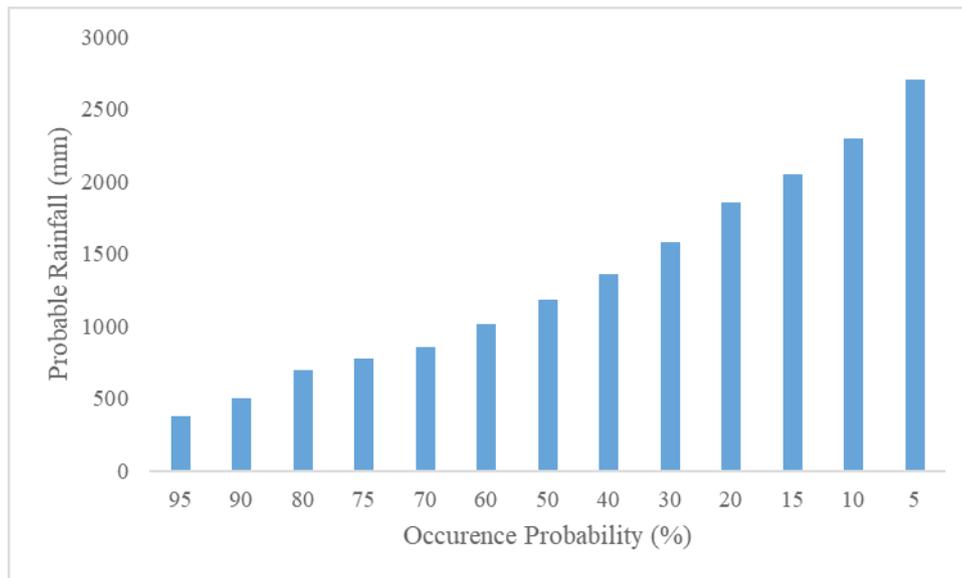


Figure 4. Annual probable rainfall with frequencies of exceedance of 95%, 90%, 80%, 75%, 70%, 60%, 50%, 40%, 30%, 20%, 15%, 10% and 5% for the municipality of Divinópolis-MG.

evaluated series was 1315.1 mm. This value is between the probability levels of 40 to 50%, which have 1364.8 mm and 1181.7 mm of rainfall, respectively. The expected annual precipitation varied from 2705.1 mm at the 5% level to 380.8 mm for the 95% probability level.

Silva *et al.* (2013a), for the municipality of Sapezal - MT, observed the annual average rainfall of 2014.3 mm, between the levels of 25 to 40% of probability, which were 2370.7 and 2107.2 mm, respectively as it is of a region with a record of

higher precipitation, compared to Divinópolis – MG.

For Nova Maringá - MT, Moreira *et al.* (2010) observed that from October to January, the average rainfall remained between the probability levels of 40 and 50%, while in the other months, the average occurrence probability decreased between 25 and 40%.

Regarding the design of hydraulic structures, Hartmann *et al.* (2011) estimated the maximum monthly rainfall for different periods and

probabilities in Presidente Prudente - SP, aiming to assist the design of hydraulic works. By using the Gumbel distribution at 95% of statistical probability, the authors found that the maximum daily rainfall for January is greater than 38 mm, whereas in this study, for the same probability, the expected monthly precipitation in January was around 100 mm.

In order to ensure safety in the design of systems with the use of supplemental irrigation, several authors indicate that levels between 70 and 80% of probability should be adopted (CASTRO & LEOPOLDO, 1995; BERNARDO, 2006; ULIANA, 2013). Thus, the use of the average as a project parameter may lead to its undersizing and, consequently, damage to the farmer (COAN *et al.*, 2014). It is also possible to adopt 90% probability levels of probable monthly precipitation for crops with greater susceptibility to agronomic yield losses due to water stress (PASSOS *et al.*, 2017).

In Brazil, according to Castro and Leopoldo (1995), rainfall is generally used as a design parameter for irrigation systems, but, as it was observed by those authors, rainfall average should not be adopted, since it has a lower depth than the precipitation with a probability of occurrence of 50%.

CONCLUSION

- Regarding the assessed distribution of probabilities, not all showed significant fit to the observed rainfall data of Divinópolis City - MG. The Fréchet model was the one with the worst performance, while the Gumbel distribution for Maximum adhered significantly to most of the historical series of monthly precipitation, but the Gamma distribution was the one that best represented the series of total annual precipitation.
- Only the Fréchet model did not adhere to the historical series data, for both fitting tests performed, the other cumulative probability functions had significant adherence by both the Kolmogorov - Smirnov test and the Chi-Square test. However, the best adjustment was for the Gumbel model for Maximums, with significant fit at 5% statistical probability

in 75% of the months for the Kolmogorov - Smirnov test and 25% for Chi-square test.

- The maximum monthly probable rainfall for the municipality of Divinópolis - MG is 527 mm, for January and associated with a probability of 5%, and the lowest, 0.0042 mm, with a probability 95% in July. In addition, the monthly probable rainfall at 75% probability, recommended for supplemental irrigation projects, was 185 mm at most, and 0.42 mm at least, for December and June, respectively.

REFERENCES

ALMEIDA, R.A.; PEREIRA, S.B.; COELHO, C.D.; DE SOUZA, D.A.N. Nota Técnica: Precipitação Pluvial Média Mensal e Anual nas Regiões Político-Administrativas do Brasil. **Revista Engenharia Na Agricultura**, v.23, n.2, p.169-175, 2015.

ALVARENGA, J.S.; THEBALDI, M.S.; FERNANDES, L.R. Precipitação mensal provável do município de formiga-mg. **Revista Brasileira de Agricultura Irrigada**, v.12, n.5, p.2823-2833, 2018.

ALVARES, C.A.; STAPE, J.L.; SENTELHAS, P.C. Köppen's climate classification map for Brazil. **Meteorologische Zeitschrift**, v.22, n.6, p.711-728, 2013.

ALVES, A.V.P.; SANTOS, G.B.S.; MENEZES FILHO, F.C.M.; SANCHES, L. Análise dos métodos de estimativa para os parâmetros das distribuições de Gumbel e Gev em eventos de precipitações máximas na cidade de Cuiabá-MT. **Revista Eletrônica de Engenharia Civil**, v.6, n.1, p.32-43, 2013.

ÁVILA, L.F.; MELLO, C.R.de; VIOLA, M.R. Mapeamento da precipitação mínima provável para o sul de Minas Gerais. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v.13, p.906-915, 2009.

BERNARDO, S.; SOARES, A. A.; MANTOVANI, E. C. **Manual de irrigação**. 8.ed. Viçosa: Imprensa Universitária, 2006. 625p.

- BORK, C.K. Projeções de temperatura e precipitação para detecção de mudanças climáticas na Bacia do Rio Taquari-Antas, RS. **Monografia**. 2015. Universidade Federal de Pelotas, Pelotas – RS, 2015.
- CALGARO, M.; ROBAINA, A.D.; PEITER, M.X.; BERNARDON, T. Variação espaço-temporal dos parâmetros para a modelagem estocástica da precipitação pluviométrica diária no Rio Grande do Sul. **Engenharia Agrícola**, v.29, n.2, p.196-206, 2009.
- CASTRO, R.; LEOPOLDO, P.R. Ajuste da distribuição gama incompleta na estimativa da precipitação pluviométrica provável para os períodos de 15 e 10 dias da cidade de São Manuel (SP). **Energia na Agricultura**, Botucatu, v.10, n.1, p.20-28, 1995.
- COAN, B.P.; BACK, A.J.; BONETTI, A.V. Precipitação Mensal e Anual Provável no Estado de Santa Catarina. **Revista Brasileira de Climatologia**, v.15, n.10, p.122-142, 2014.
- FRIZZONE, J.A. et al. Funções de produção água-cultura. In: FRIZZONE, J.A.; ANDRADE JÚNIOR, A.S.; SOUZA, J.L.M.; ZOCOLER, J.L. (Ed.). **Planejamento de irrigação: análise e decisão de investimento**. Brasília: Embrapa, p.283-314, 2005.
- HARTMANN, M.; MOALA, F.A; MENDONÇA, M.A. Estudo Das Precipitações Máximas Anuais Em Presidente Prudente. **Revista Brasileira de Meteorologia**, v.26, n.4, p.561-568, 2011.
- INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA – IBGE. **Divinópolis – Dados gerais do município**. Disponível em: <<http://cidades.ibge.gov.br/painel/painel.php?lang=&codmun=312230&search=||infnogr%Elficos:-dados-gerais-do-munic%EDpio>>. Acesso em: 02 de nov. 2017.
- MELLO, C.R.de.; SILVA, A.M. da. **Hidrologia: princípios e aplicações em sistemas agrícolas**. Ed. UFLA, 2013. p.455.
- MOREIRA, P.S.P.; DALLACORT, R.; MAGALHÃES, R.A.; INQUE, M.H; STIELER, M.C.; DA SILVA, D.J.; MARTINS, J.A. Distribuição e probabilidade de ocorrência de chuvas no município de nova Maringá-MT. **Revista de Ciências AgroAmbientais**, v.8, n.1, p.9-20, 2010.
- PASSOS, M.L.V.; RAPOSO, A.B.; MENDES, T.J. Precipitação pluviométrica mensal e anual provável para o município de São Mateus – ES, **Agropecuária Científica No Semiárido**, Patos-PB, v.13, n.2, p.9-20, abr. - jun., 2017.
- PEREIRA, A.R.; ANGELOCCI, L.R.; SENTELHAS, P.C. **Agrometeorologia: fundamentos a aplicações**. Guaíba: Agropecuária, 2002. 472p.
- RIBEIRO, B.T.; AVANZI, J.C.; MELLO, C.R.de. Comparação de distribuições de probabilidade e estimativa da precipitação provável para região de Barbacena – MG, **Ciência e Agrotecnologia**, Lavras, v.31, n.5, set.-out., p.1297-1302, 2007.
- SILVA, E.S.; ZAVISLAK, F.D.; DALLACORT, R.; CARVALHO, M.A.C.de.; ARAUJO, D.V.de. Distribuição de probabilidade de chuva no município de Sapezal, MT. **Enciclopédia Biosfera**, v.9, n.17, p.1297-1302, 2013.
- SILVA, I. N.; OLIVEIRA, J.B. de; FONTES, L.de.O; ARRAES, F.D.D. Distribuição de frequência da chuva para região Centro-Sul do Ceará, Brasil. **Revista Ciência Agronômica**, v.44, n.3, p.481-487, jul.-set., 2013.
- ULIANA, M.E.; REIS, E.F.dos.; SILVA, J.G.F.da.; XAVIER, A.C. Precipitação mensal e anual provável para o estado do Espírito Santo. **Revista Irriga**, Botucatu, v.18, n.1, p.139-147, 2013.
- SILVA, M.A.V. **Meteorologia e Climatologia**. Versão digital. Recife. PE. Brasil. 2005.