10-DAY PROBABLE RAINFALL FOR UBERLÂNDIA, MINAS GERAIS STATE, BRAZIL

PRECIPITAÇÃO DECENDIAL PROVÁVEL PARA UBERLÂNDIA, MINAS GERAIS, BRASIL

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ABSTRACT: The knowledge of probable rainfall can contribute substantially to farming activities, mainly in irrigation projects. This work was carried out aiming to determine the probable rainfall for Uberlândia, Minas Gerais State, Brazil. Daily precipitation data from 1975 to 2010 were summed in 10-day period (decennial) and applied to Gamma distribution. The probable rainfall was estimated to different probability levels (ranging 10% to 95%). The Gamma distribution was suitable to estimate the probable rainfall for 10-day period. During the wet season the historical average rainfall (10-day period) has 40% of probability of exceedance and during the dry season has 30%. From this work the 10-day period rainfall can be estimated at different probability levels and contribute to farming activities, especially to irrigation.

KEYWORDS: Irrigation. Gamma distribution. Agriculture planning.

INTRODUCTION

Uberlândia is located in Cerrado Biome – nowadays an important region of Brazilian agribusiness. Corn, soybean, citrus, vegetables, fruits, coffee, livestock and most recently sugarcane are intensively cultivated in this region (IBGE, 2011). In this context, due to the irregular distribution of rainfall during the crop season and aiming to improve the production, irrigation area has increased every year.

In many irrigation projects, the water supply has been planned in terms of total irrigation, disregarding the occurrence of rainfall. As rainfall has very spatial and temporal variability it can be suite for crop season with little rainfall. However, in years with more abundant rainfall could result in a highly uneconomic and wasteful project. Then, the estimative of probable rainfall is very important for an adequate and sustainable irrigation system planning (BERNARDO, 2005).

The minimum precipitation to be overcome in a given probability level (probability of exceedance) is called probable rainfall (BERNARDO, 2005). The knowledge of probable rainfall may avoid the oversizing of irrigation systems when the water crop requirements are considered and also to contribute to reduce the water use from rivers and reservoirs. For example, in Barbacena, in southern of Minas Gerais State, it was found that the monthly probable rainfall during cropping season (summer) attend the most of water requirement of tomato, corn and bean (RIBEIRO et al., 2007). If the probable rainfall is taken account, the costs of irrigation projects can drop significantly. Additionally, the knowledge of probable rainfall may also contribute to farming planning as soil tillage, sowing, liming, fertilization, harvesting and application of pesticides. All these activities depend on rainfall distribution.

The probability of 75% to 80% is considered suitable in irrigation projects (BERNARDO, 2005). In general, the historical average rainfall has approximately 40% of probability of exceedance (MURTA et al., 2005; RIBEIRO et al., 2007; RIBEIRO; AVANZI, 2010). So, its use can lead to error in the designing fittest irrigation system (FIETZ et al., 1998).

To estimate the probable rainfall some distribution models (Gamma, Normal, Log-Normal 2 and 3 parameters) have been applied to a historical series (decennial, monthly, annual) in different regions of Brazil. The Gamma distribution frequently has been considered more adequate (FIETZ et al., 1998; FIETZ et al., 2008; MARTINS et al., 2010; RIBEIRO et al., 2007; RIBEIRO; AVANZI, 2010; SOCCOL et al., 2010).

This work aimed to determine the 10-day probable rainfall for the municipality of Uberlândia, State of Minas Gerais, Brazil, in order to contribute to a suitable irrigation projects in this region.

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MATERIAL AND METHODS

Daily precipitation data were acquired from the Brazilian National Water Agency – ANA (HIDROWEB, 2012) from a weather station located at 18°59'18''S and 48°11'25''W and altitude of 800m. The data were summed in 10-day period (decennial) from 1975 to 2010 (36 years) and applied to Gamma distribution. This work evaluated the probable rainfall for 10-day period, considered suitable to crops with short and medium cropping seasons, while monthly periods would be more suitable to perennial or semi-perennial crops (ANDRADE; BASTOS, 1997).

Gamma model is defined by the following integral equations (LANNA, 2001):

$$\Gamma(\alpha) = \int_0^{\infty} x^{\upsilon-1} e^{-x} dx, \upsilon > 0 \quad (1)$$

$$P(\alpha, x) = \int_0^{x} x^{(\upsilon-1)} e^{-x} dx \quad (2)$$

$$P(\alpha, x) = \int_0^{x} x^{(\upsilon-1)} e^{-x/\beta} dx \quad (3)$$

The probability density function can be expressed as follows (BOTELHO, 1989):

$$FDP: f(x) = \frac{1}{\beta^{\gamma} \cdot \Gamma(\gamma)} \cdot x^{\gamma-1} \cdot e^{-x/\beta}, 0 < x < \infty \quad (4)$$

with $\gamma > 0$, $\beta > 0$, $\Gamma(\gamma) > 0$, where γ is dimensionless parameter, β is scale parameter and x is random variable (rainfall).

The ν and β parameters can be estimated by Equations 5 and 6, respectively:

$$\gamma = \frac{\bar{x}^2}{S_x^{\ 2}} \quad (5)$$

$$\beta = \frac{S_x^{\ 2}}{\bar{x}} \quad (6)$$

where $\bar{x}$ and S_x are the average and standard deviation of dataset, respectively.

The Qui-Square Test (λ^2) (α = 0.05) were used to evaluate the suitability of Gamma distribution, considering the degrees of freedom as being the number of classes minus one (FERREIRA, 2005). Once the Gamma distribution considered adequate, the decennial probable rainfall was estimated at different probability levels (ranging from 10% to 95%).

RESULTS AND DISCUSSION

The total annual historical average rainfall is 1,472 mm spread out in two different periods: spring-summer or wet season (86% of total rainfall) and fall-winter or dry season (14%) (Figure 1). There is a serious period from June to August where the monthly rainfall does not reach 16 mm and could affect the growing and development of plant species, especially perennial or semi-perennial crops, suggesting the use of irrigation. This condition is one of the characteristics of Aw climate (Koppen's classification) which dry season occurs during the winter because is under the influence of the subtropical highs and in the summer, as the intertropical convergence zone - ITCZ moves to south brings with it heavy precipitation (AHRENS, 2009).

In Table 1 are showed the descriptive statistics of decennial rainfall data, β and ν parameters from Gamma distribution, λ^2 test results and the probability of occurrence of average rainfall for each period studied. Only to the third decennial of March, the Gamma distribution was not suitable (calculated λ^2 > standard λ^2). Many others studied have found that the Gamma distribution has been most well applied to studies of probability-frequency rainfall distribution (FIETZ et al., 1998; ARAÚJO et al., 2001; RIBEIRO et al., 2007; MARTINS et al., 2010; RIBEIRO; AVANZI, 2010; SOCCOL et al., 2010).

Considering each period studied, it was observed that the probability of occurrence of historical average rainfall decreases from wet season to dry season. In the wet season the probability of occurrence of historical average rainfall is approximately 40% while in the dry season is 30%. This observation is important when the average rainfall for a given period is taken account to irrigation project due to the fact that the level of suitable probability of occurrence is between 70% and 80% (BERNARDO, 2005).

In general, the rainiest months had higher β and ν values. β values are related to variability of data and since it is directly proportional to the square of the standard deviation. This seems to be a characteristic of wet season and its inherent variability. At the same way, higher ν values were observed and this is related to asymmetry of data. The same results were found to Machado, southern of Minas Gerais State (RIBEIRO; AVANZI, 2010), for Tangará da Serra, Mato Grosso State (MARTINS et al., 2010) and for Lages, Santa Catarina State (SOCCOL et al., 2010). However, for Itapetinga and Vitória da Conquista, southwest of Bahia state, the higher ν values were found in driest months (MURTA et al., 2005).

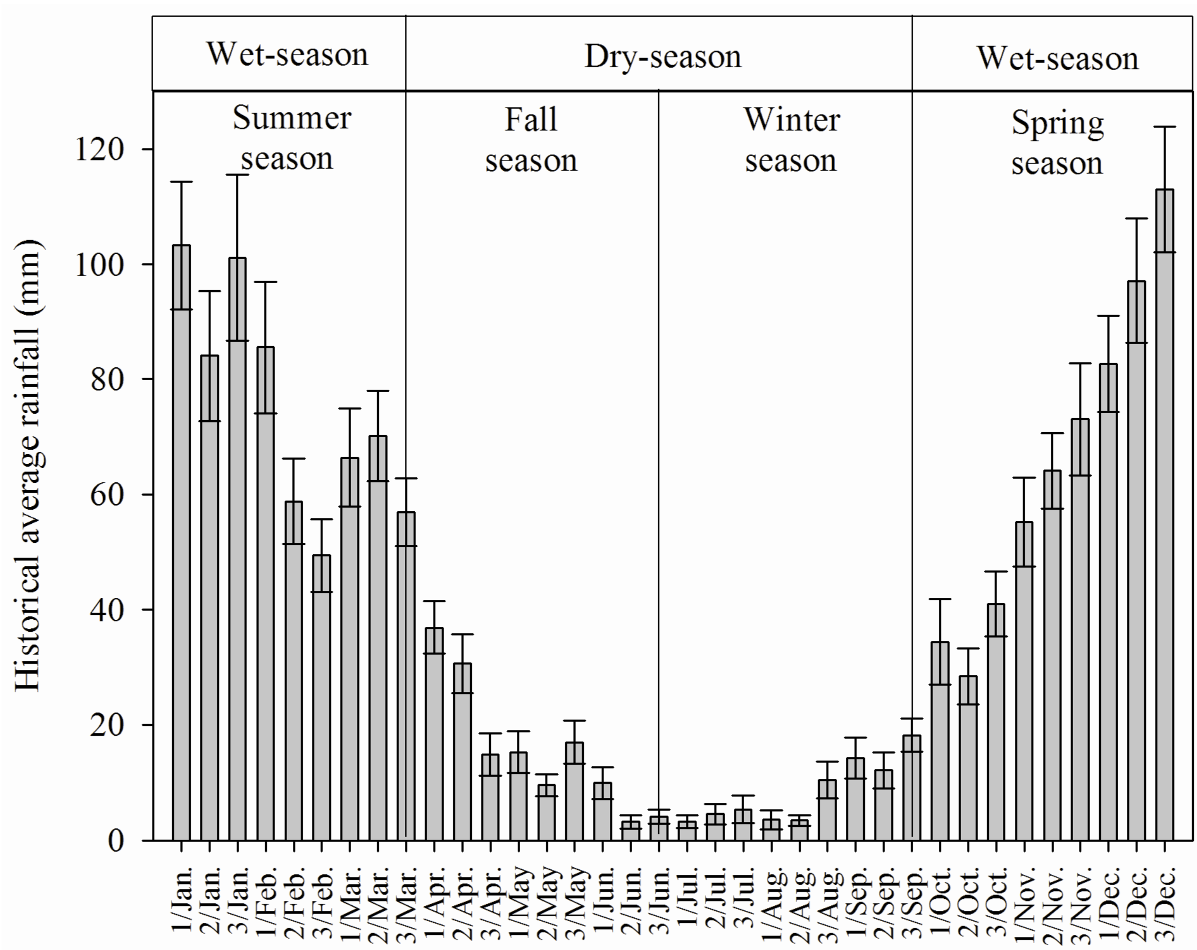

Figure 1. Historical decennial average rainfall for Uberlândia, Minas Gerais State, Brazil (1975-2010). Error bars indicate the standard error (n=36).

Table 1. Descriptive statistics, β and ν parameters and λ^2 test for decennial rainfall data of Uberlândia, Minas Gerais State, Brazil.

Period	Rainfall				Standard Deviation	β	ν	λ^{2*}	λ^{2**}	P (%)
	Average	Median	Maximum	Minimum						
1/January	103.3	92.7	300.2	19.0	66.4	42.7	2.4	1.8	7.8	42
2/January	84.1	63.0	268.1	1.4	67.9	54.8	1.5	0.7	7.8	39
3/January	101.1	86.7	345.4	0.0	86.8	74.5	1.4	0.8	7.8	39
1/February	85.5	71.4	305.1	0.0	68.9	55.6	1.5	0.8	6.0	39
2/February	58.8	60.2	173.6	0.0	44.4	33.5	1.8	1.0	7.8	40
3/February	49.5	44.7	154.7	0.0	37.7	28.8	1.7	2.7	7.8	40
1/March	66.4	61.7	169.1	0.0	51.0	39.2	1.7	0.4	7.8	40
2/March	70.2	65.5	167.5	0.0	47.0	31.5	2.2	1.9	7.8	41
3/March	57.0	61.4	123.5	0.0	35.1	21.7	2.6	12.6	9.5	42
1/April	36.9	37.6	90.8	0.0	27.6	20.7	1.8	6.0	7.8	40
2/April	30.7	25.7	148.9	0.0	30.7	30.7	1.0	0.3	6.0	37
3/April	14.8	6.7	102.2	0.0	22.3	33.5	0.4	0.06	3.8	31
1/May	15.3	5.5	95.6	0.0	21.8	31.2	0.5	0.02	3.8	32
2/May	9.6	4.1	46.2	0.0	11.4	13.7	0.7	0.5	6.0	34
3/May	17.0	6.7	93.1	0.0	22.3	29.4	0.6	0.07	3.8	33

1/June	9.9	1.0	65.5	0.0	16.4	27.2	0.4	0.02	3.8	29
2/June	3.2	1.0	41.6	0.0	7.1	15.9	0.2	0.4	3.8	23
3/June	4.1	1.0	29.2	0.0	7.2	12.6	0.3	0.06	3.8	28
1/July	3.2	1.0	35.4	0.0	6.7	14.1	0.2	0.2	3.8	25
2/July	4.5	1.0	60.0	0.0	10.6	24.8	0.2	10^{-3}	3.8	23
3/July	5.4	1.0	80.0	0.0	14.5	39.4	0.1	0.05	3.8	20
1/August	3.5	1.0	52.9	0.0	9.7	26.9	0.1	1.0	3.8	20
2/August	3.4	1.0	26.6	0.0	5.4	8.5	0.4	0.4	3.8	30
3/August	10.5	1.0	76.0	0.0	19.1	34.9	0.3	0.02	3.8	27
1/Sep.	14.3	3.6	89.7	0.0	21.2	31.6	0.5	4e-3	3.8	31
2/Sep.	12.1	3.4	89.5	0.0	18.9	29.5	0.4	0.01	3.8	30
3/Sep.	18.2	1.0	54.5	0.0	17.3	16.4	1.1	2.0	7.8	37
1/October	34.5	16.9	179.1	0.0	44.8	58.2	0.6	0.3	6.0	33
2/October	28.4	20.2	122.2	0.0	29.5	30.6	0.9	0.5	6.0	36
3/October	41.0	35.7	115.9	0.0	33.5	27.3	1.5	2.8	7.8	39
1/Nov.	55.3	52.8	229.4	0.0	46.2	38.7	1.4	2.1	6.0	39
2/Nov.	64.1	60.6	154.7	0.0	39.3	24.1	2.7	0.8	7.8	42
3/Nov.	73	59.4	268.1	0.0	58.6	47.0	1.6	0.4	6.0	39
1/Dec.	82.7	82.8	227.0	0.0	50.5	30.8	2.7	0.9	6.0	42
2/Dec.	97.1	92.6	308.0	6.0	65.3	43.9	2.2	0.02	6.0	41
3/Dec.	113.0	111.0	275.2	20.6	65.4	37.9	3.0	3.5	7.8	42

1/, 2/ and 3/ first, second and third decennial for each month; * and ** calculated and standard λ^2, respectively; P: probability of occurrence of historical average rainfall for each period studied.

From Figure 2, it is possible to observe that as the probability of exceedance increases the probable rainfall decreases, in other words, the increase in the accuracy level implies the reduction of the estimated value. Graphically it is possible to estimate the probable rainfall desired at a given probability level (MARTINS et al., 2010; RIBEIRO; AVANZI, 2010; SOCCOL et al., 2010).

Considering the wet-season, in October, for a given probability level, is expected more rainfall for the third decennial, as well for November and December. At January, the first decennial seems to concentrate most part of rainfall. This observation is clear for February and April months. The evaluation of distribution of rainfall considering the probability of occurrence may play an important role to farming planning, for example, to soil tillage, sowing, liming, fertilization, harvesting and application of pesticides.

For irrigation planning, considering the water requirement for a given crop in a given period, from Figure 2 it is possible to estimate the contribution of natural rainfall. In irrigation projects, the probability level considered suitable is between 75% and 80% (BERNARDO, 2005).

In Table 2 is summarized the rainfall expected for each period at 75% of probability of exceedance. Considering 75%, at January (for example) is expected 54, 34 and 38 mm for first, second and third 10-day period, respectively. Considering theses periods, if the water requirement for a given crop is higher than the natural rainfall expected, the complementary irrigation is recommended. For example, in Barbacena County, Minas Gerais State, the monthly rainfall expected in the wet season at 75% probability of exceedance attend the most of water requirement of tomato, corn and bean (RIBEIRO et al., 2007). On the other hand, the simple use of historical average rainfall (without probabilistic studies) can lead to oversizing or designing fittest of the irrigation systems and also to lead an unnecessary use of water from rivers and lakes – this late aspect may play an important environmental impact.

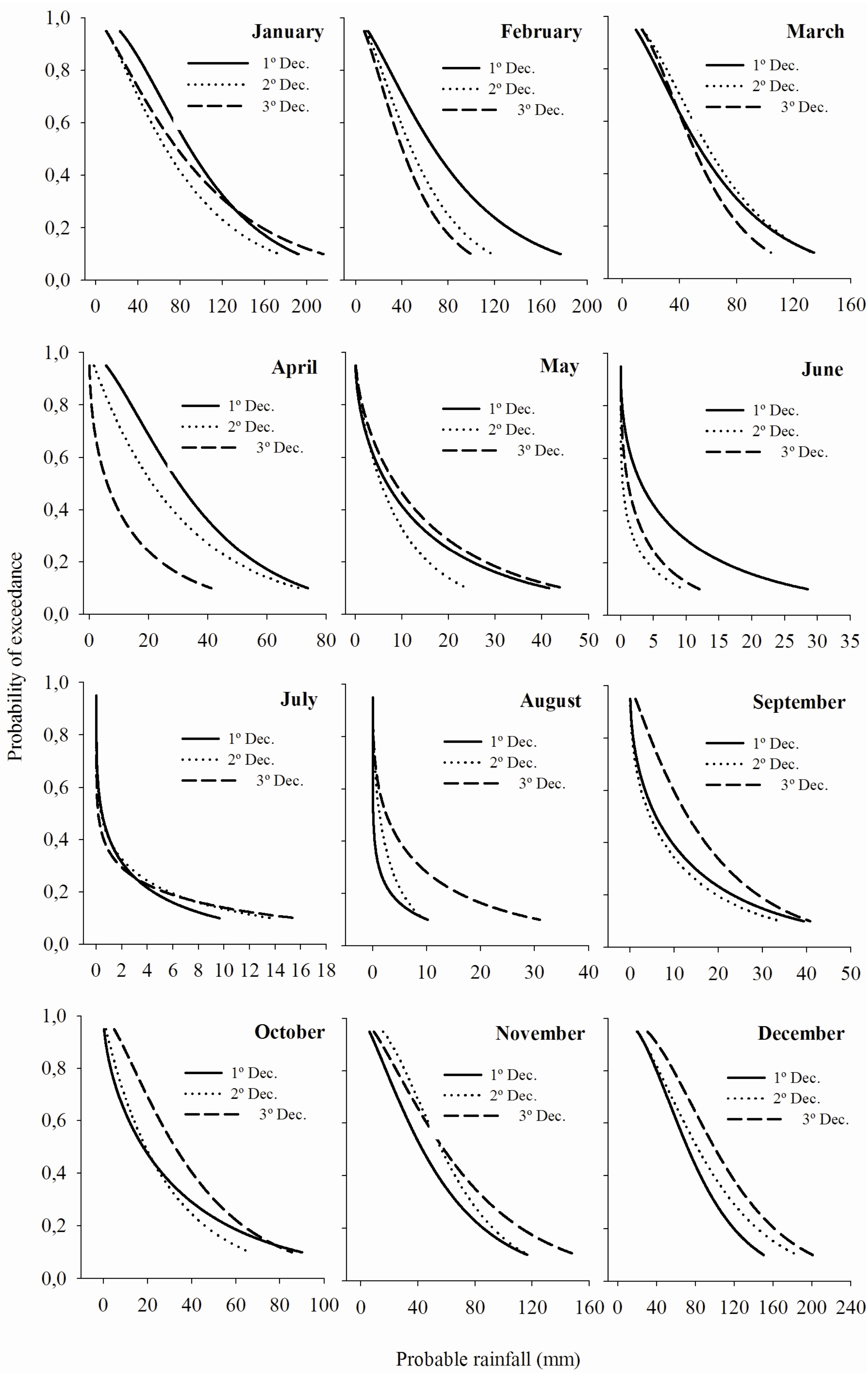

Figure 2. Probable rainfall for 10-day period (decennial) for Uberlândia, Minas Gerais State, Brazil.

Table 2. 10-day probable rainfall at 75% probability of exceedance of Uberlândia, Minas Gerais State, Brazil.

Period	Rainfall (mm)
1/January	54.45
2/January	34.51
3/January	38.01
1/February	35.17
2/February	26.28
3/February	21.82
1/March	29.00
2/March	35.64
3/March	31.14
1/April	16.67
2/April	8.81
3/April	1.14
1/May	1.48
2/May	1.77
3/May	2.28
1/June	0.45
2/June	0.01
3/June	0.13
1/July	0.02
2/July	0.01
3/July	0.00
1/August	0.00
2/August	0.21
3/August	0.24
1/September	1.14
2/September	0.77
3/September	5.80
1/October	4.87
2/October	7.56
3/October	16.62
1/November	21.60
2/November	35.22
3/November	30.24
1/December	45.57
2/December	49.15
3/December	64.86

1/, 2/ and 3/ first, second and third decennial, respectively.

CONCLUSION

The Gamma distribution was suitable to estimate the probable rainfall for 10-day period. During the wet season the historical average rainfall (10-day period) has 40% of probability of exceedance and during the dry season has 30%. These values are below that considered ideal (75-80%). From this work, the 10-day period rainfall can be estimated at different probability levels. This can contribute substantially to farming planning.

RESUMO: O conhecimento da precipitação provável pode contribuir substancialmente para as atividades agrícolas, principalmente em projetos de irrigação. Este trabalho foi realizado com o objetivo de determinar a precipitação provável para o município de Uberlândia, MG. Dados diários de precipitação de 1975 a 2010 (36 anos de observação) foram organizados em períodos decendiais e ajustados à distribuição Gamma. A precipitação provável foi estimada em diferentes níveis de probabilidade (10% a 95%). A distribuição Gamma foi adequada para estimativa da precipitação provável. Durante a estação chuvosa, a precipitação média histórica decendial teve uma probabilidade de excedência de 40% e, na estação seca, de 30%. A partir deste trabalho, a precipitação decendial pode ser estimada em diferentes níveis de probabilidade de ocorrência. Isso pode contribuir substancialmente para o planejamento das atividades agrícolas da região, especialmente irrigação.

PALAVRAS-CHAVE: Irrigação. Distribuição Gama. Planejamento da agricultura.

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