PROBABLE MONTHLY RAINFALL FOR MACHADO COUNTY, SOUTH MINAS GERAIS STATE

Precipitação mensal provável para o município de Machado, Sul de Minas Gerais

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ABSTRACT

Probabilistic studies of climatic variables (e.g., rainfall) are very important to farming planning. Machado County is located in the south of Minas Gerais State, Brazil, and it is characterized by intensive coffee production. The objectives of this work were to evaluate the suitability of Gamma distribution applied to monthly precipitation data and to estimate the probable monthly rainfall. Daily rainfall data obtained from the Brazilian National Water Agency (ANA) were summed in monthly periods from 1962 to 1998, resulting in a historical dataset with 37 years of observations. After that, the monthly rainfall data were applied to Gamma distribution and the probable rainfall estimated at different probability levels. The suitability of the Gamma distribution was evaluated by Qui-Square Test (λ^2). The Gamma distribution was adequate for monthly periods and can be used to estimate the probable rainfall and be employed in future related studies. The historical average rainfall has approximately 40% of probability to be overcome and its use may be not suitable for irrigation projects.

Key words: Gamma distribution, agriculture planning, occurrence probability.

RESUMO

Estudos probabilísticos de variáveis climáticas (e.g., precipitação) são de grande importância para o planejamento agrícola. A cidade de Machado está localizada no Sul do estado de Minas Gerais, Brasil, sendo caracterizada pela intensiva produção de café. Os objetivos deste trabalho foram: avaliar a adequabilidade da distribuição Gama aplicada a precipitações totais mensais e estimar a precipitação provável em diferentes níveis de probabilidade. Dados diários de precipitação foram obtidos junto a Agência Nacional de Águas (ANA) e totalizados em períodos mensais de 1962 a 1998, formando uma série histórica com 37 anos de observações. As precipitações totais mensais foram então aplicadas à distribuição Gama, sendo a adequabilidade desta avaliada pelo teste de Qui-Quadrado (λ^2). A distribuição Gama foi adequada para períodos mensais podendo ser usada para estimar a precipitação provável da região e, também, para estudos futuros relacionados. A precipitação média histórica tem aproximadamente 40% de probabilidade de ser superada e seu uso pode não ser satisfatório em projetos de irrigação.

Palavras-chave: distribuição Gama, planejamento agrícola, probabilidade de ocorrência.

INTRODUCTION

Machado County is located in the south of Minas Gerais state and is characterized by intensive coffee production. Many practices related to this exploration are dependent on rainfall occurrence, such as, liming, planting operations, fertilization, crop management, irrigation, harvesting and the natural drying of coffee on patios (common practice in the region). For this region, there are still no probabilistic studies of rainfall occurrence in order to estimate the probable rainfall at different probability levels.

The probable rainfall is defined as a minimum value to be overcome in a given probability level, called probability of exceedance (Bernardo et al., 2005). In other words, the probability of a given event (rainfall depths) to be overcome is known.

Many distribution models, such as, Normal, Log-Normal 2 and 3 parameters, Gamma, among others, have been applied in different regions of Brazil to describe the rainfall occurrence and to estimate the probable rainfall (Moreira et al., 2003; Junqueira Júnior et al., 2007; Ribeiro et al., 2007). The Gamma distribution has been considered the most appropriated model when applied to short periods (monthly or less) (Fietz et al., 1998; Murta et al., 2005; Ribeiro et al., 2007).

Probabilistic studies and the knowledge of probable rainfall for a given period can contribute to sustainable farming planning. For example, in irrigation projects the simple use of historical average rainfall might be not suitable. In some regions it has been found that the historical average rainfall has approximately 40% of probability of exceedance – 4 annual rainfall events every 10 years (Murta et al., 2005). In irrigation projects, the probability of exceedance of 75% is considered appropriated (Bernardo et al., 2005), in other words, 3 of every 4 annual rainfall events for a given period (e.g., decennial, biweekly, monthly).

Although Machado County is located in a region considered adequate for coffee production (Evangelista et al., 2002), the use of irrigation can contribute substantially to improve the coffee growth and productivity, especially during the dry season (Carvalho et al., 2006; Gomes et al., 2007). In this context, the knowledge of probable rainfall is very important, for example, to avoid the oversizing of irrigation systems when the all water requirements by the crops is considered, without taking into account the probable rainfall, and also to contribute to reduce the water use from rivers and reservoirs. Moreover, the use of historical average rainfall can lead to designing fittest irrigation system (Fietz et al., 1998).

The aim of this work was to evaluate the suitability of Gamma distribution applied to monthly precipitation data and to estimate the probable monthly rainfall for Machado County, south of Minas Gerais state.

MATERIAL AND METHODS

This work was carried out with measured historical daily precipitation data acquired from the Brazilian National Water Agency – ANA (Hidroweb, 2009), weather station of Machado County, south of Minas Gerais state (Code 02145033), located in the Paraná River Basin, Grande River Sub Basin, geographical reference of 21º 40’S and 45º 55’W and altitude 873 m. The weather station is controlled by the Brazilian National Institute of Meteorology (INMET). The climate is Cwa (Köppen classification), with moderate temperatures, hot and wet summers (Antunes, 1986).

The daily precipitation data were summed in monthly periods from 1962 to 1998, totaling a historical dataset with 37 years of observations. After that, the data was applied to Gamma distribution.

Gamma distribution

According to Lanna (2001), the Gamma distribution is defined by the following integral equations:

$$\Gamma(\alpha) = \int_0^{\infty} x^{\upsilon-1} e^{-x} dx, \upsilon > 0 \qquad (01)$$

$$P(\alpha, x) = \int_0^{x} x^{(\upsilon-1)} e^{-x} dx \qquad (02)$$

$$P(\alpha, x) = \int_0^{x} x^{(\upsilon-1)} e^{-x/\beta} dx \qquad (03)$$

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

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

with $\nu > 0$, $\beta > 0$, $\Gamma(\nu) > 0$, where ν 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:

$$\upsilon = \frac{\bar{x}^2}{S_x^2} \qquad (5)$$

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

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

The suitability of Gamma distribution was evaluated by the Qui-Square (λ^2) Test (α = 0.05), considering the degrees of freedom as being the number of classes minus 1 (Ferreira, 2005). Once the Gamma distribution considered adequate, the probable monthly rainfall was estimated in different probability levels, ranging from 10% to 97%.

RESULTS AND DISCUSSION

The Gamma distribution was adequate for all months studied (calculated λ^2 values < λ_α^2 critical values), as can be seen in Figure 1. In different regions of Brazil, the Gamma distribution has been considered sustainable when short periods are studied (monthly or less). For example, in Barbacena County, considered the same climate as Machado, according to Köppen Classification, the Gamma distribution was adequate for 98% of historical datasets studied (Ribeiro et al., 2007). In Dourados, Mato Grosso do Sul state, the Gamma distribution was adequate for monthly, biweekly and decennial periods (Fietz et al., 1998).

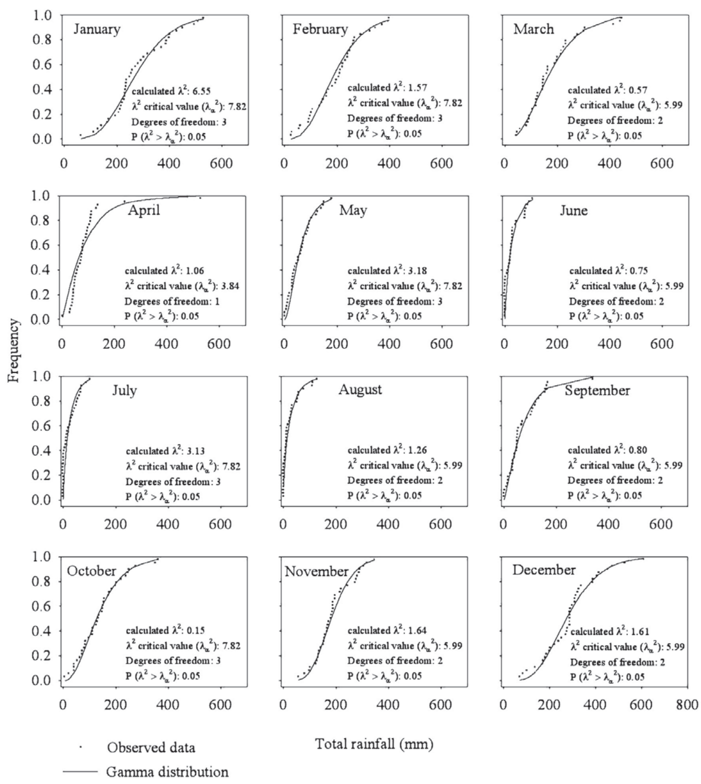

FIGURE 1 - Gamma distribution applied to monthly rainfall data from Machado County, south of Minas Gerais state.

The descriptive statistic of monthly rainfall is shown in Table 1. As expected for the region of Machado County, there are two well defined periods (Antunes, 1986): rainy summer (Dec-Feb) and dry winter (Jun-Ago). The summer rainfall corresponds to 48% of total annual rainfall (1593 mm) and the winter rainfall only 5%. The most rainfall is concentrated in seven months (Oct-Apr) corresponding to 86% of total annual rainfall. The median values were close to average values. A large variation in the monthly rainfall (difference between maximum and minimum values) was also observed, mainly in the summer season.

The β and ν parameters from Gamma distribution are also shown in Table 1. In general, it was observed that the rainiest months had higher β and ν values. Similar results to β values were found for Itapetinga and Vitória da Conquista, southwest of Bahia state (Murta et al., 2005). High β values in the rainiest months are related to variability of data since it is directly proportional to the square of the standard deviation (Equation 6). As can be seen in Table 1, the rainiest months showed higher standard error. The highest ν values found in the rainiest months are related to asymmetry of data. For the region studied by Murta et al. (2005) (southwest of Bahia state) the highest ν values were found in the driest months.

TABLE 1. Descriptive statistics of monthly rainfall data from Machado County, south of Minas Gerais state and β and ν parameters from Gamma distribution.

Month	Average	Median	Maximum	Minimum	Standard error	β	ν
	-------------------------------		---mm---		-------------------------------		
January	282	250	531	64	19	46	6
February	200	208	399	26	16	48	4
March	182	148	446	45	17	57	3
April	89	76	530	3	14	81	1
May	63	53	181	2	8	34	2
June	28	21	106	0	5	35	1
July	25	12	103	0	5	33	1
August	26	12	129	1	6	43	1
September	76	52	341	1	11	60	1
October	143	136	363	7	14	51	3
November	190	181	348	58	11	26	8
December	289	289	612	71	19	48	6

The probable rainfall for all months at different levels (10% to 97%) of exceedance is shown in Figure 2. As the probability of exceedance increases the probable estimated rainfall decreases, in other words, the increase in the accuracy level implies the reduction of the estimated value. From Figure 2 it is possible to graphically estimate the probable rainfall desired at a given probability level, in other words, the probability of the rainfall to be overcome or a minimum value to be guaranteed. For example, in general, the historical average monthly rainfall (Table 1) had approximately 40% of probability of exceedance. This value might be not suitable for irrigation projects (Murta et al., 2005). At 75% of probability of exceedance, considered adequate for irrigation projects, the probable rainfall (mm) is: Jan (199), Feb (128), Mar (107), Apr (28), May (29), Jun (6), Jul (5), Aug (4), Sep (27), Oct (80), Nov (140), Dec (204).

According to Evangelista et al. (2002), in Brazil, the best coffee growing regions are located where more than 150 mm per month occurs during the flowering, formation and maturation, which take place from October to March. At 75% of probability of exceedance, the expected rainfall in December and January is above of 150 mm (Figure 2). Considering this value as adequate monthly rainfall for coffee production, the probability of exceedance is approximately: Oct (39%), Nov (69%), Dec (90%), Jan (90%), Feb (65%) and Mar (55%). In December and January at least 150 mm are expected every 9 to 10 years. For others months of the year, complementary irrigation should be necessary to supply the water coffee crop demands, avoiding the productivity reduction due to shortage periods.

The results presented in this work can help the farming planning in Machado County since the monthly rainfall can be estimated at different probability levels. Other activities, such as civil engineering works, tourism and events can also be favored.

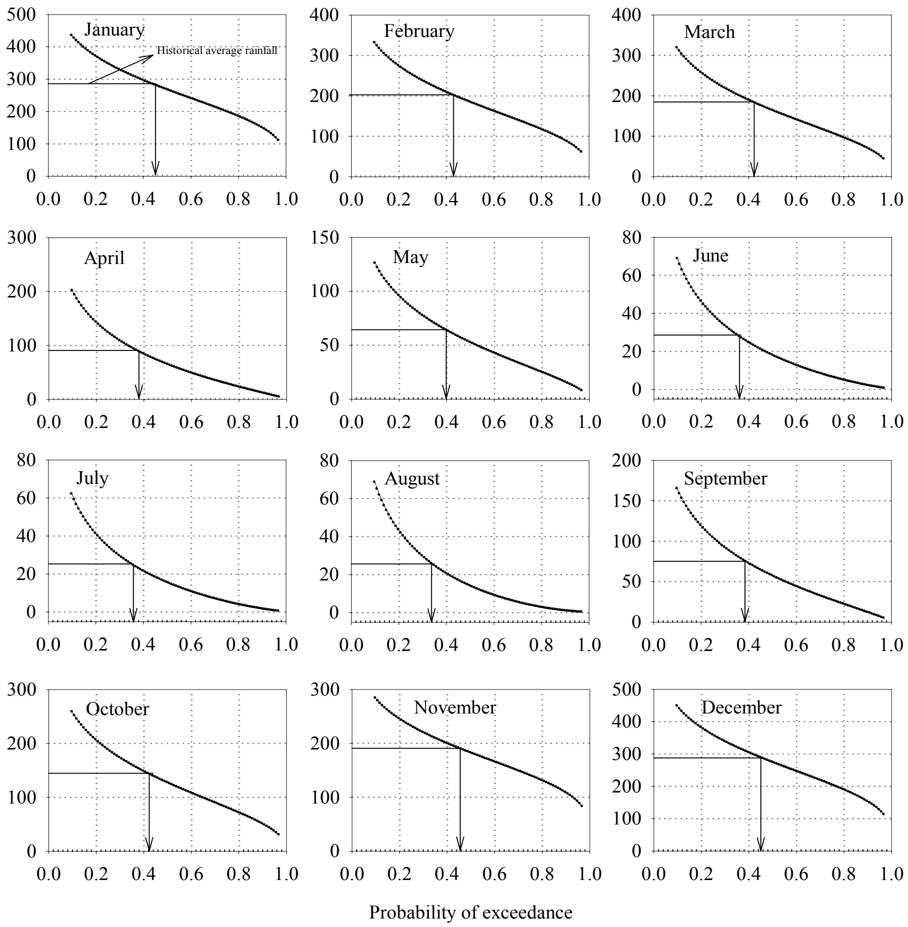

FIGURE 2 - Probable monthly rainfall estimated by Gamma distribution at different probability levels for Machado County, south of Minas Gerais state.

CONCLUSIONS

The Gamma distribution was adequate for monthly rainfall data and can be used to estimate the probable rainfall in Machado County.

The historical average rainfall has a probability of exceedance of approximately 40%; lower than that considered adequate (75%) for irrigation projects.

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