Original Article

FUNCTIONS OF PROBABILITY FOR FITTING MONTHLY RAINFALL IN SITES OF MATO GROSSO DO SUL STATE

FUNÇÕES DE PROBABILIDADE PARA AJUSTE DA CHUVA MENSAL EM LOCAIS DO ESTADO DE MATO GROSSO DO SUL

Paulo Eduardo TEODORO[1]; Alberto CARGNELUTTI FILHO[2]; Francisco Eduardo TORRES[3]; Larissa Pereira RIBEIRO[4]; Denise Prevedel CARPISTO[4]; Caio Cezar Guedes CORRÊA[1]; Elias Rodrigues da CUNHA[5]; Vitor Matheus BACANI[5]

1. Discentes do Programa de Pós-Graduação stricto sensu em Agronomia - área de concentração: Produção Vegetal, da Universidade Estadual de Mato Grosso do Sul - UEMS, Aquidauana, MS, Brasil; 2. Docente Adjunto do Curso de Agronomia e do Programa de Pós-graduação em Agronomia da Universidade Federal de Santa Maria – UFSM, Santa Maria, RS, Brasil; 3. Docente Adjunto do Curso de Agronomia e do Programa de Pós-graduação em Agronomia da UEMS/UUA, Aquidauana, MS, Brasil; 4. Discentes do curso de Agronomia da UEMS/UUA, Aquidauana, MS, Brasil; 5. Laboratório de Geoprocessamento da Universidade Federal de Mato Grosso do Sul – UFMS, MS, Brasil.

ABSTRACT: The identification of the probability distribution function for the representation of the monthly rainfall is relevant in agricultural planning, mainly regard to the establishment of crops. The aim of this work was to verify the probability distribution (exponential, gamma or normal) which best fits to data monthly rainfall of 14 sites in the state of Mato Grosso do Sul. Rainfall data of 14 stations (sites) of the State of Mato Grosso do Sul it were obtained from the National Water Agency (ANA) database, collected in the period 1975 - 2013. At each of the 168 time series of monthly rainfall was applied the Kolmogorov-Smirnov test to assess the fit to probability distributions exponential, gamma and normal. The normal probability distribution presented the best fit to monthly rainfall series of Mato Grosso do Sul and it can be used for the estimation the monthly rainfall, especially in the rainy season months (October to March). The exponential probability distribution can be used for the estimation of monthly rainfall in the driest months of the year (May to September). Thus, we recommend that these distributions be used in future research, aimed to estimate the probable rainfall for the Mato Grosso do Sul State.

KEYWORDS: Time series adherence. Exponential distribution. Gamma distribution. Normal distribution.

INTRODUCTION

The State of Mato Grosso do Sul (MS) covers an area of approximately 350,000 km², of which 13,000 km² are explored in agriculture, being the crops of higher expression soybean, maize, cotton, sugarcane and irrigated rice (CONAB, 2014). Agriculture has the rainfall as its main source of water, which may compromise the crop production due to its uneven behavior, sometimes with long periods of drought, sometimes with high intensity rains that exceed the water retention capacity of the soil, triggering floods (SILVA et al., 2007; SOCCOL et al., 2010; VIEIRA et al., 2010; CORRÊA et al., 2014). Besides the influence in agriculture, very long periods of droughts affect the water level of water sources and reservoirs of hydroelectric plants, bringing problems to the urban water supply and electric power generation (RODRIGUES et al., 2013; TEODORO et al., 2015a; TEODORO et al., 2016).

Teodoro et al. (2015b), by using the algorithm Ward to evaluate the spatial and temporal variability of rainfall in the state of Mato Grosso do Sul, identified the main systems leading producers of rainfall systems. The central region of that State is influenced by South Atlantic Sub-tropical Anticyclone, Chaco's Low, Bolivia's Upper, Low Levels Jet, Madden-Julian Oscillation and South Atlantic Convergence Zone. The northern region is is affected by Upper Tropospheric Cyclonic Vortex, Front Systems and South Atlantic Convergence Zone. The southern region is influenced by Upper Tropospheric Cyclonic Vortex and Front Systems.

The impossibility of know the exact evolution of rainfall values over time and space according to their random nature is highlighted by Sampaio et al. (2007). From these difficulties, probabilistic models are used to describe the behavior both the expected rainfall as the precipitation period, because obtaining the correct temporal distribution of rainfall is important in agricultural planning, and enable the appropriate use of water resources for given region (RODRIGUES et al., 2013).

Most of the probability density functions have from one to three parameters and the multiparameter functions generally show superior fit to rainfall when compared to a single parameter (LYRA et al., 2006). However, due to the complexity of the processes involved in space-time variation of rainfall, are selected these functions

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according to the criteria of best fit with historical data, ease of estimates of its parameters and computational flexibility (DUAN et al., 1998; TEODORO et al., 2015b).

Thus, the aim of this study was undertaken to verify the probability distribution (exponential, gamma or normal) which best fit to monthly rainfall data from 14 sites of State of Mato Grosso do Sul.

MATERIAL AND METHODS

Rainfall daily database of 14 stations (sites) of Mato Grosso do Sul, from 1975 to 2013, it were obtained of the Database of the Agência Nacional de Águas (ANA, 2014). At each site and year, it were added up the rainfall daily data to obtain the monthly rainfall (mm.monthly^{-1}), of each month of the year, as performed by Teodoro et al. (2015 b). Thus, were formed 168 time series (12 months × 14 sites), with different numbers of years of observations in each series, defined according to the availability of meteorological data (Table 1). Processing of the data removing the outliers, which are observations that deviate markedly from the others in the sample in which they occur, causing inconsistencies was carried out. About 10 % historical series showed failures (outliers), which are filled by the climatological normal of each of the 11 micro-regions of the state.

Table 1. Altitude (m), latitude (°), longitude (°) and observation period of the monthly rainfall of 14 sites in the State of Mato Grosso do Sul, Brazil.

Sites	Altitude (m)	Latitude (S)	Longitude (W)	Period
Água Clara	376	-20º06'07''	-52º55'33"	1975-2013
Bataguassu	293	-21º43'33''	-52º20'03''	1975-2013
Camapuã	404	-19º29'48''	-53º59'48''	1973-2013
Campo Grande	559	-20º28'00''	-54º40'00''	1975-2013
Coxim	250	-18º38'57''	-54º21'26''	1973-2013
Glória de Dourados	422	-22º24'21''	-54º14'07''	1973-2013
Naviraí	366	-23º3'28''	-54º11'38''	1975-2013
Paranaíba	458	-19º23'27''	-51º36'32''	1983-2013
Porto Murtinho	83	-21º42'05''	-57º53'30''	1983-2013
Ribas do Rio Pardo	373	-20º26'41''	-53º45'29''	1975-2013
Rio Negro	233	-19º26'23''	-54º59'00''	1975-2013
Santa Rita do Pardo	393	-21º17'43''	-52º48'38''	1975-2013
Selvíria	348	-20º21'49''	-51º25'26''	1983-2013
Três Lagoas	313	-20º47'41''	-51º42'46''	1975-2013

The exponential distribution generally fits well to the data that have marked asymmetry, as histograms in the shape of "J" inverted (THOM, 1958). Its probability density function f (x) is express as follows by Equation 1:

$$f(x) = \begin{cases} \lambda e^{\lambda x} & x > 0 \\ 0 & x < 0 \end{cases}$$

wherein: x is the random variable (monthly rainfall, mm) and λ is the inverse of the average.

For total rainfall of monthly periods or smaller, the distribution gamma has been one of the most used (ASSIS et al., 1996), being represented its probability density function as follows by Equation 2:

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

for $0 < x < \infty$, with $\beta, \alpha, \tau(\alpha) > 0$ and $f(x) = 0$ for $x < 0$

being: β scale parameter, α the shape parameter and τ(α) the incomplete gamma function of the parameter α, defined by Equation 3 (THOM, 1958):

$$\tau(\alpha) = \int_0^{\beta} t^{\alpha-1} e^{t} dt \quad \text{wherein} \quad t = -\frac{x}{\beta}.$$

The normal probability distribution, also called Gaussian curve presents two parameters and its probability density function is define by Equation 4 (HASTINGS; PEACOCK, 1975):

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{\left[-\frac{(x-\mu)^2}{2\sigma^2}\right]}$$

wherein: μ is the average and σ the standard deviation.

In each month and site, it were calculated the probabilities (P) of the monthly rainfall (RAINFALL) to be less than 50 mm [P (RAINFALL < 50 mm)], between 50 mm and 100 mm [P (50 mm ≤ RAINFALL < 100 mm)] and greater than 100 mm [P (RAINFALL ≥ 100 mm)]. The choice of these intervals was based on the recommendation of Assis et al. (1996) which recommends for the design of these agricultural projects. These probabilities were calculated from the parameters of the distribution (exponential, gamma and normal) of best fit, ie, the parameter with the lowest value of the statistic D maximum of the Kolmogorov-Smirnov adhesion test (KS). Statistical analyzes were performed with the use of the application Microsoft Office Excel® and of the Statistica 7.0® software (STATSOFT, 2005).

RESULTS AND DISCUSSION

In 123 of the 168 time series (12 months × 14 sites) normal distribution function showed low values of D maximum of the KS test, fitting in the class of p-value class ≥ 0.20 (Table 2). The gamma and exponential distribution functions were fit to p-value class ≥ 0.20 in 102 and 32 time series, respectively. The statistic value of D maximum of the KS test informs the maximum distance between the theoretical and empirical probabilities obtained under the probability distribution function under test (ASSIS et al., 1996). The lower the value of this statistic, the higher the p-value and, consequently, greater adherence of the data to distribution under test. Thus, it can be inferred that, in most cases, the estimates of the parameters of the normal distribution can be used to represent the behavior of the monthly rainfall of the State of Mato Grosso do Sul. Baú et al. (2006), Ávila et al. (2009) and Uliana et al. (2013) obtained similar results on researches about the probable rainfall in the States of Paraná, Minas Gerais and Espírito Santo, respectively.

Table 2. D maximun statistic and p-value classes(1) (in brackets) of the Kolmogorov-Smirnov adhesion test, applied to check the fit of time series of monthly rainfall (mm) in 14 sites of the State of Mato Grosso do Sul, to the functions of exponential, gamma and normal probability distributions.

Site	Month											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
						Exponential						
Água Clara	0.33(6)	0.35(6)	0.24(5)	0.18(2)	0.23(5)	0.32(6)	0.28(6)	0.33(6)	0.21(4)	0.31(6)	0.34(6)	0.26(5)
Bataguassu	0.27(6)	0.25(5)	0.22(5)	0.17(1)	0.08(1)	0.19(3)	0.17(1)	0.41(6)	0.14(1)	0.29(6)	0.25(5)	0.34(6)
Camapuã	0.36(6)	0.37(6)	0.29(6)	0.28(6)	0.23(5)	0.20(4)	0.29(6)	0.27(6)	0.25(5)	0.34(6)	0.36(6)	0.35(6)
Campo Grande	0.32(6)	0.33(6)	0.34(6)	0.27(6)	0.27(6)	0.15(1)	0.15(1)	0.20(3)	0.21(4)	0.29(6)	0.31(6)	0.36(6)
Coxim	0.38(6)	0.35(6)	0.33(6)	0.23(5)	0.16(1)	0.26(6)	0.34(6)	0.39(6)	0.19(4)	0.31(6)	0.32(6)	0.30(6)
Glória de Dourados	0.28(6)	0.27(6)	0.28(6)	0.24(5)	0.20(4)	0.12(1)	0.08(1)	0.17(2)	0.26(6)	0.31(6)	0.30(6)	0.36(6)
Naviraí	0.28(6)	0.26(6)	0.24(5)	0.24(5)	0.17(1)	0.09(1)	0.13(1)	0.13(1)	0.23(5)	0.25(5)	0.28(6)	0.39(6)
Paranaíba	0.45(6)	0.30(6)	0.30(6)	0.23(5)	0.20(3)	0.29(6)	0.25(5)	0.38(6)	0.07(1)	0.31(6)	0.36(6)	0.44(6)
Porto Murtinho	0.32(6)	0.33(6)	0.24(5)	0.22(4)	0.11(1)	0.16(1)	0.13(1)	0.27(6)	0.18(1)	0.29(6)	0.40(6)	0.25(5)
Ribas do Rio Pardo	0.36(6)	0.34(6)	0.31(6)	0.24(5)	0.15(1)	0.23(5)	0.17(1)	0.33(6)	0.12(1)	0.26(6)	0.29(6)	0.32(6)
Rio Negro	0.34(6)	0.38(6)	0.29(6)	0.28(6)	0.10(1)	0.23(5)	0.26(5)	0.28(6)	0.13(1)	0.36(6)	0.32(6)	0.35(6)
Santa Rita do Pardo	0.33(6)	0.32(6)	0.29(6)	0.23(5)	0.19(3)	0.11(1)	0.09(1)	0.28(6)	0.16(1)	0.35(6)	0.37(6)	0.34(6)
Selvíria	0.33(6)	0.36(6)	0.26(5)	0.21(3)	0.17(1)	0.23(5)	0.29(6)	0.45(6)	0.14(1)	0.25(5)	0.25(5)	0.32(6)
Três Lagoas	0.30(6)	0.27(6)	0.27(6)	0.18(3)	0.16(1)	0.08(1)	0.12(1)	0.37(6)	0.17(1)	0.29(6)	0.33(6)	0.29(6)
						Gamma						
Água Clara	0.12(1)	0.13(1)	0.09(1)	0.09(1)	0.19(3)	0.23(5)	0.23(5)	0.24(5)	0.13(1)	0.14(1)	0.15(1)	0.16(1)
Bataguassu	0.09(1)	0.12(1)	0.08(1)	0.16(1)	0.11(1)	0.22(4)	0.25(5)	0.27(6)	0.19(3)	0.09(1)	0.15(1)	0.07(1)
Camapuã	0.07(1)	0.09(1)	0.13(1)	0.17(2)	0.11(1)	0.28(6)	0.22(5)	0.21(4)	0.13(1)	0.09(1)	0.10(1)	0.06(1)
Campo Grande	0.19(3)	0.13(1)	0.11(1)	0.17(2)	0.26(5)	0.20(4)	0.20(4)	0.25(5)	0.25(5)	0.19(3)	0.20(4)	0.14(1)
Coxim	0.09(1)	0.11(1)	0.07(1)	0.08(1)	0.18(3)	0.17(1)	0.26(6)	0.27(6)	0.18(3)	0.08(1)	0.10(1)	0.13(1)
Glória de Dourados	0.09(1)	0.10(1)	0.08(1)	0.17(2)	0.17(2)	0.27(6)	0.16(1)	0.18(2)	0.15(1)	0.09(1)	0.12(1)	0.12(1)
Naviraí	0.09(1)	0.09(1)	0.10(1)	0.24(5)	0.17(1)	0.12(1)	0.21(4)	0.21(4)	0.11(1)	0.11(1)	0.13(1)	0.11(1)
Paranaíba	0.11(1)	0.11(1)	0.13(1)	0.22(4)	0.19(2)	0.31(6)	0.17(1)	0.25(5)	0.12(1)	0.13(1)	0.07(1)	0.20(3)
Porto Murtinho	0.10(1)	0.10(1)	0.13(1)	0.20(3)	0.19(3)	0.31(6)	0.20(3)	0.25(5)	0.23(4)	0.20(3)	0.17(1)	0.13(1)
Ribas do Rio Pardo	0.10(1)	0.17(2)	0.10(1)	0.26(5)	0.14(1)	0.16(1)	0.27(6)	0.25(5)	0.06(1)	0.11(1)	0.08(1)	0.11(1)
Rio Negro	0.07(1)	0.12(1)	0.12(1)	0.31(6)	0.12(1)	0.28(6)	0.27(6)	0.25(5)	0.09(1)	0.11(1)	0.19(3)	0.12(1)
Santa Rita do Pardo	0.08(1)	0.16(1)	0.07(1)	0.09(1)	0.18(2)	0.25(5)	0.18(2)	0.22(5)	0.14(1)	0.10(1)	0.16(1)	0.09(1)
Selvíria	0.10(1)	0.14(1)	0.09(1)	0.21(4)	0.18(2)	0.21(3)	0.22(4)	0.31(6)	0.16(1)	0.15(1)	0.14(1)	0.15(1)
Três Lagoas	0.14(1)	0.09(1)	0.08(1)	0.13(1)	0.22(4)	0.16(1)	0.19(3)	0.25(5)	0.16(1)	0.15(1)	0.06(1)	0.25(5)

						Normal						
Água Clara	0.06(1)	0.14(1)	0.11(1)	0.09(1)	0.14(1)	0.20(4)	0.26(6)	0.29(6)	0.13(1)	0.10(1)	0.13(1)	0.07(1)
Bataguassu	0.09(1)	0.11(1)	0.11(1)	0.13(1)	0.13(1)	0.20(4)	0.22(5)	0.24(5)	0.16(1)	0.13(1)	0.09(1)	0.09(1)
Camapuã	0.07(1)	0.11(1)	0.09(1)	0.12(1)	0.08(1)	0.19(3)	0.22(5)	0.27(6)	0.13(1)	0.05(1)	0.11(1)	0.11(1)
Campo Grande	0.09(1)	0.09(1)	0.11(1)	0.14(1)	0.11(1)	0.14(1)	0.15(1)	0.20(4)	0.15(1)	0.12(1)	0.09(1)	0.08(1)
Coxim	0.08(1)	0.10(1)	0.11(1)	0.13(1)	0.20(4)	0.24(5)	0.19(3)	0.24(5)	0.09(1)	0.13(1)	0.11(1)	0.10(1)
Glória de Dourados	0.15(1)	0.10(1)	0.09(1)	0.12(1)	0.19(3)	0.14(1)	0.14(1)	0.24(5)	0.10(1)	0.14(1)	0.06(1)	0.17(2)
Naviraí	0.08(1)	0.15(1)	0.17(1)	0.11(1)	0.19(3)	0.18(2)	0.21(4)	0.20(4)	0.19(3)	0.11(1)	0.11(1)	0.17(1)
Paranaíba	0.15(1)	0.11(1)	0.08(1)	0.10(1)	0.10(1)	0.19(3)	0.24(5)	0.20(3)	0.18(1)	0.07(1)	0.11(1)	0.15(1)
Porto Murtinho	0.11(1)	0.09(1)	0.09(1)	0.09(1)	0.17(1)	0.21(3)	0.16(1)	0.25(5)	0.18(1)	0.15(1)	0.12(1)	0.10(1)
Ribas do Rio Pardo	0.14(1)	0.13(1)	0.14(1)	0.12(1)	0.10(1)	0.22(5)	0.19(3)	0.20(4)	0.13(1)	0.09(1)	0.11(1)	0.06(1)
Rio Negro	0.08(1)	0.16(1)	0.12(1)	0.18(2)	0.20(4)	0.18(3)	0.20(4)	0.24(5)	0.15(1)	0.12(1)	0.12(1)	0.09(1)
Santa Rita do Pardo	0.11(1)	0.11(1)	0.10(1)	0.08(1)	0.13(1)	0.20(4)	0.20(4)	0.23(5)	0.15(1)	0.15(1)	0.10(1)	0.14(1)
Selvíria	0.08(1)	0.09(1)	0.12(1)	0.18(2)	0.16(1)	0.29(6)	0.21(3)	0.23(4)	0.13(1)	0.13(1)	0.10(1)	0.12(1)
Três Lagoas	0.20(4)	0.11(1)	0.10(1)	0.14(1)	0.13(1)	0.15(1)	0.20(4)	0.23(5)	0.15(1)	0.07(1)	0.10(1)	0.06(1)

(1) class 6: p-value<0.01; class 5: 0.01≤ p-value<0.05; class 4: 0.05≤ p-value<0.10; class 3: 0.10≤ p-value <0.15; class 2: 0.15≤ p-value <0.20; class 1: p-value ≥0.20.

The largest number of adhesions of normal distribution was observed in the months of the rainy season, identified by Teodoro et al. (2015b) among October to March, agreeing with Lyra et al. (2006) and Junqueira Júnior et al. (2007) of which the same fits well to values of weekly, monthly and seasonal rainfall that do not show many dry periods.

In the dry season, identified by Teodoro et al. (2015b) among May to September, the exponential distribution showed 31 series with fit in the p-value class ≥ 0.20, being higher than the normal distribution (29 fits), and gamma (21 fits) (Table 2). This can be explained by the higher frequency observed during the initial classes (lower value of rainfall), decreasing mildly in the shape of "J" inverted, with strong positive asymmetry. Lyra et al. (2006) and Junqueira Júnior et al. (2007) obtained similar results, concluding that in the estimating the probability of monthly rainfall, the exponential distribution showed the best results in the dry season.

According to Dourado Neto et al. (2005), one major problems of estimating the probable rainfall with gamma distribution function is the estimation of α and β parameters, due to the complexity and extension of the involved calculations. The exponential and normal distribution functions have less difficulty for obtaining the parameters and ease in the probability estimates.

Thus, estimates of the parameters λ, α, β, μ and σ in each month and site (Tables 3 and 4) enable to estimate the probabilities above or below any monthly rainfall value, in order to minimize risks and facilitating the planning of various agricultural activities. This enable the prediction of better time for the tillage, harvest, sowing, fertilizer application and defensive (SILVA et al., 2007; ÁVILA et al., 2009; VIEIRA et al., 2010).

Table 3. Estimate parameters for the functions of exponential and gamma probability distributions of time series for monthly rainfall (mm) in 14 sites of the State of Mato Grosso do Sul. Brazil.

Site	Month											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
					λ of the exponential distribution							
Água Clara	0.0037	0.0044	0.0054	0.0131	0.0142	0.0408	0.0450	0.0328	0.0146	0.0081	0.0056	0.0042
Bataguassu	0.0049	0.0058	0.0076	0.0111	0.0116	0.0190	0.0274	0.0308	0.0119	0.0094	0.0074	0.0054
Camapuã	0.0039	0.0052	0.0053	0.0119	0.0118	0.0311	0.0456	0.0377	0.0121	0.0078	0.0061	0.0046
Campo Grande	0.0048	0.0055	0.0068	0.0115	0.0110	0.0232	0.0299	0.0247	0.0119	0.0074	0.0063	0.0048
Coxim	0.0041	0.0048	0.0067	0.0130	0.0180	0.0388	0.0616	0.0575	0.0179	0.0082	0.0058	0.0046
Glória de Dourados	0.0055	0.0060	0.0064	0.0086	0.0092	0.0115	0.0203	0.0166	0.0081	0.0065	0.0065	0.0063
Naviraí	0.0066	0.0065	0.0079	0.0088	0.0084	0.0120	0.0218	0.0178	0.0088	0.0057	0.0061	0.0060
Paranaíba	0.0036	0.0050	0.0048	0.0111	0.0192	0.0421	0.0729	0.0585	0.0191	0.0089	0.0072	0.0042
Porto Murtinho	0.0052	0.0063	0.0072	0.0069	0.0108	0.0224	0.0304	0.0299	0.0135	0.0077	0.0062	0.0054
Ribas do Rio Pardo	0.0044	0.0058	0.0064	0.0105	0.0120	0.0264	0.0333	0.0321	0.0122	0.0071	0.0064	0.0051
Rio Negro	0.0048	0.0059	0.0077	0.0123	0.0122	0.0222	0.0536	0.0432	0.0135	0.0078	0.0073	0.0044

Santa Rita do Pardo	0.0046	0.0062	0.0070	0.0116	0.0116	0.0189	0.0274	0.0298	0.0117	0.0081	0.0071	0.0055
Selvíria	0.0042	0.0050	0.0062	0.0128	0.0184	0.0334	0.0705	0.0436	0.0157	0.0104	0.0080	0.0057
Três Lagoas	0.0044	0.0061	0.0065	0.0104	0.0133	0.0279	0.0345	0.0323	0.0124	0.0078	0.0066	0.0053
	α of the gamma distribution											
Água Clara	6.06	6.95	3.15	1.98	1.28	0.23	0.24	0.20	1.98	3.31	6.35	2.60
Bataguassu	3.64	2.35	2.77	1.04	0.85	0.30	0.35	0.18	0.80	3.03	2.09	7.39
Camapuã	8.49	7.71	3.43	2.34	2.50	0.32	0.24	0.25	2.30	8.33	7.22	6.78
Campo Grande	2.93	4.48	5.12	2.33	1.07	0.43	0.44	0.34	0.85	1.73	2.66	4.76
Coxim	7.23	6.65	6.11	2.45	0.88	0.27	0.24	0.19	1.10	4.74	5.63	5.32
Glória de Dourados	4.36	3.16	3.24	1.35	1.14	0.46	0.56	0.37	2.43	4.73	5.27	7.45
Naviraí	4.12	3.70	2.82	0.99	1.02	0.85	0.59	0.41	2.13	3.61	3.52	6.77
Paranaíba	13.77	4.71	3.42	1.14	1.09	0.26	0.31	0.21	0.72	3.69	6.30	12.38
Porto Murtinho	5.08	5.41	2.54	1.11	0.63	0.36	0.52	0.25	0.67	1.76	5.26	3.43
Ribas do Rio Pardo	7.03	7.57	5.11	0.90	1.03	0.37	0.36	0.21	1.53	4.77	4.54	5.45
Rio Negro	6.02	6.09	2.60	0.86	0.92	0.28	0.28	0.25	1.26	6.78	4.09	8.22
Santa Rita do Pardo	5.37	5.39	4.74	2.62	1.06	0.45	0.51	0.23	1.10	4.28	3.99	5.19
Selvíria	8.05	4.58	3.19	0.96	0.95	0.27	0.25	0.17	0.79	3.20	3.57	3.85
Três Lagoas	4.02	2.97	3.96	1.41	0.67	0.57	0.51	0.19	1.04	3.04	5.13	1.45
	β of the gamma distribution											
Água Clara	44.97	33.04	58.93	38.65	54.81	107.37	91.45	150.49	34.63	37.36	28.00	92.08
Bataguassu	55.95	72.63	47.32	86.19	101.61	173.10	104.17	177.56	105.16	35.10	64.46	25.18
Camapuã	30.43	25.06	54.96	35.99	33.95	100.62	92.62	104.88	35.84	15.44	22.87	31.85
Campo Grande	70.95	40.47	28.82	37.27	85.36	100.98	76.06	118.32	99.52	77.82	59.51	43.89
Coxim	33.68	31.25	24.25	31.32	62.78	97.15	68.94	89.46	50.94	25.75	30.39	40.66
Glória de Dourados	41.49	52.42	48.29	86.40	95.89	190.88	87.95	164.64	50.97	32.75	29.26	21.21
Naviraí	36.75	41.92	45.00	115.26	116.39	98.07	78.02	137.14	53.61	48.51	46.23	24.62
Paranaíba	20.39	42.70	60.96	79.31	47.60	91.22	44.78	81.63	72.67	30.54	21.96	19.20
Porto Murtinho	37.75	29.56	54.78	130.54	146.63	122.67	63.59	135.27	111.34	73.28	30.76	54.48
Ribas do Rio Pardo	32.48	22.61	30.40	106.21	80.68	102.89	82.64	146.38	53.67	29.48	34.24	36.20
Rio Negro	34.52	27.75	50.06	94.75	88.49	163.57	67.14	93.58	58.78	18.91	33.64	27.78
Santa Rita do Pardo	40.34	30.18	29.94	32.87	80.98	116.86	71.60	144.07	77.97	29.00	35.25	34.80
Selvíria	29.50	43.34	50.70	80.85	56.98	112.91	56.02	132.21	80.15	30.09	34.80	45.69
Três Lagoas	56.01	55.29	38.58	68.57	112.65	63.21	56.38	162.29	77.02	41.99	29.64	130.31

Table 4. Estimate parameters for the function of normal probability distribution of time series for monthly rainfall (mm) in 14 sites of the State of Mato Grosso do Sul. Brazil.

Site	Month											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	μ of the normal distribution											
Água Clara	272.56	229.65	185.80	76.61	70.35	24.50	22.22	30.44	68.50	123.51	177.76	239.38
Bataguassu	203.44	171.05	131.16	89.81	85.94	52.64	36.47	32.43	84.26	106.24	135.01	185.97
Camapuã	258.47	193.19	188.77	84.27	84.88	32.19	21.95	26.51	82.51	128.65	165.06	215.85
Campo Grande	208.12	181.25	147.44	86.82	91.16	43.12	33.48	40.43	84.31	134.47	158.06	208.87
Coxim	243.55	207.79	148.22	76.70	55.41	25.76	16.23	17.38	55.80	122.03	170.96	216.17
Glória de Dourados	180.80	165.68	156.48	116.71	108.99	87.31	49.17	60.37	123.66	154.83	154.10	158.10
Naviraí	151.31	155.01	127.01	113.72	118.99	83.19	45.96	56.31	114.09	175.00	162.62	166.70
Paranaíba	280.88	201.26	208.26	90.05	51.96	23.76	13.72	17.08	52.37	112.78	138.31	237.72
Porto Murtinho	191.93	159.96	138.87	144.34	92.86	44.70	32.89	33.47	74.12	129.23	161.90	186.91
Ribas do Rio Pardo	228.24	171.11	155.28	95.20	83.48	37.83	30.01	31.11	81.90	140.75	155.43	197.18
Rio Negro	207.81	169.08	130.25	81.36	81.63	45.06	18.65	23.14	74.10	128.13	137.58	228.40
Santa Rita do Pardo	216.73	162.54	141.92	86.17	85.84	52.91	36.45	33.59	85.72	124.11	140.80	180.47
Selvíria	237.54	198.33	161.60	77.87	54.31	29.98	14.19	22.92	63.69	96.15	124.33	175.75
Três Lagoas	225.35	164.08	152.76	96.40	75.45	35.88	29.02	31.00	80.39	127.77	151.93	189.18
	σ of the normal distribution											
Água Clara	101.12	86.46	99.02	49.66	45.40	28.59	30.68	44.92	46.88	59.16	67.38	119.72

Bataguassu	106.41	95.08	79.07	64.40	73.96	63.54	40.13	44.79	68.15	59.07	72.02	67.06
Camapuã	86.88	68.76	88.63	50.65	48.60	34.41	28.94	40.14	47.11	42.91	60.39	84.91
Campo Grande	97.43	81.52	59.78	49.73	59.22	40.31	32.54	41.36	54.80	70.55	73.32	80.40
Coxim	85.00	78.37	58.43	44.30	48.59	36.17	17.99	24.83	36.48	56.57	71.52	87.84
Glória de Dourados	90.12	81.37	84.08	67.57	76.04	77.66	45.75	70.28	68.20	67.38	62.86	60.56
Naviraí	72.17	78.83	76.35	72.39	100.24	75.50	40.90	54.84	73.48	87.45	83.66	71.47
Paranaíba	80.77	90.24	96.59	49.94	34.42	26.10	16.79	20.28	49.20	49.59	56.81	60.80
Porto Murtinho	84.31	69.90	75.82	79.87	80.13	45.56	30.87	47.89	63.11	81.76	61.51	94.56
Ribas do Rio Pardo	87.37	60.44	73.16	54.53	55.59	48.59	31.86	36.91	66.75	60.36	70.81	77.39
Rio Negro	82.24	71.63	75.40	52.06	71.85	50.13	19.75	28.89	59.02	47.12	53.16	77.10
Santa Rita do Pardo	89.06	62.55	64.92	48.66	59.16	57.24	37.18	46.26	62.37	58.59	58.11	85.78
Selvíria	79.88	80.55	86.83	53.44	41.17	49.75	16.44	30.16	50.57	49.01	57.98	75.73
Três Lagoas	115.06	81.20	72.05	74.36	60.26	33.92	31.07	42.26	58.56	63.86	64.11	81.70

Estimates of probability of the monthly rainfall are less than 50 mm, between 50 mm and 100 mm and greater than 100 mm are contained in Table 5. The estimated rainfall with certain level of probability is of great importance for agricultural planning, particularly in relation to irrigation management in a particular region and water suplly. Ribeiro et al. (2007), Danfá et al. (2010) and Soccol et al. (2010) emphasizes that the use of occurrence probability values for monthly rainfall in irrigation projects decreases the system costs and can reduce awarded flows, facilitating the approval of these projects at environmental agencies.

Table 5. Probability (P) of the montlhy rainfall (PREC) be less than 50 mm, between 50 mm and 100 mm and greater than 100 mm, in 14 sites of the State of Mato Grosso do Sul.

Site	Month											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	P (RAINFALL < 50 mm)											
Água Clara	0.014	0.001	0.043	0.296	0.327	0.814	0.863	0.827	0.347	0.107	0.029	0.057
Bataguassu	0.075	0.101	0.121	0.268	0.441	0.613	0.746	0.653	0.448	0.168	0.119	0.003
Camapuã	0.008	0.002	0.059	0.249	0.236	0.698	0.865	0.838	0.318	0.033	0.005	0.002
Campo Grande	0.052	0.054	0.052	0.230	0.244	0.568	0.775	0.710	0.266	0.116	0.070	0.024
Coxim	0.011	0.022	0.017	0.343	0.594	0.841	0.970	0.906	0.437	0.063	0.012	0.029
Glória de Dourados	0.021	0.078	0.063	0.162	0.343	0.436	0.638	0.563	0.140	0.028	0.049	0.006
Naviraí	0.080	0.050	0.126	0.189	0.339	0.452	0.663	0.589	0.207	0.037	0.089	0.007
Paranaíba	0.000	0.011	0.051	0.211	0.477	0.843	0.927	0.948	0.615	0.103	0.021	0.001
Porto Murtinho	0.010	0.058	0.121	0.119	0.416	0.673	0.781	0.805	0.351	0.166	0.034	0.074
Ribas do Rio Pardo	0.001	0.023	0.023	0.204	0.273	0.764	0.811	0.696	0.389	0.066	0.031	0.029
Rio Negro	0.004	0.009	0.133	0.273	0.458	0.539	0.944	0.824	0.458	0.024	0.050	0.010
Santa Rita do Pardo	0.005	0.036	0.038	0.229	0.272	0.611	0.746	0.807	0.426	0.072	0.059	0.012
Selvíria	0.009	0.033	0.060	0.301	0.458	0.818	0.985	0.815	0.393	0.173	0.100	0.048
Três Lagoas	0.013	0.067	0.045	0.342	0.336	0.752	0.821	0.673	0.302	0.112	0.025	0.044
	P (50 mm ≤ RAINFALL < 100 mm)											
Água Clara	0.030	0.036	0.168	0.385	0.416	0.182	0.080	0.081	0.403	0.239	0.095	0.065
Bataguassu	0.091	0.126	0.290	0.295	0.247	0.237	0.189	0.282	0.247	0.368	0.195	0.078
Camapuã	0.026	0.062	0.100	0.373	0.386	0.278	0.078	0.088	0.380	0.219	0.127	0.049
Campo Grande	0.081	0.106	0.162	0.375	0.316	0.353	0.174	0.206	0.347	0.197	0.144	0.064
Coxim	0.034	0.062	0.203	0.397	0.241	0.089	0.030	0.094	0.450	0.333	0.142	0.064
Glória de Dourados	0.148	0.132	0.225	0.241	0.247	0.246	0.231	0.246	0.224	0.205	0.146	0.144
Naviraí	0.158	0.222	0.301	0.235	0.228	0.248	0.223	0.242	0.310	0.178	0.138	0.131
Paranaíba	0.001	0.104	0.081	0.368	0.441	0.156	0.056	0.052	0.237	0.296	0.242	0.011
Porto Murtinho	0.111	0.138	0.184	0.171	0.243	0.220	0.171	0.095	0.308	0.194	0.123	0.105
Ribas do Rio Pardo	0.036	0.097	0.197	0.331	0.343	0.124	0.153	0.273	0.311	0.183	0.207	0.076
Rio Negro	0.069	0.137	0.289	0.366	0.248	0.324	0.056	0.172	0.284	0.289	0.190	0.038
Santa Rita do Pardo	0.070	0.123	0.249	0.383	0.322	0.238	0.189	0.091	0.260	0.323	0.182	0.130
Selvíria	0.033	0.078	0.214	0.360	0.408	0.095	0.015	0.179	0.370	0.358	0.237	0.110

Três Lagoas	0.091	0.212	0.225	0.286	0.322	0.187	0.147	0.275	0.329	0.220	0.207	0.093
P (RAINFALL ≥ 100 mm)												
Água Clara	0.956	0.963	0.788	0.319	0.257	0.004	0.057	0.091	0.251	0.654	0.876	0.878
Bataguassu	0.834	0.773	0.590	0.437	0.312	0.150	0.064	0.066	0.305	0.464	0.687	0.919
Camapuã	0.966	0.936	0.842	0.378	0.378	0.024	0.057	0.074	0.302	0.748	0.867	0.950
Campo Grande	0.866	0.841	0.786	0.395	0.441	0.079	0.050	0.084	0.387	0.687	0.786	0.912
Coxim	0.954	0.915	0.780	0.260	0.165	0.070	0.000	0.000	0.113	0.604	0.846	0.907
Glória de Dourados	0.831	0.790	0.711	0.598	0.410	0.318	0.131	0.191	0.636	0.766	0.805	0.850
Naviraí	0.761	0.728	0.573	0.575	0.434	0.301	0.113	0.169	0.482	0.785	0.773	0.863
Paranaíba	0.999	0.885	0.869	0.421	0.081	0.002	0.017	0.000	0.148	0.602	0.738	0.988
Porto Murtinho	0.879	0.804	0.696	0.711	0.341	0.107	0.048	0.101	0.341	0.640	0.843	0.821
Ribas do Rio Pardo	0.963	0.880	0.780	0.465	0.383	0.112	0.036	0.031	0.300	0.750	0.762	0.895
Rio Negro	0.927	0.854	0.578	0.360	0.294	0.137	0.000	0.004	0.259	0.687	0.760	0.952
Santa Rita do Pardo	0.925	0.841	0.713	0.388	0.405	0.151	0.064	0.101	0.314	0.605	0.759	0.858
Selvíria	0.957	0.889	0.725	0.339	0.134	0.087	0.000	0.005	0.236	0.469	0.663	0.841
Três Lagoas	0.896	0.721	0.730	0.372	0.342	0.062	0.032	0.051	0.369	0.668	0.768	0.862

In each month and site, the probabilities were calculated from the best fit distribution parameters.

In general, it appears that the probability of monthly rainfall be greater than 100 mm is higher than in regions with high altitudes compared with those of the lower areas. Baú et al. (2006), Ávila et al. (2009) and Uliana et al. (2013) obtained similar results on researches about the probable rainfall in the States of Paraná, Minas Gerais and Espírito Santo, respectively. This behavior shows that despite the tropical features present in the State of Mato Grosso do Sul, the altitude is among the physiographic factors that more influence in the monthly rainfall (TEODORO et al., 2015 a,b; TEODORO et al., 2016).

CONCLUSION

The normal probability distribution fits better to the series of monthly rainfall in the state of Mato Grosso do Sul and can be used for estimating the monthly rainfall, especially during the months of the rainy season (October to March). The exponential probability distribution can be used for estimating the monthly rainfall in the driest months of the year (May to September). Thus, we recommend that these distributions be used in future research, aimed to estimate the probable rainfall for the Mato Grosso do Sul State.

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RESUMO: A identificação da função de distribuição de probabilidade para representação da chuva mensal é relevante no planejamento agrícola, sobretudo no que diz respeito à instalação de culturas. O objetivo deste trabalho foi verificar qual a distribuição de probabilidade (exponencial, gama ou normal) se ajusta melhor aos dados de precipitação pluvial mensal de 14 locais do Estado do Mato Grosso do Sul. Os dados pluviométricos de 14 estações (locais) do Estado do Mato Grosso do Sul foram obtidos do Banco de Dados da Agência Nacional de Águas (ANA), coletados do período de 1975 a 2013. Em cada uma das 168 séries temporais de chuva mensal aplicou-se o teste de Kolmogorov-Smirnov para avaliar o ajuste às distribuições de probabilidade exponencial, gama e normal. A distribuição de probabilidade normal apresentou melhor ajuste as séries de chuva mensal do Estado de Mato Grosso do Sul, podendo ser utilizada para estimativa da precipitação pluvial mensal, principalmente, nos meses de período chuvoso (outubro a março). A distribuição de probabilidade exponencial pode ser utilizada para estimativa da chuva mensal nos meses mais secos do ano (maio a setembro). Desta forma, recomendamos que estas distribuições sejam utilizadas em futuras pesquisas, que visem estimar a precipitação provável para o Estado de Mato Grosso do Sul.

PALAVRAS-CHAVE: Ajuste de séries temporais. Distribuição exponencial. Distribuição gama. Distribuição normal.

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