Original Article

PROBABLE MONTHLY RAINFALL ASSOCIATED WITH DISTINCT BIOMES OF MATO GROSSO DO SUL STATE

PRECIPITAÇÃO MENSAL PROVÁVEL ASSOCIADA AOS DIFERENTES BIOMAS DO ESTADO DE MATO GROSSO DO SUL

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ABSTRACT: The aim of this study was to determine the probable monthly rainfall for the state of Mato Grosso do Sul, considering the level of 75% probability, and study the spatial distribution associated with its different biomes. The rainfall data of 32 stations (sites) in the state of Mato Grosso do Sul were collected in the period 1954-2013. In each of the 384 series, the average monthly rainfall was calculated, for at least 30 years of observation. The Kolmogorov-Smirnov adhesion test was applied to the rainfall time series to check the fit of the data to a normal distribution. The likely fallout was estimated at 75% probability, using the normal probability distribution and, subsequently, it was adopted the method of Ordinary Kriging interpolation mathematics to spatial data. Based on the likely monthly precipitation estimated, the State of Mato Grosso do Sul possess three distinct periods, with the precipitation associated with different biomes: the rainy season (between the months November to March, where increased precipitation occurred in the Savanna biome), dry season (between the months from June to August, when the highest rainfall occurred in the Atlantic Forest) and transition period (April and May and September and October).

KEYWORDS: Atlantic Forest. Pantanal. Savanna. Normal distribution.

INTRODUCTION

Mato Grosso do Sul State (MS) covers an area of approximately 350,000 km^2, of which 13,000 km^2 are exploited by agriculture, especially soybean, corn, cotton, sugarcane sugar and irrigated rice (CONAB, 2014), which are distributed differently in three biomes of peculiar climatic attributes: Pantanal, Savanna and the Atlantic Forest (TEODORO et al., 2016a,b). Among the main factors that influence crop production, the rainfall and its variation are the most relevant for planning agricultural activities, allowing for better approaches and more reliable decisions (ARAI et al. 2010).

Correa et al. (2014) emphasize that it is possible to plan the best time of tillage, harvest, sowing and fertilizer and defensive application from probable monthly rainfall estimates. Besides the influence in agriculture, very long dry seasons affect the level of water sources and reservoirs of hydroelectric power plants, causing problems to the urban water supply and the electricity generation (RODRIGUES et al. 2013). According to Togashi et al. (2012), Moura et al. (2009) and Arcova et al. (2003) research on this subject is critical for the management of areas subject to flooding, as well for preventing potential problems caused by climate change.

According to Bernardo et al. (2006), probable rainfall can be defined as the minimum amount of precipitation within a given probability of occurrence. Usually, the probability of 75% is used in irrigation, ie, is the minimum monthly rainfall that should occur in 75% of the folloing years. These statiscal analyses of rainfall are important for planning of agricultural activities, but also of other activities such as construction, tourism and transport (ULIANA et al. 2013).

Researches investigating the climate in the State of Mato Grosso do Sul are still scarce. There is a variety of meteorological phenomena in this region, from micro-scale to large-scale, which require a better understanding, as for example, soil–vegetation–atmosphere interaction processes during dry spells and flood in the Pantanal, which have local and wider climatic effects, especially on rainfall patterns (MESQUITA et al. 2013). Given the above, the aim of this study was to determine the probable monthly rainfall for Mato Grosso do Sul State, considering the level of 75% probability, and studying the spatial distribution associated with the different biomes of the region.

MATERIAL AND METHODS

Characterization of the study area

Mato Grosso do Sul State lays in the center of the South American continent and has several

edaphoclimatic features distributed among three biomes: Savanna, Atlantic Forest and Pantanal. Altitudes vary from 24 to 1,000 m (TEODORO et al., 2015).

Savanna (or Cerrado) is the second largest biome in South America (SA) and covers 22% of the Brazilian territory. It is this biome that is the source of three major watersheds of South America (Amazônica/Tocantins, São Francisco and Prata), which results in high aquifer potential and great biodiversity. Due to its latitudinal position, the region is characterized by the transition between the warm low latitude climates and mesothermal type climates of mid-latitudes (NIMER, 1989).

Atlantic Forest is an environmental complex that includes mountain ranges, valleys and plateaus. It was already one of the richest and most varied rainforests of South America, but is currently recognized as the most disturbed and threatened Brazilian biome (Teodoro et al., 2015).

Pantanal covers 25% of Mato Grosso do Sul State and it is a biome almost exclusive to Brazil. It is characterized by long-term flooding (due to low permeability soil) that occur each year on the plain, and cause changes in the environment, wildlife and local populations daily life. Pantanal climate is Tropical of Savanna (AW), with rainfall totals ranging between 1,000 and 2,000 mm, and two distinct seasons: a dry (May to September) and a rainy (October to April), this latter accounting for more than 80% of the total annual rainfall (MESQUITA et al. 2013).

Historical Series of Monthly Rainfall

Rainfall data of 32 stations (sites) of Mato Grosso do Sul (MS) were obtained of the Agência Nacional de Águas (ANA 2014), collected from 1954 to 2013 (Table 1). At each site and year, the rainfall daily data were added up to obtain the monthly rainfall (mm monthly^{-1}), of each month of the year. Thus, they formed 384 time series (12 months × 32 sites), with different numbers of observations years in each series, defined according to the availability of meteorological data.

Table 1. Altitude (m), latitude and longitude (°), and observation period of monthly rainfall of 32 municipalities in Mato Grosso do Sul State, Brazil.

Site	Altitude (m)	Latitude (S, °)	Longitude (W, °)	Period (years)
Água Clara	376	20º6'7''	52º55'33''	1975-2013
Amambai	395	22º55'59''	55º13'0''	1973-2013
Anastácio	106	19º34'0''	56º12'0''	1960-2000
Anaurilândia	284	22º11'11''	52º42'48''	1975-2013
Aparecida do Taboado	375	20º1'6''	51º6'13''	1983-2013
Aquidauana	155	20º27'24''	55º40'17''	1960-2000
Bataguassu	293	21º43'33''	52º20'3''	1975-2013
Bodoquena	133	19º52'15''	56º59'1''	1954-2013
Caarapó	454	22º37'28''	54º49'29''	1973-2013
Camapuã	404	19º29'48''	53º59'48''	1973-2013
Campo Grande	559	20º28'0''	54º40'0''	1975-2013
Chapadão do Sul	570	18º59'52''	52º35'17''	1983-2013
Corumbá	101	17º37'24''	56º57'54''	1983-2013
Costa Rica	635	18º32'50''	53º8'7''	1983-2013
Coxim	250	18º38'57''	54º21'26''	1973-2013
Dourados	293	22º23'53''	54º47'30''	1973-2013
Glória de Dourados	422	22º24'21''	54º14'7''	1973-2013
Iguatemi	333	23º40'55''	54º33'42''	1975-2013
Inocência	502	19º44'11''	51º56'1''	1983-2013
Maracaju	356	21º37'7''	55º8'13''	1973-2013
Miranda	140	20º6'7''	56º47'43''	1960-2000
Navirai	366	23º3'28''	54º11'38''	1975-2013
Nova Andradina	271	21º36'55''	53º3'8''	1975-2013
Paranaíba	458	19º23'27''	51º36'32''	1983-2013
Ponta Porã	650	22º32'0''	55º43'0''	1973-2013
Porto Murtinho	83	21º42'5''	57º53'30''	1983-2013
Ribas do Rio Pardo	373	20º26'41''	53º45'29''	1975-2013
Rio Brilhante	287	21º38'50''	54º25'31''	1973-2013
Rio Negro	233	19º26'23''	54º59'0''	1975-2013
Santa Rita do Pardo	393	21º17'43''	52º48'38''	1975-2013
Selviria	348	20º21'49''	51º25'26''	1983-2013
Três Lagoas	313	20º47'41''	51º42'46''	1975-2013

The processing and the organization of rainfall data of 32 sites in the State were performed. The historical series with failures were eliminated and filled by the climatologically normal from each of the 11 regions of Mato Grosso do Sul State according to the performed by Teodoro et al. (2015).

Estimate of the Probable Rainfall

In each of the 384 time series of monthly rainfall was calculated the average (m), at least 30 years of observation. The Kolmogorov-Smirnov adhesion test (ASSIS et al., 1996) was applied on 384 monthly rainfall time series to verify their fit to normal distribution.

Probable rainfall was estimated at 75% probability, using the normal probability distribution according Torres et al. (2016), also named Gaussian curve, which shows two parameters and its probability density function is defined by the equation (HASTINGS; PEACOCK, 1975):

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

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

Statistical analyzes were performed with the software Genes (CRUZ, 2013) and Microsoft Office Excel®.

Geographical Distribution of the Probable Rainfall

In this study was adopted the ordinary kriging mathematical interpolation method (OK) which allows to calculate local averages, limiting the average stationary domain to local neighborhood centered on the point to be estimated. Values of z dimension are estimated at spatial locations (x_j, y_j) unobserved, without the need to know the stationary average, from a linear combination of the values of a local sampling subset. The condition set out in this study was the sum of the weights of OK $\lambda_i (x_j, y_j)$ to be equal to 1 (Equation 2).

$$Z(x_j, y_j) = \sum_{i=1}^{n(j)} \lambda_i (x_j, y_j) \times Z(x_i, y_i),$$

where:

$Z(x_j, y_j)$ is the value estimated by kriging in the point (x_j, y_j); $Z(x_i, y_i)$ is the value of the sample in the point (x_i, y_i); $\lambda_i (x_j, y_j)$ is the weight of the OK to the specified location.

It was utilized the circular theoretical mathematical model, as recommended by Correa et al. (2014). The spatial distribution of the probable monthly rainfall data was analyzed with the assistance of geostatistical software ArcGis 10.1®.

RESULTS AND DISCUSSION

Kolmogorov-Smirnov test revealed that the data of 359 monthly rainfall time series (93.49%) fit to normal distribution (P>0.01) (Table 2). Given these high percentages with fit to normal distribution, it can be concluded that the use of normal distribution has credibility for estimating the monthly rainfall in the Mato Grosso do Sul State, agreeing with the results obtained by Torres et al. (2016).

Table 2. Normality tests (*Kolmogorov-Smirnov,* KS) regarding to 384 monthly rainfall time series in sites of Mato Grosso do Sul State.

City	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Água Clara	S	S	S	S	S	S	N	N	S	S	S	S
Amambai	S	S	S	S	S	S	S	S	S	S	S	S
Anastácio	S	S	S	S	S	S	S	S	S	S	S	S
Anaurilândia	S	S	S	S	S	S	S	S	S	S	S	S
Aparecida do Taboado	S	S	S	S	S	N	S	S	S	S	S	S
Aquidauana	S	S	S	S	S	S	S	S	S	S	S	S
Bataguassu	S	S	S	S	S	S	S	S	S	S	S	S
Bodoquena	S	S	N	S	S	N	S	N	S	S	S	S
Caarapó	S	S	S	S	S	S	S	S	S	S	S	S
Camapuã	S	S	S	S	S	S	S	N	S	S	S	S
Campo Grande	S	S	S	S	S	S	S	S	S	S	S	S
Chapadão do Sul	S	S	S	S	S	S	S	S	S	S	S	S
Corumbá	S	S	S	S	S	S	S	S	S	S	S	S
Costa Rica	S	S	S	S	S	S	S	S	S	S	S	S
Coxim	S	S	S	S	S	S	S	S	S	S	S	S
Dourados	S	S	S	S	S	S	S	N	N	S	S	S
Glória de Dourados	S	S	S	S	S	S	S	S	S	S	S	S
Iguatemi	S	S	S	S	S	S	S	S	S	S	S	S
Inocência	S	S	S	S	S	S	S	S	S	S	S	S

Maracaju	S	S	S	S	S	S	S	S	S	S	S	S
Miranda	N	N	N	N	N	N	N	N	N	N	N	N
Navirai	S	S	S	S	S	S	S	S	S	S	S	S
Nova Andradina	S	S	S	S	S	S	S	S	S	S	S	S
Paranaíba	S	S	S	S	S	S	S	S	S	S	S	S
Ponta Porã	S	N	S	S	N	S	S	S	S	S	N	S
Porto Murtinho	S	S	S	S	S	S	S	S	S	S	S	S
Ribas do Rio Pardo	S	S	S	S	S	S	S	S	S	S	S	S
Rio Brilhante	S	S	S	S	S	S	S	S	S	S	S	S
Rio Negro	S	S	S	S	S	S	S	S	S	S	S	S
Santa Rita do Pardo	S	S	S	S	S	S	S	S	S	S	S	S
Selviria	S	S	S	S	S	N	S	S	S	S	S	S
Três Lagoas	S	S	S	S	S	S	S	S	S	S	S	S

S = Normal distribution, by Kolmogorov-Smirnov test (P>0.01). N = non-normal (P≤0.01).

The greatest probable precipitation values at 75% probability by normal distribution occurred between the months of November to April, which allows us to classify these months as the rainiest months of the year in Mato Grosso do Sul (Figure 1).
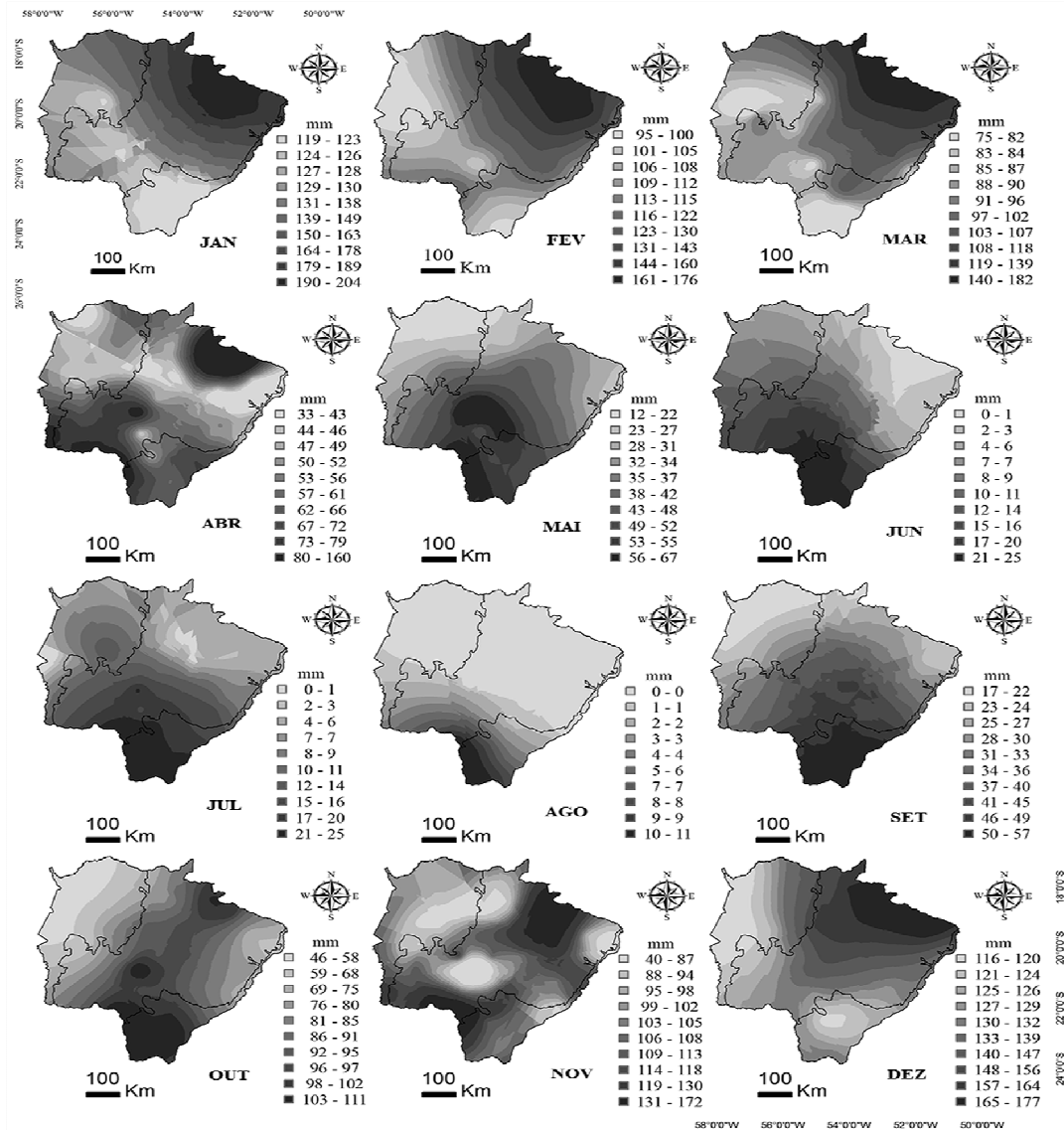
Figure 1. Probable rainfall for Mato Grosso do Sul State from January to December, estimated by normal distribution at 75% probability of occurrence.

The lowest probable precipitation values at 75% probability by normal distribution occurred between the months of June, July and August, demonstrating that this is the driest period of the year in the Mato Grosso do Sul State. In addition to this, April, May, September and October showed intermediary probable monthly rainfall, being characterized as transitional periods between the rainy and the dry season of the year.

Moreover, we verified that the municipalities located in the Savanna biome had the highest values. This region is under the influence of the South Atlantic Subtropical Anticyclone and the Polar migratory, Chaco's Low and Bolivia's High, which operate in the summer and spring and influence the weather conditions in the Midwest region. Another weather system that determines the rainfall pattern in the whole region is the South Atlantic Convergence Zone, favored by Low Level Jet, its draining comes from the channeling of the trade winds that enter the South American continent, carrying water vapor from the Equatorial Atlantic and the Amazon basin towards the southwest Atlantic (CARVALHO et al. 2004; KELLER FILHO et al., 2005).

The municipalities located in the Atlantic Forest had higher probable rainfall at 75% probability by the normal distribution during the months of May to October. The Upper Level Low, acts from a subtropical origin, that causes rain and strong winds in this region (CASTRO et al., 1994) and finally the passage of Frontal Systems. The complex action of these weather systems explains the highest average monthly rainfall in dry seasons (KELLER FILHO et al., 2005).

The municipalities located in Pantanal showed intermediate probable rainfall during most of the year, except for the months of August,

September and October, which showed lower estimates at 75% probability of occurrence. In this biome, the main weather systems responsible for rainfall are the passages of Frontal Systems and heated branches, which hold 67% of the rainfall origins, followed by the South Atlantic Convergence Zone and Upper Level Low from the subtropical origin (KELLER FILHO et al., 2005).

The topographic aligning, arranged in the longitudinal direction (NE-SW) shows morphological features clearly defined: the plain and the plateau. This behavior shows that despite the tropical features present in Mato Grosso do Sul, the altitude is among the physiographic factors, followed by the latitude, the most factor influential in the monthly rainfall during dry, transitional, and rainy seasons, regardless of the period of the year, resembling the results obtained in studies performed in other Brazilian States (BAÚ et al., 2006; ÁVILA et al., 2009; ULIANA et al., 2013).

CONCLUSIONS

The State of Mato Grosso do Sul possess three distinct rainfall periods, associated with different biomes: the rainy season (between the months November to March, where increased precipitation occur in the Savanna biome), dry season (between the months from June to August, when the highest rainfall occurring in the Atlantic Forest) and transition period (April and May and September and October).

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RESUMO: O objetivo estudo foi determinar a precipitação mensal provável para o Estado de Mato Grosso do Sul, considerando o nível de 75% probabilidade e estudar sua distribuição espacial associada aos seus diferentes biomas. Os dados de precipitação pluvial de 32 estações (locais) do Estado do Mato Grosso do Sul foram coletados do período de 1954 a 2013. Em cada uma das 384 séries temporais de precipitação pluvial mensal calculou-se a média, com no mínimo 30 anos de observação. Foi aplicado o teste de aderência de Kolmogorov-Smirnov nas 364 séries temporais de precipitação pluvial mensal para verificar o ajuste dos dados a distribuição normal. A precipitação provável foi estimada a 75% de probabilidade, utilizando-se a distribuição de probabilidade normal e, posteriormente, foi adotado o método de interpolação matemática da Krigagem Ordinária para espacialização dos dados. Com base na precipitação mensal provável, estimada pela distribuição normal a 75% de probabilidade, o Estado do Mato Grosso do Sul possuí três períodos distintos, estando à precipitação associada aos diferentes biomas: período chuvoso (entre os meses de novembro a março, onde as maiores precipitações ocorrem no bioma Cerrado), período seco (entre os meses de junho a agosto, onde as maiores precipitações ocorrem no bioma Mata Atlântica) e período de transição (meses de abril e maio e setembro e outubro).

PALAVRAS-CHAVE: Série temporal Erro de estimação. Tamanho de amostra. Amostragem.

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