Diagnosis and Trend of Precipitation in the Rain Basin River Uruçuí Preto - Piauí, Brazil

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Abstract

The goal of this study was to analyze the timeline distribution of a time series and the trend of rainfall to 25 counties and 24 farms that make up the catchment area of the river Uruçuí Preto- Piauí (BHRUP), which is an important center for agriculture and water resources sectors. They were performed in this study linear regression and measures of central tendency and dispersion of the monthly and annual rainfall. Based on the results it was found that the median was the measure of central tendency with the largest representation. The rainy season was marked during the months from October to April with an average value of 936.8 mm in the period, corresponding to 96% of annual precipitation. The months with the lowest rainfall ranged from May to September, corresponding to 4% of the annual total, showing up over time one characteristic timeline variability of the cerrado region and cerradão. The possibility in the future of extreme events occur with heavy rainfall in short periods of time is expected for this area, and with the knowledge of climate trends they can plan the most out of handling the water resources.

Keywords: Variability timeline, trend, linear regression.

1. Introduction

Human activities require various environmental resources to promote their survival, and water is the most common mineral resource to meet the economic and social needs of a region.

The water is a component summarily important in almost all sectors of human activity. The planning and management of water resources emerged in order to reduce conflicts over water use, caused by fast population growth and the growing expectative for best quality of life, according Matondo (2002).

The water, although considered as a renewable and inexhaustible resource, only a portion of this feature is available for consumption, and allied to this are the global changes taking place, such as unplanned growth of cities, deterioration of natural areas,

contamination by pollutants, pesticides, sewers, among others that are bringing serious problems to the sources potable and water resources.

It is known that human actions and climate change are directly impacting the frequency and intensity of rainfall, because these are factors that are contributing to the frequency of flooding events or droughts in Brazil and in the world, as described by some authors as Grimm (2011) and Min et al. (2011). Therefore, it is necessary to know how the rains are distributed spatially and temporally, mainly related issues in the management, soil and water conservation, and construction of waterworks, to define the flow of projects, investigated by some authors (Rodrigues, 2008; Cecilio, 2009; Santos et al., 2010; Aragon, 2013).

Nowadays it is noticeable the importance of research involving the study of climate in the pursuit of building new parameters of knowledge and consistent application in the various human activities that depend on data and increasingly concise information on rainfall, droughts, storms and events extreme, in short medium and long term generates the information with a high degree of accuracy, according to Viana (2010). Thus, studies of intense peak precipitations are carried out to have a rain exploration behavior throughout the years, and can avoid future accidents related to extreme events.

Precipitation is one of the most important variables, as a fundamental variable to climate characterization, and features a large variability in time and space. The study of extreme events of maximum annual daily rainfall is related to severe damage human activities in almost all regions of the world due to its potential to cause water saturation of the soil, runoff and erosion, as demonstrated (IPCC, 2007; Tammets and Jaagus, 2013).

The monitoring of rainfall is of fundamental importance for the management and maintenance of water resources, it provides data that contribute in public planning and studies that seek the sustainable use of water.

On projects in the area of water resources, it is necessary to know the number of flow records. This must be representative of the events in the watershed, and therefore consists of a database of a long number of years. From these data, the engineer search to know the "full project", which is the biggest flood for which water works that will be projected. In contrast to this need, major problem for this type of study is the data being scarce or even not exist. This lack is due to the high cost of obtaining data, maintenance of the equipment used or preservation of data already collected.

In studies conducted by several authors as D'Almeida et al. (2006), Costa (2007), Sampaio (2007) and Coe et al. (2009), they investigated and show that the rainfall data are essential for studies and concluded that deforestation of the Amazon forest is directly influencing the environmental imbalance, especially in the hydrological cycle, where in simulations showed a significant decrease in evapotranspiration and precipitation.

Several authors evaluated the trend in precipitation observed in the Northeast Brazil region (NEB) during the twentieth century. For example, Haylock et al. (2006) conducted an analysis of rainfall over South America, and observed an increasing trend of annual rain all over NEB. The study by Santos and Brito (2007) used indices of climate extremes and the correlation SST anomalies, and also showed a trend of increasing annual rainfall in the states of Paraíba and Rio Grande do Norte.

The study to analyze trends in historical series of rainfall is important to check the interannual climate variability and decadal so those are identified as climate change can modulate these temporal patterns of variability.

Medeiros (2012) investigated and analyzed the climatology of precipitation in the municipality of Cabaceiras - PB in the period 1930-2011 as a contribution to agribusiness, and found that the gauges indices are essential to agribusiness sustainability.

Silva et al. (2013) investigated and identified that the state of Piauí have climate differentiated conditions, with fluctuation in indices rainfall whose origin is quite individualized, presenting also temperatures average annual relative variables. The objective of this study was to analyze the municipal rainfall variability between different regimes for the State of Piauí (North, Central and South), and check that they have common areas of rainfall occurrences with their respective provocateurs systems and inhibitors rainfall has a high spatial and temporal variability, showing two rainy regimes: the southern state rains november to March; in the center and north the rainy season begins in December and lasted until May. The rainfall varies between 700 mm and 1.300 mm in the south, between 500 mm and 1.450 mm in the central region and between 800 mm and 1.680 mm in the northern in the state. In the Northern region the rainfall have a more even distribution than in Central and South areas, showing the physiographic features, relief, fauna, flora and from the sea. Because of the wide variation in rainfall over the years, one can observe that phenomena of macro, meso and micro scales are of great importance to the rainfall regimes the state of Piauí, which follow chronological time of its activities and duration.

The distribution of rainfall is very irregular in time and space, and the rainy seasons occur differently in amount, duration and distribution. The objective of this study was to present a historical timeline distribution and future rainfall trends for the basin area hydrographic river Uruçuí Preto - PI, using a historical series of 30 years of data, between the period 1960-1990, to 25 municipalities and 24 farms that make up that area. We used the Mann-Kendall test in order to detect trends in rainfall hydro series of river basin Uruçuí Preto, and generate information that can assist the sectors related to water resources.

2. Materials and methods

2.1 Study area

The region is drained by the river Uruçuí Preto and the tributaries, Ribeirão dos Paulos Castros, Colheres and Morro da Água, and the rivers of Estiva and Corrente, both perennial. The

river basin Uruçuí Preto is mainly inside the sedimentary basin of Parnaiba River, establishing itself as one of the main tributaries on the right bank. It has a total area of approximately 15,777 km², representing 5% of Piauí territory and covers part of the Southwest region, projecting from south to north spear-shaped, based (COMDEPI, 2002).

The total basin area is located between the geographic coordinates that determine the rectangle of 07°18'16" to 09°33'06" south latitude and 44°15'30" to 45°31'11" west longitude of Greenwich (Figure 1).

For the analysis of intermunicipal climatic behavior of the river basin Uruçui Preto, rainfall data were used acquired through Superintendência do Desenvolvimento do Nordeste (SUDENE, 1990) and Empresa de Assistência Técnica e Extensão Rural do Estado do Piauí, based on EMATERPI (2013), for the period 1960-1990, comprising 49 rainfall stations located in the study area.
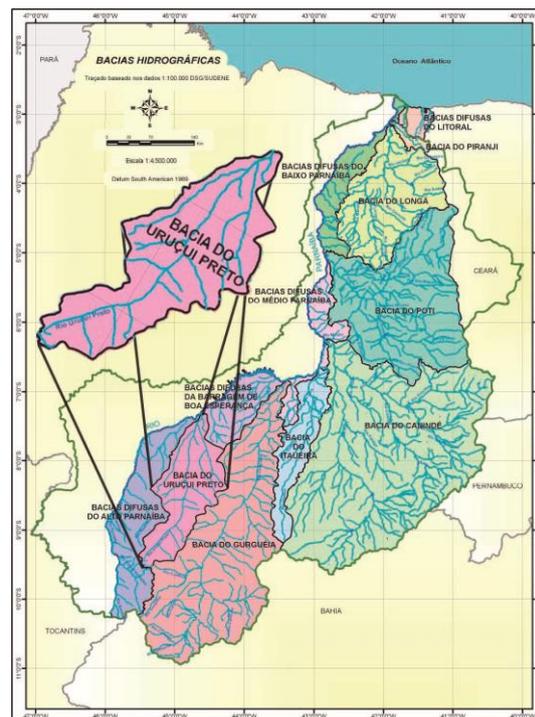

Figure 1 - Location of River Basin Uruçuí Preto – PI (Source Adapted: Medeiros, 2013).

The river basin Uruçuí Preto consists of 25 municipalities (Table 1) and 24 farms containing rainfall data with a series of 30 years (period 1960-1990). The annual maximum temperature is 32.1°C, annual minimum is 20.0°C and the average annual temperature of 26.1°C.

Climate classification was used based on Köppen and Geiger Systems (1928), which distinguished two climatic types in the river basin Uruçui Preto - PI, Aw, hot and humid tropical with rainfall in the summer and dry in winter; BSh, hot semi-arid with summer rains and dry winter. Medeiros

(2013) as EMBRAPA (1986) investigated and reported the three most common classes of soils identified in Uruçuí Preto River basin are yellow latosol (predominant in the bowl), neossolos and neossolos quatzarêncios and hidromorphics. The municipal rainfall has a spatial irregular and temporal distribution, which is a characteristic of the Brazilian Northeast, due to this the seasonality of precipitation concentrates most of its volume during the five months during the rainy season described by Silva (2004).

Average monthly weather data were grouped in 30 years, featuring a period of climatological normal. Computer programs were used to extract the values of the average monthly, annual, standard deviation, and coefficient of variance of precipitation, maximum and minimum absolute values of the precipitation period, for the period between 1960-1990.

Table 1 - List of rainfall stations of the municipalities and their respective geographical coordinates, and Köppen climate classification according to river basin Uruçui Preto. (Source: SUDENE / EMATERPI).

MUNICIPALITIES /COORDINATES	LAT	LONG	ALT	KÖPPEN
	(° ')	(° ')	(metros)	
Alvorada Gurguéia	08° 25'	43° 46'	281	Bsh
Alto Parnaíba - MA	09° 07'	45° 56'	220	AW
Avelino Lopes	10° 08'	43° 57'	400	Bsh
Barreira do Piauí	09° 55'	45° 28'	500	AW
Bom Jesus	09° 04'	44° 21'	220	Bsh
Colônia do Gurguéia	08° 10'	43° 48'	200	Bsh
Corrente	12° 26'	45° 09'	434	AW
Cristalândia	10° 39'	45° 11'	600	AW
Cristino Castro	08° 48'	44° 13'	240	Bsh
Curimatá	10° 02'	44° 17'	350	Bsh
Currais	09° 00'	44° 24'	320	Bsh
Elizeu Martins	08° 12'	43° 23'	210	Bsh
Gilbués	09° 49'	45° 21'	500	AW
Júlio Borges	10° 19'	44° 14'	389	AW
Manoel Emídio	07° 59'	43° 51'	200	Bsh
Monte Alegre	09° 45'	45° 17'	454	AW
Morro Cabeça no Tempo	09° 43'	43° 54'	479	Bsh
Palmeira do Piauí	08° 48'	44° 18'	268	Bsh
Parnaguá	10° 13'	44° 38'	316	AW
Redenção Gurguéia	09° 30'	44° 36'	365	Bsh
Riacho Frio	10° 07'	44° 57'	400	AW
São Gonçalo do Gurguéia	10° 01'	45° 18'	440	AW
Santa Filomena	09° 05'	46° 51'	380	AW
Santa Luz	08° 55'	44° 03'	340	Bsh
Sebastião Barros	10° 49'	44° 50'	360	AW

2.2 Linear regression and statistics

The Mann-Kendall Test (S) was utilized to analyze the linear trend of the series. This non-parametric test can be used in series with unknown discontinuous distribution, with the advantage of using the relative magnitude of the series values. However, the data needs to be random variables, independent and identically distributed, based on Gilbert (1983).

The test applied to the area of the river basin Uruçuí Preto has shown a high level of reliability and increasingly significant enough tendency or decreasing rainfall for all 49 locations analyzed in the basin of river Uruçuí Preto, as there is rainfall variability trend in the river's headwaters, this fact is positive for agriculture and water resources sectors, in the study area, which also suffer from anthropogenic effects degrading them and endangering the sustainability of local natural resources. From

climate trends one can improve the agriculture, reducing losses and minimizing expenses for irrigation.

Linear regression is a method for estimating the conditional (expected value) of a variable, given the values of some other variable x. Regression generally deals with the issue of estimating an expected conditional value. In many situations, a linear relationship can be worthwhile to summarize the association between the variables Y and X.

Using descriptive statistics, we can have essential features for frequency histogram of training for a hydrological data sample according to Naghettini (2007). For this study were calculated measures of central tendency and dispersion. Using the measures of central tendency and dispersion one can analytically verify the parameters and see if the samples are different or similar.

3. Results and discussion

The distribution of the annual average rainfall values, based on data from historical series from 1930 to 1990 for the catchment area of the river Uruçuí Preto showed a significant variation in precipitation (Figure 2).

The highest rainfall recorded in the municipalities for the series 30 years of observed data occurred on farms that are located in the municipality of Gilbués, in Corrente (1064.7 mm.year^{-1}), Farm Genipapeiro (1044.3 mm.year^{-1}), Galheiro farm with 1129.8 mm.year^{-1}, Bela Vista Farm (1075.7 mm.year^{-1}) and farm Melância with 1,150.9 mm.year^{-1}.

The lower rainfall recorded in the municipalities were in Santa Luz with 756.6 mm.year^{-1}, Redenção Gurguéia (754.4 mm.year^{-1}, Palmeira do Piauí with 680.2 mm.year^{-1}, Manoel Emidio (698.2 mm.year^{-1}) e Colonia Gurguéia with 478.7 mm.year^{-1}, they are due to variability of weather systems of large scale active in these locations. For the catchment area of study is not observed long term trend, but there is interdecenal variability, with drier decades preceded by rainier decades and vice versa.

There is a high spatial and temporal variability of rainfall in the months of January, February, March, October, November and December (Figure 3 - a, b, c, j, k, l, respectively). The low variability rainfall concentrated in July, August and September (Figure 3 - g, h, i) and moderate variability occur in the months of April, May and June (Figure 3 - d, e, f).
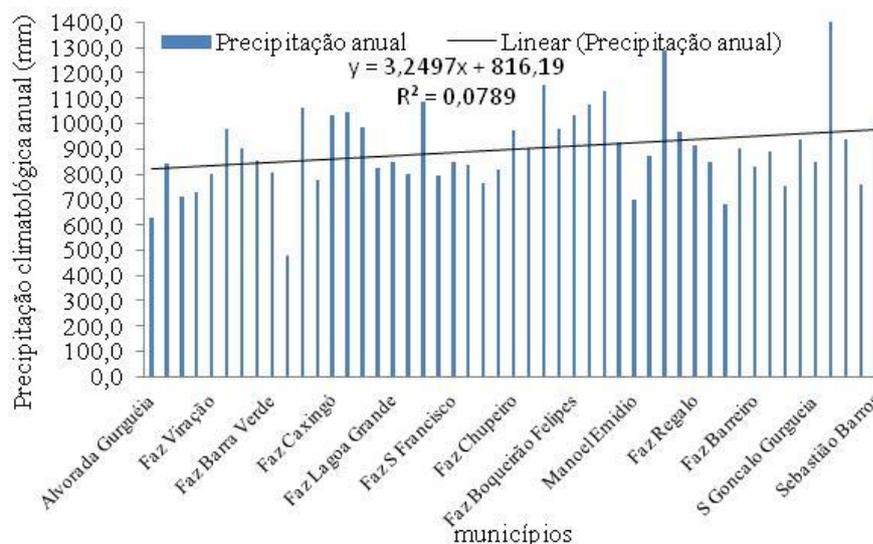

Figure 2 - Spatial temporal distribution, and linear regression analysis of rainfall in the catchment area of the river Uruçui Preto - PI.

The rainy season began in the second fortnight of October with pre-season rain, characterization occurs in the first days of

November and lasts until the month of March, with the wettest quarter the months of December, January and February, the driest quarter are the
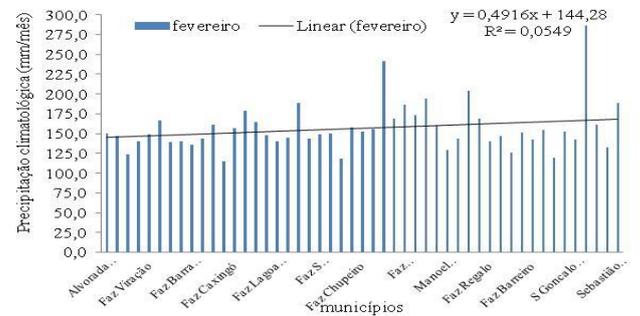
months of June, July and August, the use of spatial average rainfall totals may have understated trends.

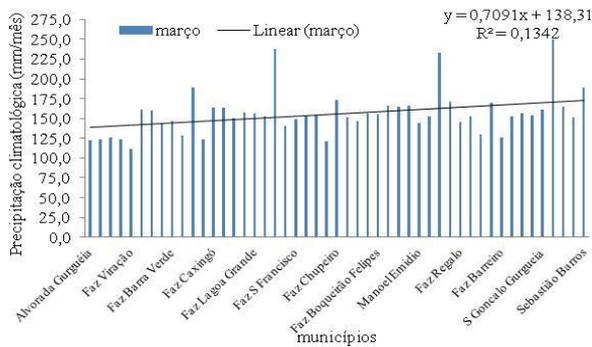In the studied precipitation series, the rainfall is very complex and diversified seasonally, with large interannual variability and intermunicipal.
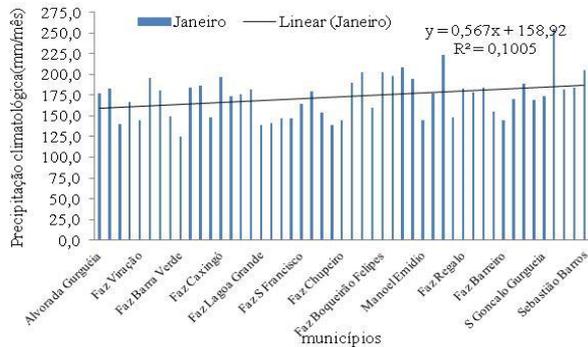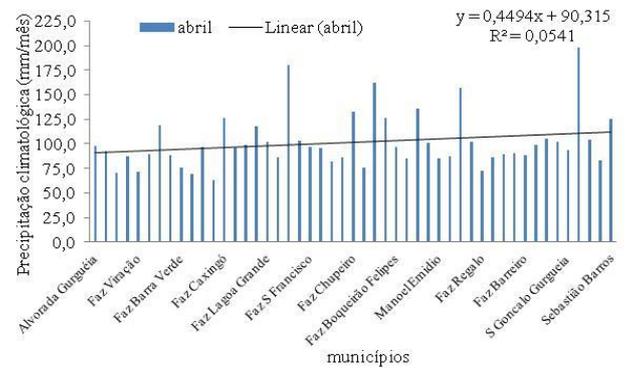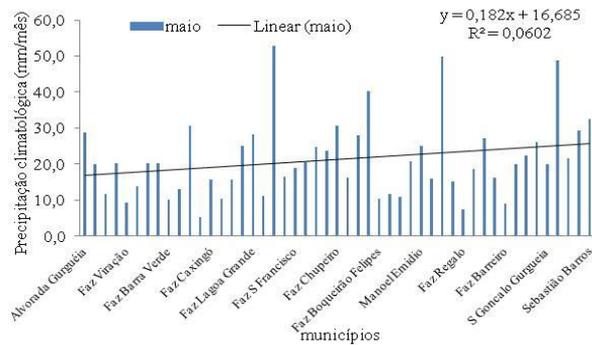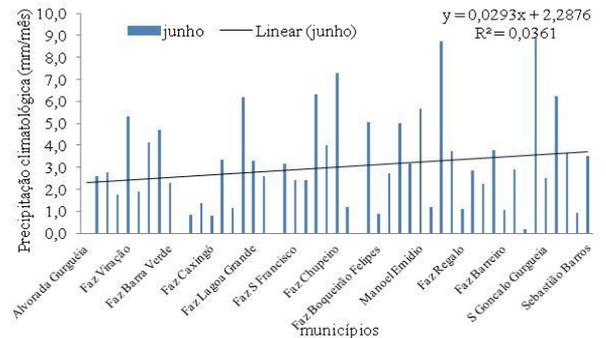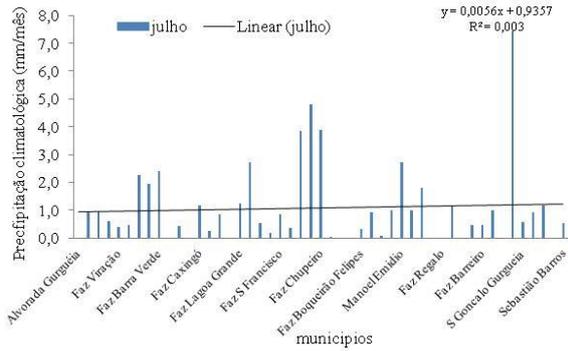

(a)

(b)

(c)

(d)

(e)

(f)

Figure 3 - Spatial and temporal distribution and the linear regression analysis of monthly rain precipitation from January to December, for the catchment area of the river Uruçuí Preto- PI.
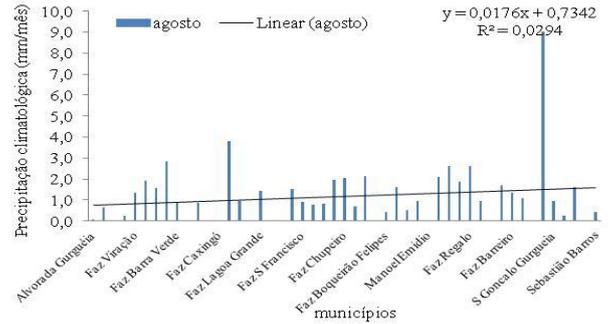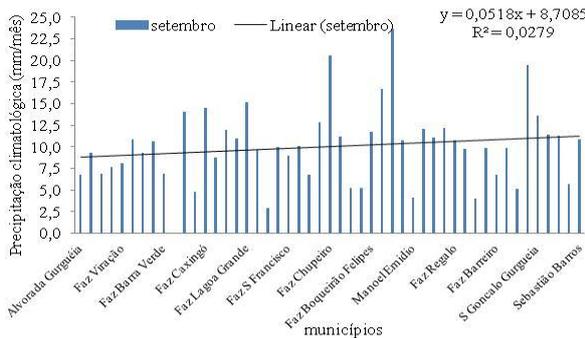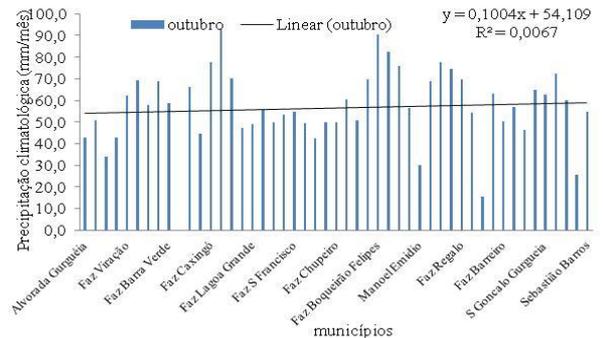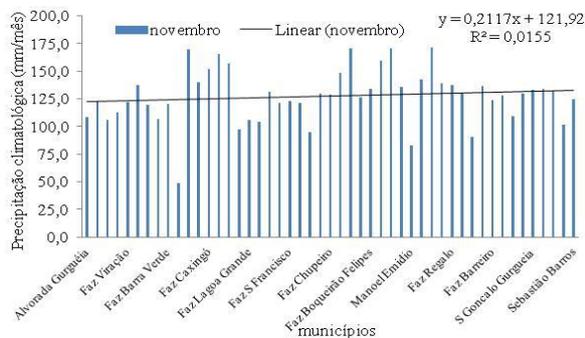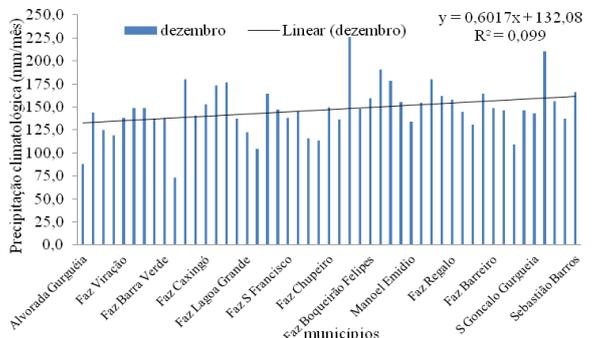
Continued

(g)

(h)

(i)

(j)

(k)

(l)

Figure 3 - Spatial and temporal distribution and the linear regression analysis of monthly rain precipitation from January to December, for the catchment area of the river Uruçuí Preto- PI.

3.1 Future trend Monthly and Annual

Table 2 it appears that the best of the regression coefficients of determination (R^2= 0,1005; 0,1342 and 0,099) for the months of January, March and December and the worst of the regression coefficients of determination were the months of July and October and November respectively (R^2= 0,003 e 0,0067). When the value is higher, indicating the degree of approximation of the average model, and when it is lower indicates the degree of the average model of distance, indicating an unsatisfactory result.

It is observed in Figure 4 that the months October to April concentrate the highest average monthly rates of rainfall, with an average value of 9363.8 mm period, corresponding to 96% of annual precipitation. The months with the lowest

rainfall ranged from May to September, corresponding to 4% of the annual total, showing up over time typical timeline variability in the region of cerrados and cerradão.

3.2 Statistical Analysis

Table 3 it can be seen that the average and median values were disconnected, showing that there was the presence of discordant extreme values in the sample. The month of maximum rainfall is January with 175.9 mm, the lowest rates occurs between the months of June, July and August with 3.2 mm; 1.2 mm and 1.2 mm respectively. It is observed that the median showed rates higher than the average for the said period and the months of lower rainfall the median was occurring in almost every month had a higher variation than the annual average, indicating dispersion in rainfall.

Table 2 - Linear equation, the regression coefficient of determination (R^2), and monthly historical average and annual total rainfall in the watershed area of the river Uruçui Preto – PI.

Month	Linear Equation	R²	Average
Janeiro	Y=0567x+158092	0,1005	175,9
Fevereiro	Y=0,4916x+144,28	0,0549	162,2
Março	Y=0,7091x+138,31	0,1342	158,8
Abril	Y=0,4494x+90,315	0,0541	105,2
Maio	Y=0,182x+16,685	0,0602	22,4
Junho	Y=0,0293x+2,2876	0,0361	3,2
Julho	Y=0,0056x+0,9357	0,003	1,2
Agosto	Y=0,0176x+0,7342	0,0294	1,2
Setembro	Y=0,0518x+8,7085	0,0279	10,0
Outubro	Y=0,1004x+54,109	0,0067	57,5
Novembro	Y=0,2117x+121,92	0,0155	128,1
Dezembro	Y=0,6017x+132,08	0,099	149,0
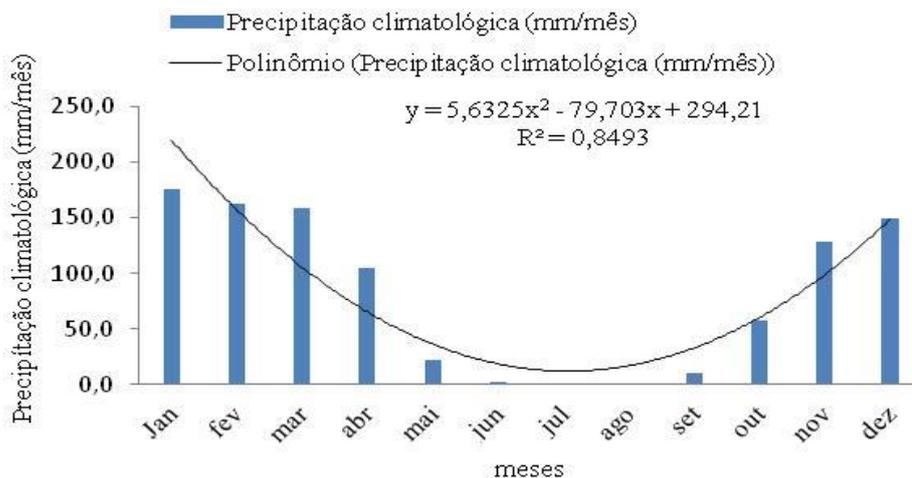
Figure 4 - Histogram of the climatological average rainfall and polynomial trend in the catchment area of the river Uruçuí Preto - PI.

The standard deviation observed influence of minor deviations in the months from May to September with fluctuating between 1.5 to 13.3 mm, and the month of February the largest deviation (50.2 mm), showing the forceful dispersion data. The monthly variability in the median indicates that this measure of central

tendency may not be the most probable value to occur in this type of distribution.

It is noteworthy also that the average monthly exceeds the median values.

Since then, the monthly rainfall distribution models are asymmetrical, with positive skewness coefficient. With this, the median is more likely to occur than the average, according to results found by Almeida and Pereira (2007).

Table 3 - Measures of central tendency and dispersion of the catchment area of the river Uruçuí Preto - PI.

Months	Average (mm)	Standard Deviation (mm)	Median (mm)	Coef. Variance (%)	Acc. Max (mm)	Acc. Min (mm)
January	175,9	33,0	177,0	0,187	319,0	124,7
February	162,2	50,2	150,2	0,310	438,6	115,3
March	158,8	34,7	122,2	0,218	302,3	111,9
April	105,2	37,9	98,3	0,360	283,5	62,8
May	22,4	13,3	28,6	0,593	77,1	5,3
June	3,2	2,6	0,0	0,819	13,1	0,0
July	1,2	1,6	0,0	1,349	7,5	0,0
August	1,2	1,5	0,1	1,267	9,0	0,0
September	10,0	4,4	6,8	0,444	23,7	0,0
October	57,5	18,7	42,9	0,325	103,4	0,0
November	128,1	25,3	108,3	0,198	178,2	48,4
December	149,0	30,9	88,0	0,208	248,8	73,3
Annual	916,0	214,3	625,3	0,234	1851,6	478,7

Legend: Coef. Variance = coefficient of variance; Acc. Max = absolute maximum rainfall; Acc. Min = absolute minimum rainfall.

4. Conclusions

Based on the results it was found that the median is a measure of central tendency most likely to occur to the rainy season between October and April, with average of 936.8 mm period, corresponding to 96% of annual precipitation. In 30 years of observed rainfall has become a climatological average of 916 mm.year^{-1}.

Trend were observed growing or downward rains for all 49 locations analyzed in the basin of river Uruçuí Preto, as the trend of variability of rainfall in the headwaters of the river, this fact is positive for agriculture and sectors of water resources, the study area, which also suffer from anthropogenic effects on water resources, degrading them and endangering the sustainability of local natural resources. From climate trends can be programmed and plan water resources in a region, making it possible to optimize agriculture and economy, thus decreasing losses in any area.

As the linear regression analysis of the time series of precipitation of the municipalities that make up the catchment area of the river Uruçuí Preto, the trend of increased rainfall variability focuses during the months from October to April, which has high rain rates for the region and the lowest rainfall is centered between the months of May to September, which has low rainfall.

For this area of study will possibility of extreme events with heavy rainfall in short periods of time is expected.

Acknowledgements

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