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PROBABILIDADE DE OCORRÊNCIA DA PRECIPITAÇÃO PLUVIAL EM TRÊS CIDADES DA BACIA HIDROGRÁFICA DO ALTO JURUÁ

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1 RESUMO

A precipitação pluvial é um componente hídrico de extrema importância em diversas áreas, principalmente, para a agricultura. Seu estudo possui considerável relevância a fim de minimizar possíveis perdas, maximizar os ganhos, além de possibilitar viabilizar um manejo sustentável dos cultivos, bem como do uso da água. Neste estudo objetivou-se analisar a distribuição dos dados de precipitação pluvial em três estações meteorológicas da Bacia Hidrográfica do Alto Juruá, bem como avaliar o seu ajuste a seis distribuições de probabilidade (Log-Normal, Weibull, Gama, Normal, Logística e Cauchy), considerando um período de 27 anos, calculados em períodos de 10, 20 e 30 dias, em níveis de probabilidade de 50, 70, 80, 90 e 95%. Observou-se que as distribuições Normal, Logística, Cauchy e Weibull foram as que apresentaram melhor ajuste para os dados de precipitação pluvial. Ao adotar o valor de 80% de probabilidade, foi possível notar que na maioria dos decêndios avaliados, o valor médio ficou abaixo da probabilidade de 80%, o que caracterizou subdimensionamento dos sistemas de irrigação.

Palavras-chave: chuva, irrigação, probabilidade.

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PROBABILITY OF PRECIPITATION OCCURRENCE IN THREE CITIES IN THE ALTO JURUÁ RIVER BASIN

2 ABSTRACT

Precipitation is a water component of extreme importance in several areas, mainly for agriculture. Its study has considerable relevance to minimize possible losses, maximize gains,

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in addition to enabling sustainable management of plantations and water use. The objective was to analyze the distribution of precipitation data in three meteorological stations in the upper Juruá river Basin, as well as to evaluate their adjustment to six probability distributions (Log-Normal, Weibull, Gama, Normal, Logistic and Cauchy), considering a period of 27 years, calculated over periods of 10, 20, and 30 days, at probability levels of 50, 70, 80, 90, and 95%. It was observed that the Normal, Logistic, Cauchy, and Weibull distributions showed the best fit for the rainfall data. When adopting the value of 80% of probability, it was possible to notice that in most evaluated ten years, the average value stayed below the probability of 80%, which characterizes an undersizing in the irrigation systems.

Keywords: rainfall, irrigation, probability.

3 INTRODUCTION

Rainfall is a meteorological variable that significantly influences environmental conditions and various human activities (SILVA *et al*., 2021). Estimating rainfall is crucial for monitoring extreme weather events and their associated risks, as well as for characterizing the potential of areas for different uses and projects, such as agriculture, energy, and transportation (MARINHO; RIVERA, 2021). Understanding rainfall behavior is crucial for designing crop irrigation projects; furthermore, knowledge of rainfall patterns each season allows for planning ~~and~~ sustainable management of water resources (TUO *et al*., 2016).

Before designing an irrigation system, one must first determine whether irrigation is necessary and whether the available water source is sufficient to meet crop demand. The decision to irrigate must consider several factors, the most important of which, for determining the crop's irrigation needs in a hypothetical region, are the amount and distribution of rainfall, as well as the crop's sensitivity to water deficit (ALBUQUERQUE; DURÃES, 2008) . According to Vela, Dallacort, and Nied (2007) , knowledge of rainfall history is important for monitoring the impacts caused by excessive or prolonged rainfall in a given region. Understanding rainfall and its dynamics is of paramount importance for strategic studies associated with environmental planning, energy generation, and agricultural management, especially in tropical conditions (BARRETO *et al* ., 2015) .

Direct monitoring of water resources and hydrological modeling have been the main approaches for assessing water resource potential and allocating it among uses in a river basin or region (HERMAN *et al* ., 2018) . The design of hydraulic projects using probable rainfall as a reference is recommended since the use of average values can result in oversizing, as these may have low probabilities of occurrence (LONGO; SAMPAIO; SUSZEK, 2006; OLIVEIRA; CARVALHO, 2003; SOCCOL; CARDOSO; MIQUELLUTI, 2010) . Estimating rainfall with a given level of probability is highly important in agricultural planning, as it allows the determination of the best time for soil preparation, harvesting, sowing, application of fertilizers and pesticides, and supplementary irrigation depth (AVILA; MELLO; VIOLA, 2009) . Knowledge of the probabilities of rainfall occurrence becomes highly important in the planning of activities related to agriculture and in the monitoring of hydrological processes concerning the management of river basins (KIST; VIRGENS FILHO, 2015)

According to Barreto *et al* . (2015) , the use of probability functions is directly linked to the nature of the data to which they relate. In this context, some have good estimation capacity for small datasets, whereas others require a large series of observations. In humid climates, rainfall is sufficient for crop water consumption. However, due to their irregular occurrence, some crops experience reduced productivity because they are sensitive to water deficits. For the production of lower commercial value crops, such as grains and pasture, a probability level of 75% can be adopted, whereas for crops with higher economic returns, higher probabilities should be used (ALBUQUERQUE; DURÃES, 2008) .

When designing irrigation systems, the use of probable rainfall, which represents the minimum amount of precipitation with a given probability of occurrence, has been suggested (FRIZZONE *et al* ., 2012) . For irrigation purposes, the ideal approach is to work with probable rainfall for periods of 5, 10, and 15 days, or at most, monthly. The usual probability levels are 75% or 80%, that is, with a minimum rainfall level that can be expected three out of every four years (75%) or four out of every five years (80%) in a given period of the year (FRIZZONE *et al* ., 2012) . The probability of rainfall occurrence plays an important role in the planning of irrigation systems, reducing acquisition costs and the risk of water shortages (BERNARDO; SOARES; MANTOVANI, 2006) .

The study of the estimate of probable rainfall has been validated in several regions of Brazil since irrigation projects are generally dimensioned in terms of total irrigation, aiming to cover the water needs of the plant without considering the contribution of rainfall (SAMPAIO; CORRÊA; BÔAS, 2000) . Silva (1982) emphasized that by adopting the practice of supplementary irrigation in a well-planned manner, the results are lower investments, lower operational costs and, consequently, the possibility of greater profits.

The study of the distribution of variables over time, as a means of understanding meteorological phenomena, determining their patterns of occurrence, and allowing reasonable predictability of a region's climate behavior, is a valuable tool for planning and managing various agricultural and human activities (ASSIS *et al*., 2004). However, research in the northern region of the country, particularly in the Upper Juruá River Basin, remains scarce.

In this sense, this work aimed to analyze the adjustment of six probability distributions to rainfall data, considering a period of 27 years distributed between the municipalities of Cruzeiro do Sul, Marechal Thaumaturgo and Porto Walter, calculated in periods of 10, 20 and 30 days with different levels of probability, to evaluate the dimensioning of irrigation systems for the study region.

4 MATERIALS AND METHODS

The Upper Juruá River Basin is located in the extreme west of the state of Acre and south of the state of Amazonas and east of the Republic of Peru (Figure 1), between the geographic coordinates of 7 and 11° S (Latitude) and 74 to 70° W (Longitude). The climate, according to the Köppen-Geiger classification, is defined as tropical equatorial (Af) (ALVARES *et al*., 2013), with an average accumulated annual rainfall equal to 2,206 mm. The average annual temperature is approximately 24.5°C (MACÊDO *et al*., 2013).

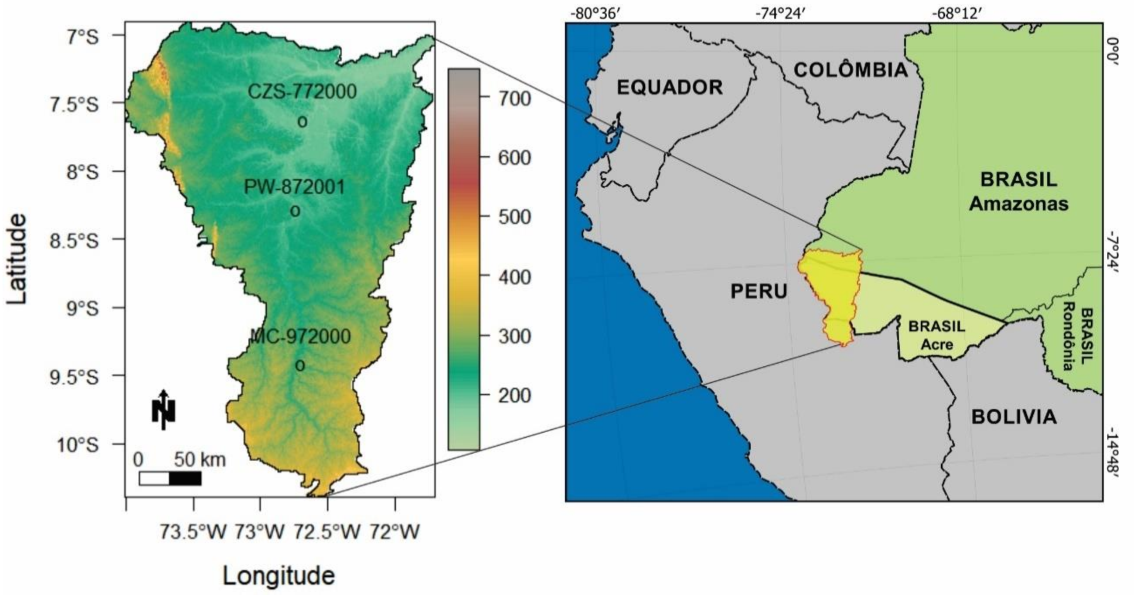
Data were obtained from the HidroWeb portal of the National Water Resources Information System (SNIRH) of the National Water and Sanitation Agency . The geographic coordinates of the rainfall stations and their respective recorded historical series are shown in Table 1 and Figure 1.

Table 1. Geographic location and historical series of rainfall stations considered in the study (Upper Juruá Basin, Acre)

Station	Latitude	Longitude	Altitude (m)	Series (years)	Period
CZS	-7.611	-72,681	170	16	1975-1990
PW	-8,267	-72,734	211	20	1983-2002
MC	-9,402	-72.702	283	12	1991-2002

CZS Cruzeiro do Sul; PW Porto Walter; MC Marechal Thaumaturgo

Figure 1. Locations of the rainfall stations in the Upper Juruá River Basin



Rainfall values were accumulated over periods of 10, 20, and 30 days. Frequency distribution analyses of accumulated probable rainfall were fitted to six probability distributions as follows: (i) log-normal, (ii) Weibull, (iii) gamma, (iv) normal, (v) logistic, and (vi) Cauchy distributions. (NAGHETTINI; PINTO, 2007).

The probable accumulated rainfall for probability levels equal to 50, 70, 80, 90, and 95% corresponds to return times (T) of 2, 3, 5, 10, and 20 years, respectively. The parameters of the probability distributions were estimated via the maximum likelihood method. The probability distribution that best fit the data were chosen on the basis of the lowest Akaike information criterion (AIC) value. To verify the fit of the rainfall data to the probability distributions, the Anderson–Darling test was applied at a 5% significance level (NAGHETTINE; PINTO, 2007).

Free R Statistical® *software* was used, executing packages for the insertion and analysis of the tabulated data. The manipulation of accumulated rainfall data and the adjustment of distribution models were performed via the *fitdistrplus package, and the goodness-of-fit test was performed via the ADGofTests* package. The graphs were created with the following packages: *ggplot2, ggpmisc, tidyverse, plyr, raster, geobr, rasterVis, and fields. geosphere* and *latticeExtra.*

5 RESULTS AND DISCUSSION

The annual distribution of rainfall in the regions of the Upper Juruá River Basin (Figure 2D) indicates that the Porto Walter and Cruzeiro do Sul stations had the highest number of years with rainfall above the average of 2,071.1 mm. Marechal Thaumaturgo had the lowest accumulated rainfall, indicating that the cities located in the lower Juruá River tended to have higher levels of accumulated rainfall than did Marechal Thaumaturgo.

The Cruzeiro do Sul station had an average annual rainfall of 2,083.5 mm, taking into account the 15 years evaluated, with 1990 being the rainiest year in the region with an annual rainfall exceeding the station average of 2,878.6 mm; 1985 had the lowest annual rainfall, with 1,576.5 mm.

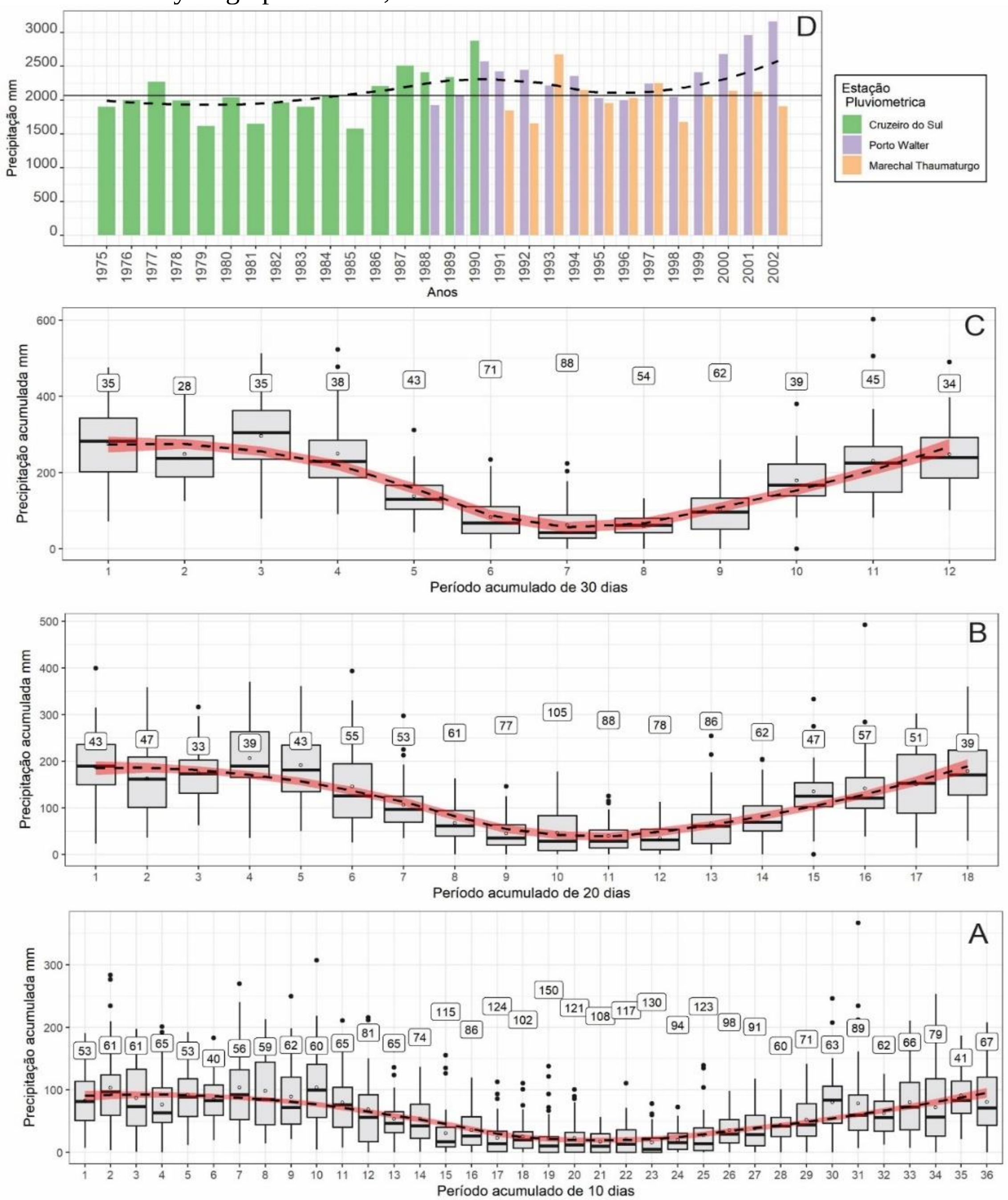
At Porto Walter station, the average annual precipitation was 2444.54 mm. The rainiest year was 2002, with a precipitation of 3235.7 mm, which exceeded the regional average. The least rainy year was 1988, with a precipitation of 1,948.2 mm. Marechal Thaumaturgo had an average annual precipitation of 2,089.2 mm; the rainiest year was 1993, with a precipitation of 2,738.6 mm, and the least rainy year was 1998, with a precipitation of 1,700.7 mm (Figure 2D).

Evaluating the distribution of rainfall on a monthly scale, for the Alto Juruá Hydrographic Basin, the precipitation indices can be divided into two periods: the rainy season and the dry season (Figure 2C). As highlighted by Macêdo *et al* . (2013) , the climate of the state of Acre is hot and humid, with a minimum annual temperature of approximately 24 °C and two distinct seasons: a dry season (Amazonian summer, which generally occurs between the months of May and September) and another rainy season (Amazonian winter, which generally occurs between the months of October and April), with a relative humidity above 80%.

The period with the highest rainfall in the region, which extends from October to April, presented monthly rainfall ranging from 179.3 mm to 296.1 mm. Considering this same period, an accumulated rainfall of 1,726 mm was observed, representing approximately 79.4% of the annual rainfall. This period with the highest rainfall values presented less variability in the data; that is, the precipitation indices were consistent in relation to the months and other seasons. March presented the highest precipitation values, reaching 286.1 mm (Figure 2C).

The dry season runs from May to September, with monthly rainfall ranging from 59.6 mm to 138.5 mm, reaching a cumulative total of 446.5 mm, representing 20.6% of the annual rainfall index. The months that comprised this dry season, in addition to presenting low rainfall levels, also presented greater data variability than did the wet season, with July having the greatest variability (88% coefficient of variation) and August having the lowest rainfall, with 59.6 mm. The critical months for the water regime are June, July, and August, which presented an average of 68.36 mm, increasing in May and September, which are considered transition months (Figure 2C). According to Duarte (2005), the Amazon region is influenced by several hydroclimatic phenomena, and the state of Acre is located at a point where there is considerable interannual variability, especially in rainfall.

Figure 2. Distribution of mean rainfall values on a 10 (a), 20 (b) day, monthly (c) and total annual (d) scale observed in historical series for three rainfall stations in the Alto do Juruá Hydrographic Basin, Acre.



Another point that demonstrates this division of seasons in the Upper Juruá Basin between the wettest and driest is the average rainfall in each period. Thus, starting in April (the end of the rainy season), there is a decrease in the average values, indicating that in the following months, the precipitation rates are lower than those in the previous months. This continues until September, after which the average rainfall increases again, ushering in the rainy season. Thus, the months of April and September can be defined as transition months between seasons (Figure 2C).

The ten-day distribution in Figure 2A shows that from the thirteenth ten-day period, with an average of 53.4 mm, there is a decrease in rainfall levels, with the averages of the following days being lower than the previous ones until the twenty-sixth ten-day period, when the averages are higher again. This period of days grouped into ten-day periods is associated with the region's wet and dry seasons. The thirteenth ten-day period occurs at the end of April and beginning of May, marking the end of the wet season and the beginning of the dry season with low rainfall levels. The twenty-sixth ten-day period, with an average of 35.8 mm, occurs in September, which marks the end of the dry season and the beginning of the wet season, from which point rainfall levels begin to increase.

According to Figure 2A, the period with the greatest data variability and the lowest rainfall rates is located between the seventeenth and twenty-fifth decennials, which comprise the months of June and August, respectively. During this period, the accumulated decennial rainfall did not exceed 50 mm. In 16 of the 36 decennials, which is equivalent to 44.4%, values above 100 mm were observed, with the seventh and twenty-third decennials presenting the highest and lowest average rainfall, with values equal to 103.8 mm and 15.8 mm, respectively.

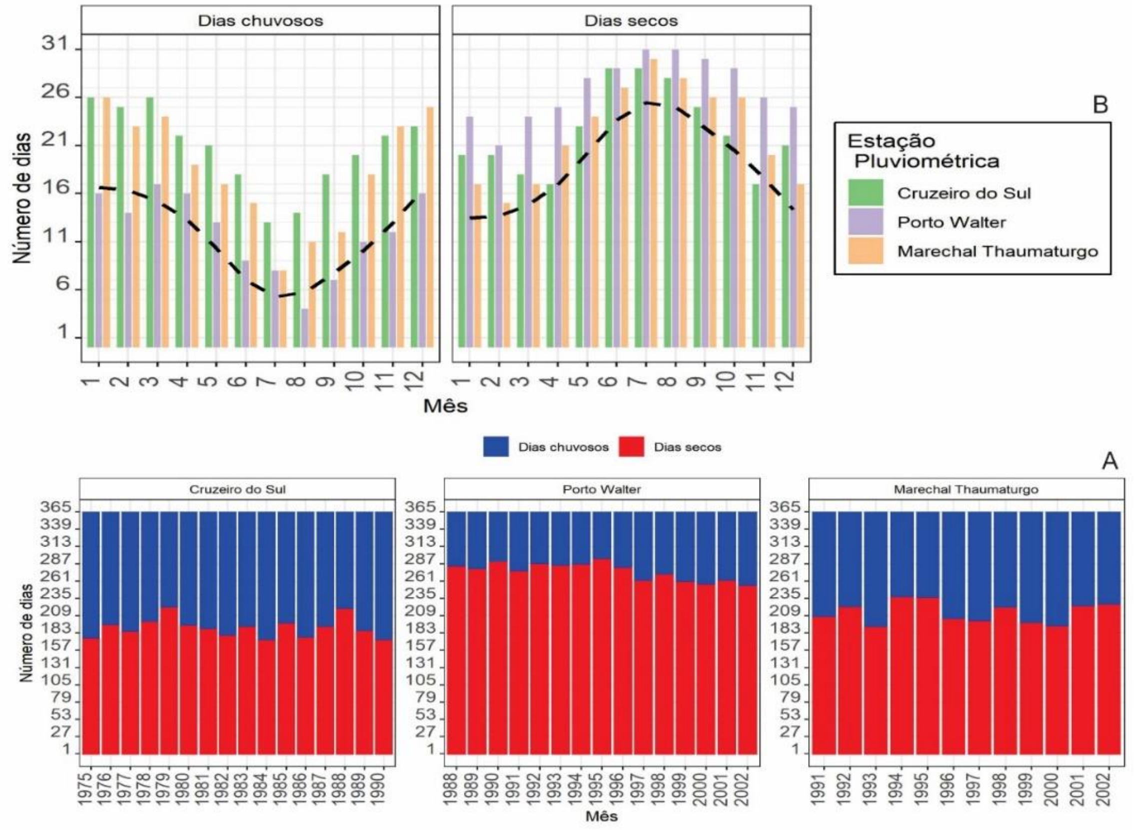
The variability of rainfall indices during the dry season causes considerable dispersion in the average rainfall values expected to meet the water demand of agricultural crops. According to Dallacort *et al* . (2011) , rainfall variability ultimately subjects farmers to a series of challenges, whether due to excessive or low rainfall levels. These inconveniences result in annual variations in agricultural yield, as well as in production costs (ELY; ALMEIDA; NETO, 2003) . According to Assad, Masutomo, and Assad (1992) , average rainfall values are not necessarily a good measure of trends to represent rainfall quantity in agricultural activity planning.

Figure 3A shows the monthly occurrence of dry and rainy days for the three rainfall stations studied in the Upper Juruá Basin. The months with the most rainy days were recorded between October and April, with Cruzeiro do Sul having the highest number of rainy days, with monthly averages ranging from 10 to 26 days, followed by Marechal Thaumaturgo, which had averages ranging from 11 to 26. The Porto Walter station (Figure 3A) had the highest number of dry days in all months of the year, with averages ranging from 21--31 days, with June, July, and August characterized as the most critical periods for rainfall due to having the highest dry day rates.

According to Silva *et al*. (2021), the variability of precipitation indices may be related to the atmospheric circulation patterns prevalent in the Amazon region, which are influenced by disturbances at regional and global scales. These disturbances interfere with the region's hydrological regime on a temporal scale (NOBRE; SAMPAIO; SALAZAR, 2007; NÓBREGA, 2014).

Figure 3B presents the annual averages of dry and rainy days for the three rainfall stations in the Upper Juruá Basin. The Cruzeiro do Sul station had a rainy day count ranging from 143--193, with 1990 having the highest number of rainy days (193 days) and 1979 having the highest number of dry days (221 days). Marechal Thaumaturgo, along with Cruzeiro do Sul, had more rainy than dry days, with 1993 having the most rainy days (173 days). The year with the highest number of dry days was 1995, with 236 days without rainfall. The Porto Walter station had more dry days than rainy days and, therefore, is the city with the longest dry periods compared to the other rainfall stations analyzed, with 1995 being the driest year, with 294 days, and 2002 having the highest number of rainy days, reaching 111 days.

Figure 3. Annual (a) and monthly (b) occurrence of rainy and dry days in the historical series for three rainfall stations in the Alto do Juruá Hydrographic Basin, Acre



Tables 2, 3 and 4 present the results for the probability distributions that best fit the rainfall data of the Upper Juruá River Basin on their respective accumulated days. Notably, the six distributions were accepted at all stations and accumulated days according to the Anderson–Darling goodness-of-fit test and were significant at p<0.05.

Table 2. Parameters of the best probability distribution model used in the analysis of the frequency of probable rainfall on a 10-day scale for three rainfall stations in the Alto do Juruá Hydrographic Basin, Acre.

Esc10	F	p 1	p 2	Esc 10	F	p 1	p 2	Esc 10	F	p 1	p 2
Station 772000 – Southern Cross											
1	N*	82.0	46.1	14	N*	41.3	27.1	27	N*	46.3	38.9
2	N*	76.6	43.1	15	LO*	34.3	17.5	28	N*	50.3	23.9
3	N*	78.2	55.9	16	N*	30.4	20.5	29	LO*	51.6	18.5
4	N*	84.0	42.6	17	N*	29.8	31.7	30	LO*	79.2	28.7
5	N*	74.7	38.8	18	N*	15.4	15.0	31	N*	57.8	30.8
6	LO*	87.6	20.4	19	W*	9.2	9.7	32	LO*	64.4	15.6
7	N*	79.8	39.6	20	LO*	20.6	10	33	LO*	67.3	27.2
8	N*	89.1	53.3	21	W*	9.0	6.9	34	LO*	67.6	35.4
9	N*	91.9	45.8	22	LO*	16.7	8.1	35	N*	75.8	34.6
10	N*	81.3	38.0	23	N*	28.4	23.7	36	N*	70.3	50.1
11	LO*	68.7	22.5	24	LO*	20.1	11.7	37	W*	45.6	13.7
12	N*	65.1	43.3	25	W*	20.5	13.6				
13	LO*	58.1	18.3	26	N*	34.0	24.2				
Station 972000 – Marshal Thaumaturgo											
1	N*	84.8	42.7	14	LO*	54.1	23.7	27	N*	29.6	25.1
2	W*	120	16.3	15	W*	10.7	6.1	28	LO*	34.7	11.6
3	N*	68.5	38.5	16	N*	35.4	27.6	29	N*	48.8	36.7
4	W*	48.6	8.41	17	W*	7.21	6.3	30	N*	89.7	50.9
5	N*	100.4	55.3	18	N*	23.9	19.9	31	N*	102.7	62.3
6	N*	73.2	29.6	19	W*	8.26	6.7	32	LO*	38.3	15.7
7	N*	126.1	64.9	20	W	1.22	3.1	33	N*	66.5	38.6
8	N*	78.6	52.8	21	N*	17.6	18.2	34	N*	76.4	57.1
9	W*	48.9	11.7	22	W	0.89	4.4	35	N*	86.2	22.3
10	N*	99.7	56.1	23	W*	1.91	3.2	36	N*	73.9	51.4
11	LO*	62.4	21.6	24	N*	14.6	13.3	37	LO*	45.7	18.6
12	N*	51.7	43.7	25	W*	4.68	6.4				
13	LO*	36.7	14.2	26	N*	34.8	11.6				
Station 872001 – Porto Walter											
1	N*	81.7	40.2	14	N*	63.4	43.5	27	N*	35.9	32.9
2	LO*	105.5	37.9	15	LO*	23.3	15.4	28	N*	40.4	28.5
3	N*	111.2	48.4	16	N*	41.9	39.5	29	N*	54.3	39.3
4	N*	81.8	62	17	LO*	13.3	12.5	30	N*	66.7	38.8
5	N*	103.5	44.2	18	LO*	32.3	18.1	31	LO*	61.5	40.5
6	N*	86.6	31.2	19	LO*	17.8	22.6	32	N*	74.0	45
7	N*	111.6	59.7	20	LO*	15.4	14.4	33	N*	98.2	60.5
8	N*	123.6	57.4	21	N*	16.6	18.9	34	N*	65.6	45.2
9	N*	93.9	57.3	22	N*	21.5	24.9	35	N*	111.5	40.5
10	N*	131.1	75.2	23	LO*	5.3	7.2	36	N*	96.9	54.4
11	N*	97.3	62.4	24	N*	21.4	19.4	37	N*	73.1	41.8
12	N*	86.3	68.2	25	N*	23.1	22.8				
13	LO*	53.4	18.1	26	LO*	28.6	21.7				

Esc10 10-day scale; 1 (01-01 to 10-01); 2 (10-01 to 19-01); 3 (20-01 to 29-01); 4 (30-01 to 08-02); 5 (09-02 to 18-02); 6 (19-02 to 28-02); 7 (01-03 to 10-03); 8 (10-03 to 19-03); 9 (20-03 to 29-03); 10 (30-03 to 08-04); 11 (09-

04 to 18-04); 12 (19-04 to 28-04); 13 (29-04 to 08-05); 14 (09-05 to 18-05); 15 (19-05 to 28-05); 16 (29-05 to 07-06); 17 (08-06 to 17-06); 18 (18-06 to 27-06); 19 (28-06 to 07-07); 20 (08-07 to 17-07); 21 (18-07 to 27-07); 22 (28-07 to 06-08); 23 (07-08 to 16-08); 24 (17-08 to 26-08); 25 (27-08 to 05).

Table 3. Parameters of the best probability distribution model used in the analysis of the frequency of probable rainfall on a 20-day scale for the three rainfall stations in the Alto do Juruá Hydrographic Basin, Acre.

Esc 20	**F**	**p 1**	**p 2**	**Esc 20**	**F**	**p 1**	**p 2**	**Esc 20**	**F**	**p 1**	**p 2**
Station 772000 – Southern Cross											
1	N*	161.8	76.1	7	LO*	95.2	22.3	13	N*	69.4	54
2	LO*	151.3	46.7	8	LO*	67.2	16.9	14	N*	96.1	61.9
3	LO*	157.5	27.1	9	N*	35.6	27.9	15	W*	117.8	17.9
4	N*	179.7	77.8	10	LO*	40	16.5	16	W*	115.2	19.8
5	LO*	160.5	33.3	11	N*	40.5	33.8	17	N*	142.9	75.4
6	LO*	130.2	33.3	12	N*	48.7	27.9	18	N*	164.1	71.9
Station 972000 – Marshal Thaumaturgo											
1	N*	213.4	64.2	7	W*	75.9	16.8	13	LO*	57.9	31.3
2	N*	128.5	55.4	8	N*	58.1	34.4	14	N*	67.6	28.3
3	N*	173.7	60.5	9	N*	43.9	30.9	15	N*	137.7	68.2
4	LO*	196.6	38.9	10	W*	12.4	9.92	16	N*	145.1	62.5
5	N*	180.4	82.9	11	LO*	37.9	17.2	17	N*	143.1	67.8
6	W*	102.3	21.9	12	N*	23.3	14.5	18	N*	160.2	47.3
Station 872001 – Porto Walter											
1	LO*	188.3	46.1	7	N*	119.2	57.1	13	LO*	56.9	27.2
2	N*	193.1	67.5	8	N*	71.8	52.1	14	N*	76.3	45.4
3	N*	190.2	56.2	9	N*	55.8	39.7	15	N*	121.1	55
4	N*	235.2	78.3	10	N*	47.9	58.4	16	W*	117.5	39.5
5	N*	225	88.8	11	LO*	32.2	20.7	17	N*	163.9	81.6
6	N*	183.6	95.8	12	N*	29.8	27.4	18	N*	208.4	71.3

Esc20 20-day scale; 1 (01-01 to 10-01); 2 (10-01 to 19-01); 3 (20-01 to 29-01); 4 (30-01 to 08-02); 5 (09-02 to 18-02); 6 (19-02 to 28-02); 7 (01-03 to 10-03); 8 (10-03 to 19-03); 9 (20-03 to 29-03); 10 (30-03 to 08-04); 11 (09-04 to 18-04); 12 (19-04 to 28-04); 13 (29-04 to 08-05); 14 (09-05 to 18-05); 15 (May 19 to May 28); 16 (May 29 to June 7); 17 (June 8 to June 17); 18 (June 18 to June 27), F Probability distribution function; N Normal (p1 – mean and p2 – standard deviation); LO Logistic (p1 – log (mean) and p2 – log (standard deviation); C Cauchy (p1 – location and p2 – scale); * Anderson–Darling goodness-of-fit test significant ($p<0.05$)

Table 4. Parameters of the best probability distribution model used in the frequency analysis of probable monthly rainfall for the three rainfall stations of the Alto do Juruá Hydrographic Basin, Acre

30-day scale	**F**	**p 1**	**p 2**	**F**	**p 1**	**p 2**	**F**	**p 1**	**p 2**
	Southern Cross			Marshal Thaumaturgo			Port Walter		
Jan	WE*	2.7	272.2	WE*	3.6	313.9	N*	305.1	89.6
Feb	WE*	4.6	260.4	WE*	4.4	256.9	N*	272	77.5
Sea	WE*	2.6	307.7	LN*	5.6	0.3	N*	329.1	81.6
Apr	LN*	5.3	0.4	G*	18.6	0.1	N*	314.7	100.8
May	LO*	138.5	20	LN*	4.7	0.5	N*	149	65.6
June	WE*	1.1	75.1	WE*	1.51	87.9	N*	97.8	62.5
Jul	WE*	1.4	64.2	WE*	1.21	70.8	W*	31	16.6
Aug	LO*	79.1	15.8	WE*	1.6	51.3	N*	51.4	26.6
Set	WE*	1.8	138.2	WE*	2	94.5	N*	97.6	60.9
Out	LN*	5.2	0.3	WE*	3.1	197.1	LO*	164.8	35.3
Nov	LN*	5.3	0.4	G*	6.9	0.1	W*	233.7	40.7
Ten	WE*	3.4	357.8	G*	8.7	0.1	LO*	265.4	49.1

F Probability distribution function; N Normal (p1 – mean and p2 – standard deviation); LN Log-Normal (p1 – log (mean) and p2 – log (standard deviation); C Cauchy (p1 – location and p2 – scale); LO Logistic (p1 – log (mean) and p2 – log (standard deviation); WE Weibull (Par1 – scale and Par2 – shape); Gamma (Par1 – rate and Par2 – shape), * Anderson–Darling goodness-of-fit test significant ($p<0.05$),

According to Tables 2, 3 and 4, the probability distributions were adjusted to the rainfall data in all periods of accumulated days, of which the normal, logistic and Cauchy methods stood out, which were present in the periods of 10 and 20 accumulated days (Tables 2 and 3). Furthermore, it is important to highlight that these distributions were present and adjusted to the data from the Porto Walter station in the accumulated period of 30 days, all with significant results according to the Anderson–Darling adherence test ($p<0.05$).

Thus, given the data presented, it can be confirmed that the normal, logistic and Cauchy distributions tend to present a better fit to the data in periods of accumulated days shorter than the 30-day scale, considering that, when tested for a longer accumulated period, they only adjusted to one of the stations in the Upper Juruá Hydrographic Basin. However, the Weibull, log-normal and gamma distributions presented a better fit only to the data referring to 30 accumulated days (Table 4); that is, when working on longer periods, these probability distributions tended to have a better fit to the rainfall data.

Of the 198 tests performed on rainfall data from the Upper Juruá Basin, only two were rejected, which were found in the 10-day cumulative period, specifically in the twentieth and twenty-second ten-day periods. The probability distribution that best fit most of the rainfall series was the normal distribution, with 30, 42, and 33 cases for the Cruzeiro do Sul, Porto Walter, and Marechal Thaumaturgo stations, respectively, followed by the logistic distributions with 19 and 15 cases for the Cruzeiro do Sul and Porto Walter stations, respectively. The Weibull distribution was well fitted in 7 and 8 cases for the Cruzeiro do Sul and Marechal Thaumaturgo stations, respectively. Considering the three rainfall stations studied, the normal distribution best fit 105 data series, all of which were significant according to the Anderson–Darling goodness-of-fit test.

Over a 10-day cumulative period and considering a 5-year return period for the Marechal Thaumaturgo station, there is an 80% probability that rainfall in the 23rd ten-day period will be greater than or equal to 8.40 mm or that, in four out of every five years, the rainfall in August should be at least 8.40 mm (Figure 3). The same situation occurs in the 21st (17.62 mm) and 23rd (8.42 mm) ten-day periods in Cruzeiro do Sul (Figure 4) and Porto Walter (Figure 5), respectively. Notably, at the Cruzeiro do Sul station, the minimum probable rainfall occurs in July.

Figure 3. Probable and average rainfall over accumulated days of 10, 20, and 30 with probabilities of occurrence of 50, 70, 80, 90, and 95% for the Marechal Thaumaturgo rainfall station, Acre

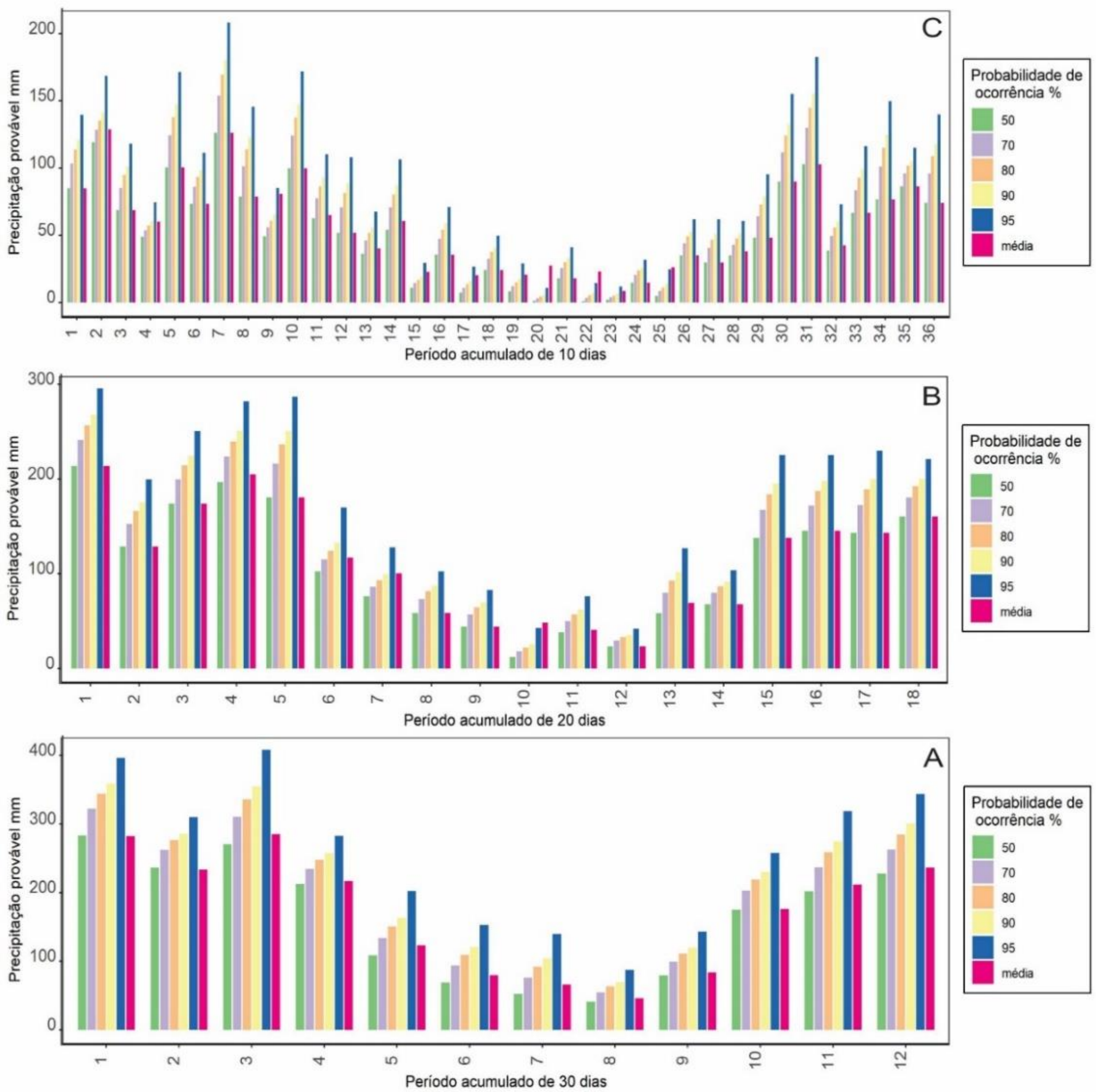


Figure 4. Probable and average rainfall of accumulated days of 10, 20, and 30 with probabilities of occurrence of 50, 70, 80, 90, and 95% for the Cruzeiro do Sul station, Acre.

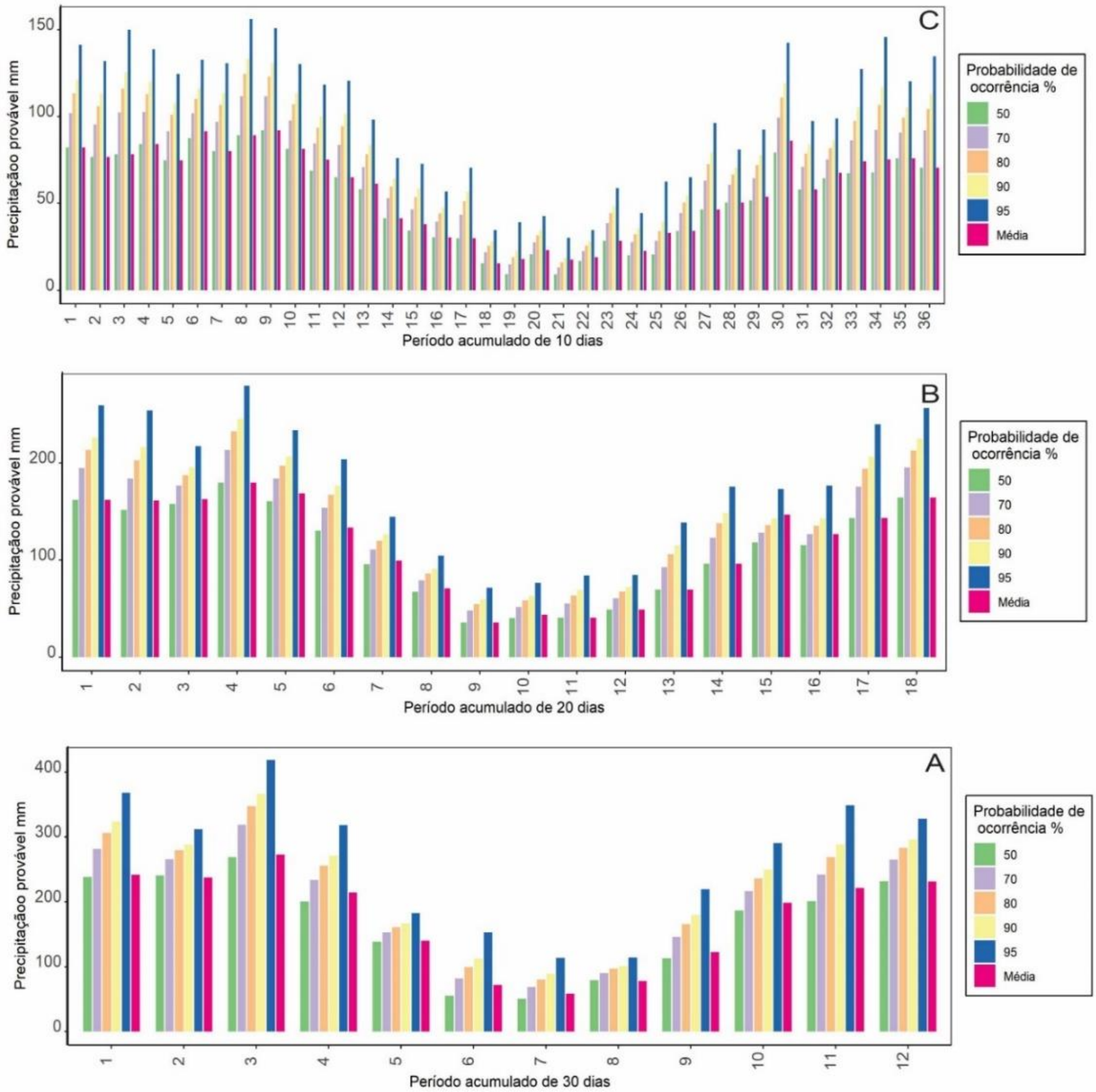
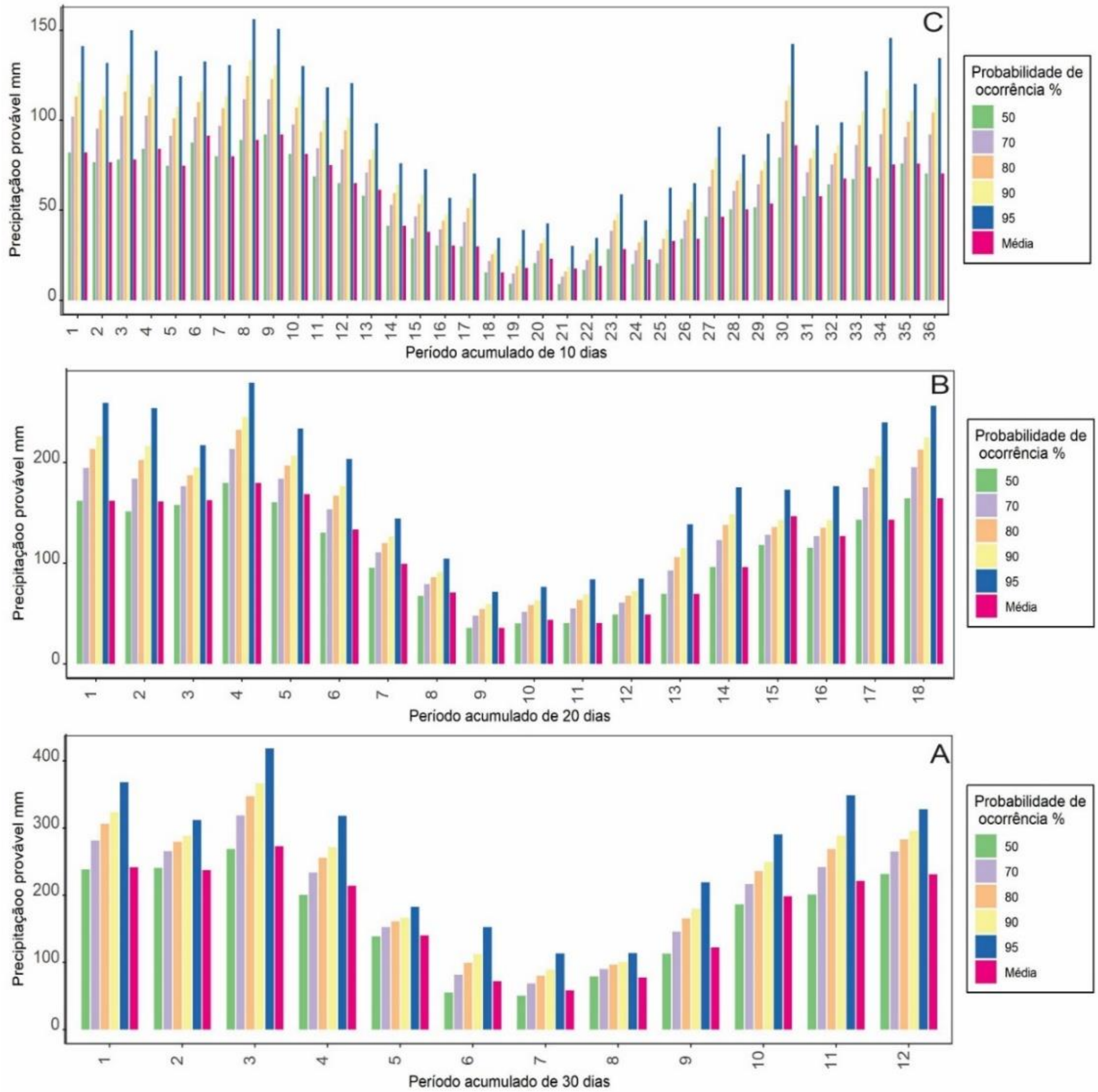


Figure 5. Probable and average rainfall over accumulated days of 10, 20, and 30 with probabilities of occurrence of 50, 70, 80, 90, and 95% for the Porto Walter station, Acre



Notably, except for the 15th, 17th, 19th, 20th, 22nd, 23rd and 25th ten-day periods, the average rainfall is below or below the 80% probability in relation to the estimated rainfall values at the Marechal Thaumaturgo station (Figure 3), which would characterize the undersizing of the irrigation systems if the average rainfall value was adopted. At the Cruzeiro do Sul (Figure 4) and Porto Walter (Figure 5) stations, this exception occurred only in the 21st ten-day period for both stations.

In a 30-day accumulation period, considering 5 years as the return period, for the Cruzeiro do Sul station (Figure 4), there is an 80% probability that rainfall in March will be greater than or equal to 300 mm or that, in four out of every five years, the rainfall in March will be at least 300 mm. For the Marechal Thaumaturgo station (Figure 3), considering 5 years as the return period, there is an 80% probability that rainfall in the months of January and March will be greater than or equal to 300 mm or that, in four out of every five years, the rainfall in

January and March will be at least 300 mm. For the Porto Walter station (Figure 5), considering the same parameters as the other two stations, there is an 80% probability that rainfall in the months of January, March, and April will be greater than or equal to 300 mm or that, in four out of every five years, the precipitation values in January, March and April must be at least 300 mm.

Except in January and February, the average precipitation value was greater than the 50% probability. When considering an 80% probability, the recommended value for irrigation projects, there are significant differences between the recommended probability level and the average value. The average value is lower than the 80% probability level in all months of the year, except for July at the Porto Walter station, where the average precipitation value was greater than the 80% probability level. In this case, when the average value is adopted for sizing irrigation systems, the systems are undersized.

Notably, as the probability level increases, the probable rainfall also increases for all the accumulated periods analyzed. Vieira *et al* . (2010) , when analyzing monthly rainfall data for the city of Diamantina, MG, also reported an increase in probable rainfall as the probability level increased.

For the Cruzeiro do Sul and Marechal Thaumaturgo rainfall stations, in the months of April and August, the probable rainfall tends to decrease, and from September onward, it tends to increase. At the Porto Walter station, the decrease in probable rainfall occurs from May onward. According to Fietz *et al.* (1998), when shorter analysis periods (ten- and fortnightly periods) are used, there is a greater risk of average precipitation values underestimating the projects. In this case, when all the accumulated periods studied are analyzed, when the average value is adopted, the system size can be underestimated. During dry periods, the average values overestimate the probable values, and finally, during wet periods, the average values underestimate the probable values with a probability above 50%.

6 CONCLUSION

The logistic, Cauchy and Weibull probability distributions presented the best fit for the rainfall data from the Alto Juruá Hydrographic Basin, state Acre.

The estimated rainfall values suggest that irrigation systems designed on the basis of the average value of records are prone to a relatively high probability of undersizing.

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