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ANALYSIS OF PRECIPITATION AND DRY SPELL IN THE CENTER WESTERN MESOREGION OF PARANÁ STATE, BRAZIL - A SPECIFIC STUDY IN SEPTEMBER 2020

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ABSTRACT

The occurrences of dry spells are becoming frequent nowadays, in the context of global climate change. Thus, the key objective of this study was to analyze the variability of precipitation and the probability of occurrence of dry spell in the Center-Western Mesoregion of Paraná State, Brazil. As a specific objective, was to analyzed the occurrence extreme dry spell occurrences during September 2020 of the year 2020. For this, maps were used to regionalize the pluviometric heights. Box plot plots and probabilities were created to study regional precipitation behaviour. The annual precipitation in the Mesoregion showed an appropriated annual and monthly distribution, showing positive extract from the CLIMWB. However, the Mesoregion exhibits a significant variability, with months over 500 mm between the rainiest and driest months. The occurrence of dry spell also showed significant values. In August, were verified 60 % probability of dry spell. Reflection of this significant variability occurred in 2020, which with a series of data older than 40 years, showed the driest month in history, much attributed to the current atmospheric circulation with blocks caused by the intense mass of hot air, linked to the recent fires occurrences on the Brazilian Pantanal and Amazon.

Keywords: Precipitation. Climatic risks. Dry spell. Climate change.

ANÁLISE DA PRECIPITAÇÃO E DE VERANICO NA MESORREGIÃO CENTRO OCIDENTAL PARANAENSE, BRASIL – ESTUDO DE CASO DO MÊS DE SETEMBRO DE 2020

RESUMO

Episódios de seca estão se tornando cada vez mais comuns atualmente no cenário de mudanças climáticas. Desta forma, o objetivo desta pesquisa foi analisar a variabilidade de precipitação e a probabilidade de ocorrência de veranico na Mesorregião Centro Ocidental Paranaense. Como objetivo secundário, analisou-se a ocorrência de um veranico extremo no mês de setembro de 2020. Para isso, foram criados mapas com interpolações para regionalizar as alturas pluviométricas. Criou-se gráficos de *box plot* e probabilidades para identificar o comportamento pluviométrico regional, além da análise gráfica e sinótica das chuvas de setembro de 2020. A precipitação anual na Mesorregião apresentou distribuição considerável anual e mensal, com valores médios que mostram extrato do balanço hídrico todo positivo. Porém, a região possui grande variabilidade e amplitude de mais de 500mm entre os meses mais chuvosos e mais secos. Na ocorrência de períodos secos, também se identificou valores alarmantes, com agosto apresentando até 60% de probabilidade de veranicos. Reflexo dessa grande variabilidade ocorreu em 2020, cuja série de dados maior que 40 anos, apresentou o mês de setembro mais seco da história, atribuído à circulação atmosférica vigente com bloqueios causados pela intensa massa de ar quente atrelados às queimadas no Pantanal e na Amazônia brasileira.

Palavras-chave: Chuvas. Riscos climáticos. Secas. Mudanças Climáticas.

INTRODUCTION

The conditioning and development of meteorological elements is not static, due the dynamics on the atmosphere that show variability from one place to another, accompanying territorial peculiarities at different scales (SCORER, 1997; BARRY and CHORLEY, 2009; GORDON et al., 2016). In the context of global climate change, these elements are fundamental for studies to aid the comprehension of its harm effects (D'AGOSTINO and SCHLENKER, 2016; LESK; ROWHANI; RAMANKUTTY, 2016; LIANG et al., 2017; WANG et al., 2017; BOCCHIOLA et al., 2019; KISAKA et al., 2020; PRĂVĂLIE et al., 2020). Analyzing meteorological phenomena, which can bring harm impact on the environments, climatic transformations and their intensity (BONFANTE et al., 2018), is notorious for determining improvements in the social and socioeconomic processes of necessary international political actions.

The occurrence of the dry spell is characterized as a consecutives days with no precipitation during the rainy periods (AYOADE, 2007), exhibiting potential negative consequences for crops productions and urban and rural water management (ASSAD, 1994; SIFER et al., 2016; BAKO et al., 2020). Agriculture is one of the most dependent economic activities on the weather conditions (ANGELOCCI; SENTELHAS; PEREIRA 2002; CHAVAS et al., 2019), thus, the occurrence of dry spell may causes directly impact, increasing water stress, harming the physiology of the crops (FREITAS et al., 2014).

There is a key interaction between crops productions and variability of precipitation (FERREIRA et al., 2020). For Paraná state (Brazil), in 2019, agricultural production of grains as soybeans, corn and wheat, recorded 35.252.573 tons (IPARDES, 2020); while only in Center-Western Mesoregion of Paraná state (MCOPR), in 2019, was responsible for 12.94 % of this production (4.564.020 tons). Thus, the importance of studying the frequency of dry spell and the variability of precipitation is fundamental due the key agriculture participation for the state economy, in addition, contributing to decision-making and agricultural planning.

Even though the Paraná State is one the more rainny Brazilian states (CARAMORI et al., 2008), several studies suggest occurrences of dry periods in its Interior (SALTON; MORAIS; LOHMANN 2021). In the Western Mesoregion, near to the area of study, Ferreira et al. (2020) identified high probability of dry periods occurrences, between the Fall and Winter seasons. For the Paraná state, Salton, Morais e Lohmann (2021) identified extreme and moderate dry periods can occur more frequently during the La Nina conditions, when the weaker dry periods, in El Nino conditions, however, in this case, there is not a tendency of increasing or reducing dry periods for the different areas in Paraná state. Caldana et al. (2021) pointed out that the analysis of this climatological events are relevant for decision-making agricultural management in Paraná State, due these events are responsible for prejudice or even crop failure, in Paraná State. Especially the month of September is an important time frame for analysis since it is one of the soybean sowing periods in the state of Paraná.

Thus, the general objective of this study was to analyze the variability of precipitation and the probability of occurrence of dry spells in the Center-Western Mesoregion of Paraná state. For this, were studied statistical and spatial application of the data of pluviometric and meteorological stations. As a specific objective, this study aims to verify the occurrence of an extreme dry spell during September (2020).

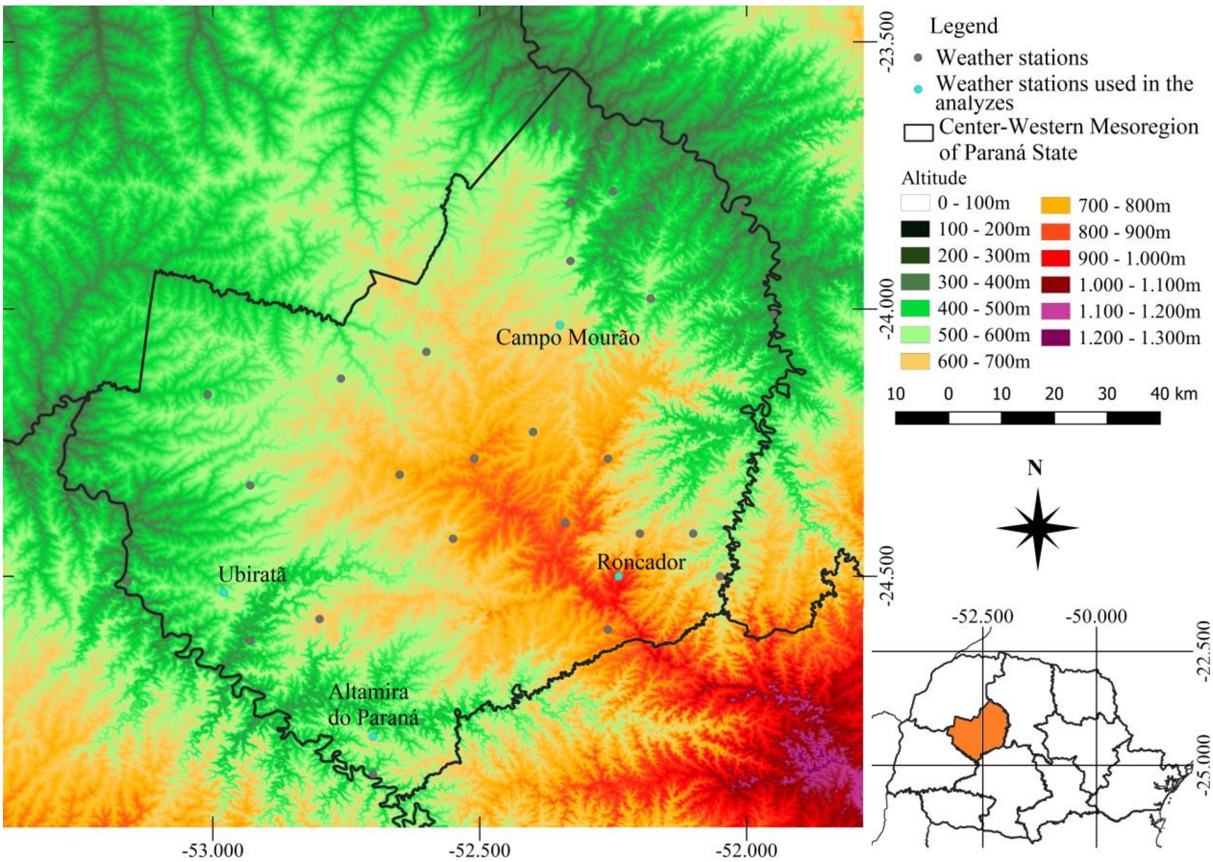
METODOLOGY

Area of the study

The MCOPR (Figure 01) has approximately 400 thousand inhabitants (IBGE, 2020). It has an important area for crops production, especially soybean, which are higher dependent on the meteorological conditions (LIMA et al., 2006; FERREIRA et al., 2020).

The region has a significant area with a “Cfa” climatic classification (subtropical, with no dry season and hot summer). The exception occurs in the range above 900 m, near to the municipality of Roncador, with “Cfb” climatic classification (subtropical, without dry season), according to the classical Köppen climatic classification (NITSCHE et al., 2019). The average temperature varies 22°C, near to the Ivaí River channel, at 19.1°C in the region of higher altitudes. The topography has an altitude of 200 m, near to the channel of the Rivers Ivaí and Piquiri, reaching peaks of 950 m at the Southeast area of the MCOPR (Figure 01).

Figure 01 - Localization of the stations and the topography of MCOPR.



Source - INPE (2011); ANA (2020); IDR (2020).Organized by authors (2020).

Statistical analyses

For the characterization of precipitation at MCOPR, were used data from 31 meteorological stations from the Instituto de Desenvolvimento Rural do Paraná (IDR-Paraná) and the Instituto Água e Terra do Paraná (IAT, 2020) (Figure 01 and Table 01), located along the Mesoregion, in a historical series from 1976 to 2019. In addition, data from September 2020 were used to do a specific climatic study.

The spatialization of these data was performed through interpolation, which is an effective method for the spatial visualization of climatic data. This was done using isohyets in the values adjusted regression statistics and using the spatial interpolation algorithm Inverse Distance Weighted (IDW) (MUELER, 2004).

To analyze the regional distribution and rainfall variability, were used box plot graphics to measure, the position of the median, the one that shows where 50 % of the data is located, its asymmetry and the presence of discrepant points or outliers and extremes (LEM et al., 2013; SCHNEIDER e SILVA, 2014). Being an effective method to analyze rainfall variability, especially for showing extreme and outliers in the historical series (DEVAK and DHANYA, 2014).

Box plots represent by: median, discrepancies and extremes and maximum and minimum values. Three quartiles (Q) were classified with 25 % of the data each, in addition to the median value, which is equivalent to the second quartile – 50 % of the data (LEM et al., 2013; SCHNEIDER E SILVA, 2014). Discrepancies are divided into outliers (values above the maximum, but which are not extreme) and extremes, considering any values $> Q3 + 1{,}5\,(Q3 - Q1)\ ou < Q1 - 1{,}5\,(Q3 - Q1)$

For the analysis using a box plot, were used data from the rainfall stations in the municipality of Altamira do Paraná, Campo Mourão, Roncador and Ubiratã, aiming to study different values of precipitation to establish a parameter.

For identify the probability of the occurrence of dry spell, the frequencies of the number of consecutive days with precipitation equal to or less than 1 mm day^{-1} or 10 mm day^{-1} were determined, lasting at least 10 days, being the precipitation value used to represent agronomic drought (CAVIGLIONE et al., 2000). Frequency analyzes were carried out using mobile ten days (1-10 / 01, 2-11 / 01, 3-12 / 01, and so on). This procedure avoids the omission of consecutive ten-days periods without rain that can occur when considering only ten days 1-10, 11-20 and 20-30 of each month. Only values greater than or equal to 1 mm were considered as rain. This method was used by Ferreira et al. (2020) to study the frequency of periods with no precipitation. It was considered risk value for agricultural practice was considered to be greater than 50% probability of occurrence.

The probability of dry spell occurrence was analyzed by means of mobile days series with periods that vary in 10 days. This analysis becomes predominant, as it allows to verify the variation within a given month, drier or rainier months, aiding to promote agricultural planning. This method was used by Ferreira et al. (2020) to study the variability of precipitation in the Western of Paraná state.

Table 01 - Climatic information from the stations analyzed.

State Agency (data)	Station (Municipality)	Longitude	Latitude	Altitude	Historical Series
ANA	Altamira do Paraná	-52.70	-24.80	650 m	1976-2019
ANA	Alto São João (Roncador)	-52.05	-24.50	950 m	1976-2019
ANA	Balsa do Cantú (Altamira do Paraná)	-52.70	-24.75	360 m	1976-2019
ANA	Barbosa Ferraz	-51.95	-24.01	320 m	1976-2019
ANA	Bela Vista do Ivaí (Fênix)	-52.01	-23.81	420 m	1976-2019
ANA	Campina da Lagoa	-52.80	-24.58	618 m	1976-2019
ANA	Campo Mourão	-52.35	-24.03	591 m	1976-2019
ANA	Engenheiro Beltrão	-52.25	-23.78	520 m	1976-2019
ANA	Farol	-52.60	-24.08	582 m	1976-2019
ANA	Goioerê	-53.01	-24.16	497 m	1976-2019
ANA	Guarani (Mamborê)	-52.55	-24.43	650 m	1976-2019
ANA	Iretama	-52.1	-24.42	584 m	1976-2019
ANA	Janiópolis	-52.76	-24.13	350 m	1976-2019
ANA	Luiziana	-52.26	-24.28	800 m	1976-2019
ANA	Malu (Terra Boa)	-52.36	-23.66	474 m	1976-2019
ANA	Mamborê	-52.51	-24.28	702 m	1976-2019
ANA	Marilu (Iretama)	-52.20	-24.42	603 m	1976-2019
IDR	Nova Cantú	-52.34	-24.40	540 m	1976-2019
ANA	Peabiru	-52.33	-23.91	527 m	1976-2019
ANA	Pensamento (Mamborê)	-52.65	-24.31	638 m	1976-2019
ANA	Ponte do Goio Bang (Campina da Lagoa)	-52.90	-24.58	320 m	1976-2019
ANA	Ponte do Piquiri (Ubiratã)	-53.16	-24.51	310 m	1976-2019
ANA	Porto Bananeira (Engenheiro Beltrão)	-52.11	-23.67	520 m	1976-2019
ANA	Primavera (Juranda)	-52.93	-24.33	515 m	1976-2019
ANA	Quinta do Sol	-52.18	-23.81	315 m	1976-2019
ANA	Rio da Vargem/Mourão (Campo Mourão)	-52.40	-24.23	668 m	1976-2019
ANA	Roncador	-52.26	-24.60	730 m	1976-2019
ANA	Saltinho (Engenheiro Beltrão)	-52.33	-23.80	550 m	1976-2019
ANA	Santo Antônio (Roncador)	-52.24	-24.50	819 m	1976-2019
ANA	Silviolândia (Peabiru)	-52.23	-23.99	425 m	1976-2019
ANA	Ubiratã	-52.98	-24.53	509 m	1976-2019

Source - ANA (2020); IDR (2020). Organized by authors (2020).

The Climatological Water Balance (CLIMWB) according to the Thornthwaite and Mather method (1955), using the equation considering the values of several meteorological variables and the available soil water storage (SWS) proportional to the effective depth of the roots of the analyzed species. For this, were considered the mean monthly precipitation data (from monthly totals for each year) and the monthly mean temperature (from monthly averages of daily values for each year) were considered. Then, potential evapotranspiration (PET) was calculated using the Thornthwaite method (equation 1). First, standard potential evapotranspiration (ETPp, mm. month^{-1}) was calculated using the empirical formula (equation 2):

When: $0 < \mathrm{Tn} < 26{,}5°\mathrm{C}$ (1)

$$\mathrm{ETPp} = 16\left(10\,\frac{\mathrm{Tn}}{\mathrm{I}}\right)^{a}$$

When: $\mathrm{Tn} \geq 26{,}5º\mathrm{CTn}^2$ (2)

$$\mathrm{ETPp} = -415\ 85, + 32\ 24, \mathrm{Tn} - 43{,}0\ \mathrm{Tn}^2$$

Where: Tn - average temperature of month n, in ºC; and I is an index that expresses the heat level in the region. Subscript n represents the month, that is, n = 1 is January; n = 2 is February; etc.

The value of I depends on the annual rhythm of the air temperature, integrating the thermal effect of each month, being calculated by the formula: $\mathrm{I} = 12(0{,}2\ \mathrm{Ta})^{1{,}514}$

The exponent “a”, being a function of I, is also a regional thermal index, and is calculated (equation 3):

$$a = 0{,}49239 + 1{,}7912x10^{-2}\, I - 7{,}71\mathrm{x}10^{-5}\, I^2 + 6{,}75\mathrm{x}10^{-7}\, I^3 \quad (3)$$

The ETPp value represents the total monthly evapotranspiration that would occur under the thermal conditions of a standard month of 30 days, and each day with 12 hours of photoperiod (N). Therefore, ETPp must be corrected according to N and the number of days in the period (NDP) (equation 4).

$$COR = \left(\frac{N}{12}\right)\left(\frac{NDP}{31}\right) \quad (4)$$

Therefore, the climatic classification by the method of Thornthwaite and Mather (1955), considers that after obtaining the climatological water balance (CLIMWB) according to the method of Thornthwaite and Mather (1955), assuming an available water capacity in the soil effective root depth in mm, water indexes (Ih) should be evaluated (equation 5):

$$Ih = \frac{EXC}{ETP}100 \quad (5)$$

Where: EXC - water surplus (mm); ETP - reference or potential evapotranspiration (mm).

Specific study of case

Were used images from the METEOSAT satellite available by Brazilian Weather Forecast and Climate Studies Center (CPTEC, 2020) to study the genesis and identification of the precipitation system active and to monitoring of daily meteorological conditions. The images were collected every day and at 3 pm. Then, the atmospheric patterns and circulation were analyzed, and the days 3, 10, 15, 18, 22 and 30 were extracted for the study due it showed changes in the atmospheric circulation.

In addition, images were extracted from the meteorological radar from the Sistema Meteorológico do Paraná - SIMEPAR, which is updated every 15 minutes to identify the type of instability and its displacement over the MCOPR.

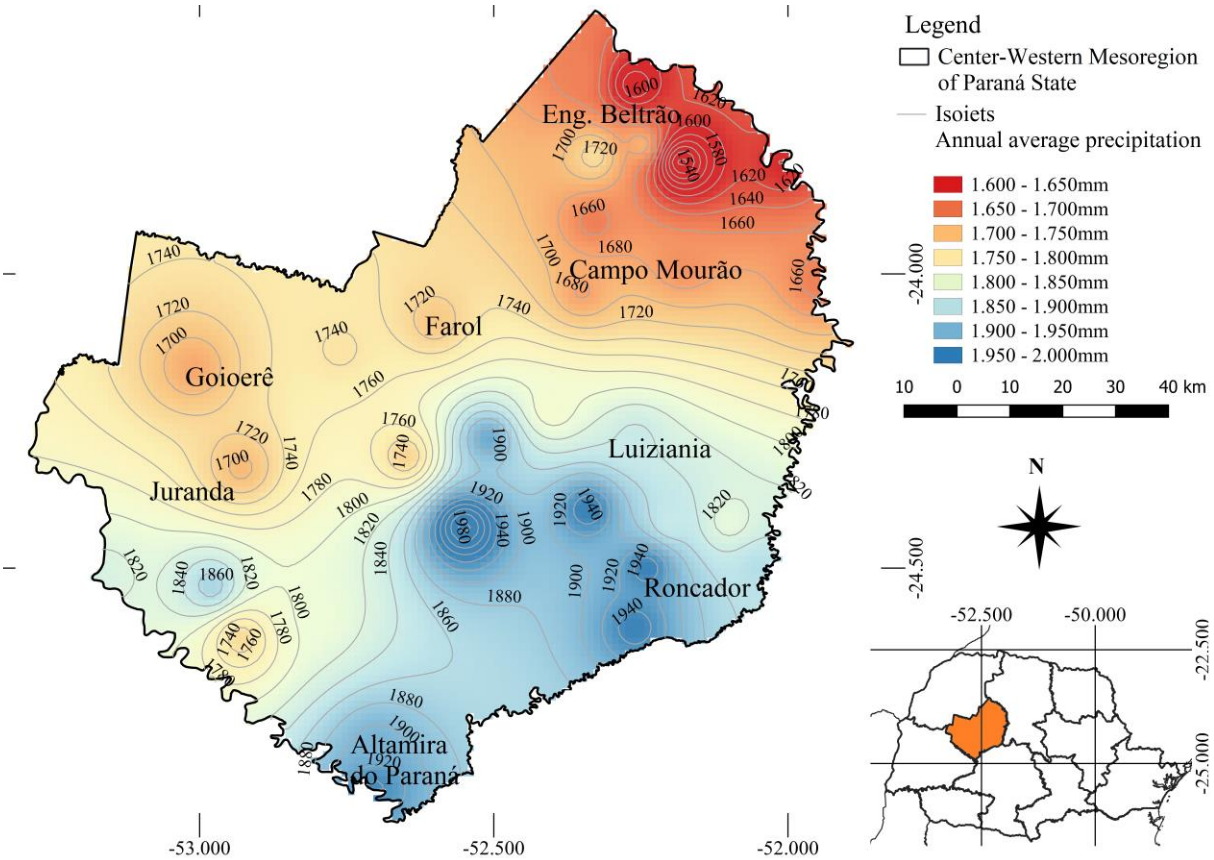
To analyze the magnitude of the dry spells occurrences, the monthly average of rain in September and the total from 2020 were extracted to create maps using the IDW interpolator. In addition, the Climatological Water Balance (CLIMWB) was created to aid the compression the effects of the dry spells impacts on the soils.

RESULTS AND DISCUSSION

The average annual precipitation in the MCOPR – Center Western Mesoregion of Paraná state (Figure 02) exhibited a significant variability. The rainfall ranged from 1,540 to 1,980 mm. In the municipality of Engenheiro Beltrão, far Northern region of MCOPR, near to the Ivaí River channel, the lowest precipitation heights were verified was 1,688 mm, ranging from 1,540 to 1,720 mm, in the isohyets. For this region, the altitude varies from approximately 300 to 600 m, and the topography decreases in direction of displacement of instabilities, justifying the low average annual precipitation.

For Western region of the MCOPR, in the municipality of Goioerê, 497 m of altitude, intermediate precipitation values were verified, with an average of 1,682 mm and a variation from 1,700 to 1,740 mm in the isohyets, near the Piquiri River.

Figure 02 - Annual average precipitation (from 1976 to 2019) at MCOPR.



Source - ANA (2020); IDR (2020). Organized by authors (2020).

It was identified the MCOPR rainiest area is in the municipality of Roncador, located in the Southeast area and with an altitude from 400 to 900 m (Figure 01) in the direction of displacement of the instabilities, culminating in high pluviometric heights, with an annual average of 1,952 mm and variation of isohyets from 1,880 to 1,940 mm.

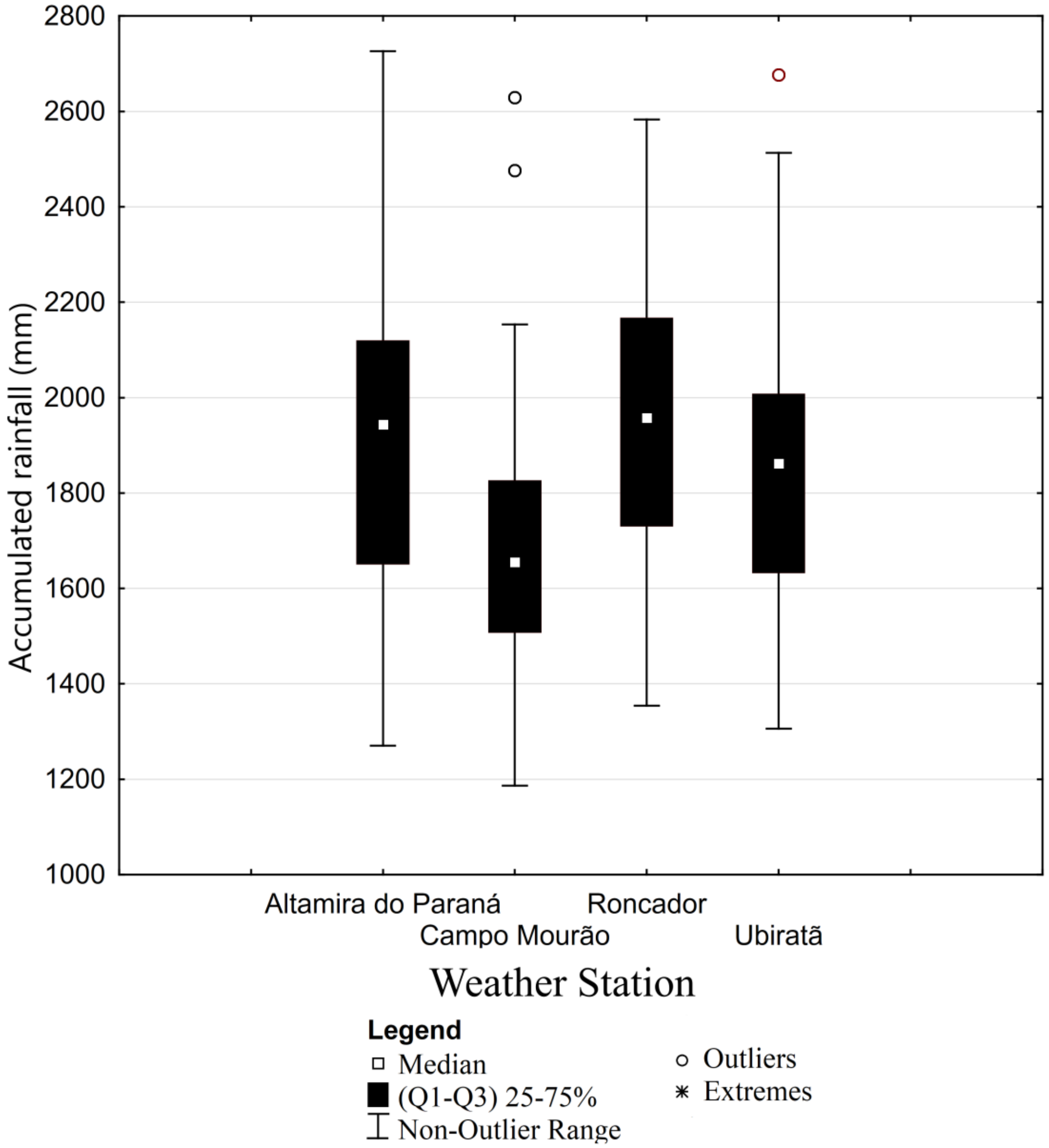
As verified by researchers Berezuk (2017) and Caldana et al. (2019) heated and low altitude areas in Paraguay tend to raise the heated air adiabatically and form isolated storm clouds or nuclei of convective systems. These systems cause a rapid change in pressure causing a change in the wind pattern and strong gusts, lightning strikes, intense and punctual rains and, in few cases, hail ocurrences (FERREIRA, 2006).

The differential warming between the lower altitudes of Paraguay and Paraná / Mato Grosso do Sul, tend to aid the displacement of these convective systems in the Western-Eastern direction. If the topography rises in altitude in this direction, the air will rise with greater force, even if it is not rain of the orographic type, the instability in this direction will intensify causing more rains in these areas (BEREZUK, 2017; CALDANA et al., 2019). Thus, there is a greater accumulation of rainfall in the annual average in the areas where the topography increases altitude in the direction of displacement of convective instabilities, the pattern is repeated with the Mesoscale Convective Complexes.

A similar process occurs with cold fronts, another instability that causes rain in Paraná state. These have preferential displacement of Southwest-Northeast or Southern-Northern in Paraná, as identified by Berezuk and Sant'Anna Neto (2006) and Caldana et al. (2021). If the shape of the topography increases the altitude in the direction of displacement of the cold front instability line, these areas tend to have a greater accumulation of rain than the areas where the topography decreases in this direction. At MCOPR, this can be verified considering the difference in average annual rainfall between the high region of Roncador (1,952 mm) and the region of Campo Mourão (1,677 mm).

The box plot graph (Figure 03) was used to analyze the annual precipitation variability, allowing a better interpretation of the data through the amplitudes, interquartile variation and median position. All the analyzed stations exhibited a significant amplitude of the precipitation, thus, it was verified extremely rainy and dry years.

Figure 03 - Annual variability of precipitation (from 1976 to 2019) at MCOPR.



Source - ANA (2020). Organized by authors (2020).

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The analysis of data from the Altamira do Paraná rainfall station showed the highest precipitation height, with a maximum of 2,726 mm. The box for this station had a median of 1,943mm and a variation from Q1 to Q3 between 1,653 to 2,118 mm, registering the highest interquartile range. While the Roncador station, compared to the first (Altamira do Paraná), has a height close to the median (1,957 mm) and Q3 (2,166 mm), Q1 was higher with 1,738 mm. Even though Altamira do Paraná has the highest rainfall, the minimum rainfall (1,270mm) is below that of Roncador (1,354mm), so the first station has a drier period than the second, with great rainfall and periods of low rainfall.

For the Ubiratã station, the intermediate position is evidenced by the registration of maximum annual precipitation of 2,513 mm and minimum of 1,306 mm, showing a significant amplitude. The Q1 and Q3 shows a variablity from 1,632 mm to 1,999 mm and the median was 1,853 mm, with an interquartile range and median less than the two mentioned above. Up to 50 % of the pluviometric heights are concentrated below 1,853 mm, while the largest 25 % are between 1,999 and 2,513 mm. Divergent heights are verified at 2,676 mm.

The municipality of Campo Mourão, among the four pluviometric stations, recorded the smallest and most disparate precipitation heights, with a maximum of 2,153 mm and a minimum of 1,186 mm. The interquartile range had a height of 1,507 to 1,808 mm and the median 1,644 mm, which means up to 50 % of the precipitations are concentrated below this value, exhibiting a higher occurrence of dry periods than the other stations analysed. Still under analysis at this station, there are two discrepancies in the accumulated annual rainfall, with a record of 2,629 mm and 2,476 mm.

Average annual precipitation aids to study the precipitation over a long period in an area, however, only with this parameter it is not possible to study and verify the variability. For this, were used a box plot graph of the variations in monthly precipitation (Figure 04), showing the transformations each month for the four stations evaluated, in the MCOPR.

In the first three stations (Altamira do Paraná, Campo Mourão and Roncador), January showed the rainiest and with the highest median, indicating that among all this is the month in which even the first 50 % of precipitation records are the highest. The exception occurs for the station from the municipality of Ubiratã, Western area of MCOPR, which recorded a median of 187 mm in October while was verified 182 mm, in January. The month of May is the one with the greatest amplitude, which were verified a significant contrast between height of low and high precipitation, with great variation in all pluviometric stations. The month of August, Winter in Southern hemisphere and typically dry, were verified lowest rainfall and median heights.

This precipitation behaviour during October was also identified in all the Western region of Paraná. Caldana et al. (2020), identified the wettest month, in the Paraná state (except the Metropolitan of Curitiba) is January, while the entire Western region and this fragment of the Western Center, the wettest month is October, due to instabilities formed at high temperatures in Paraguay and advancing over the Paraná state. The proximity of the Western region of Paraná to Paraguay, ensures that these convective systems have a greater impact on the rains this month, than in the rest of the state.

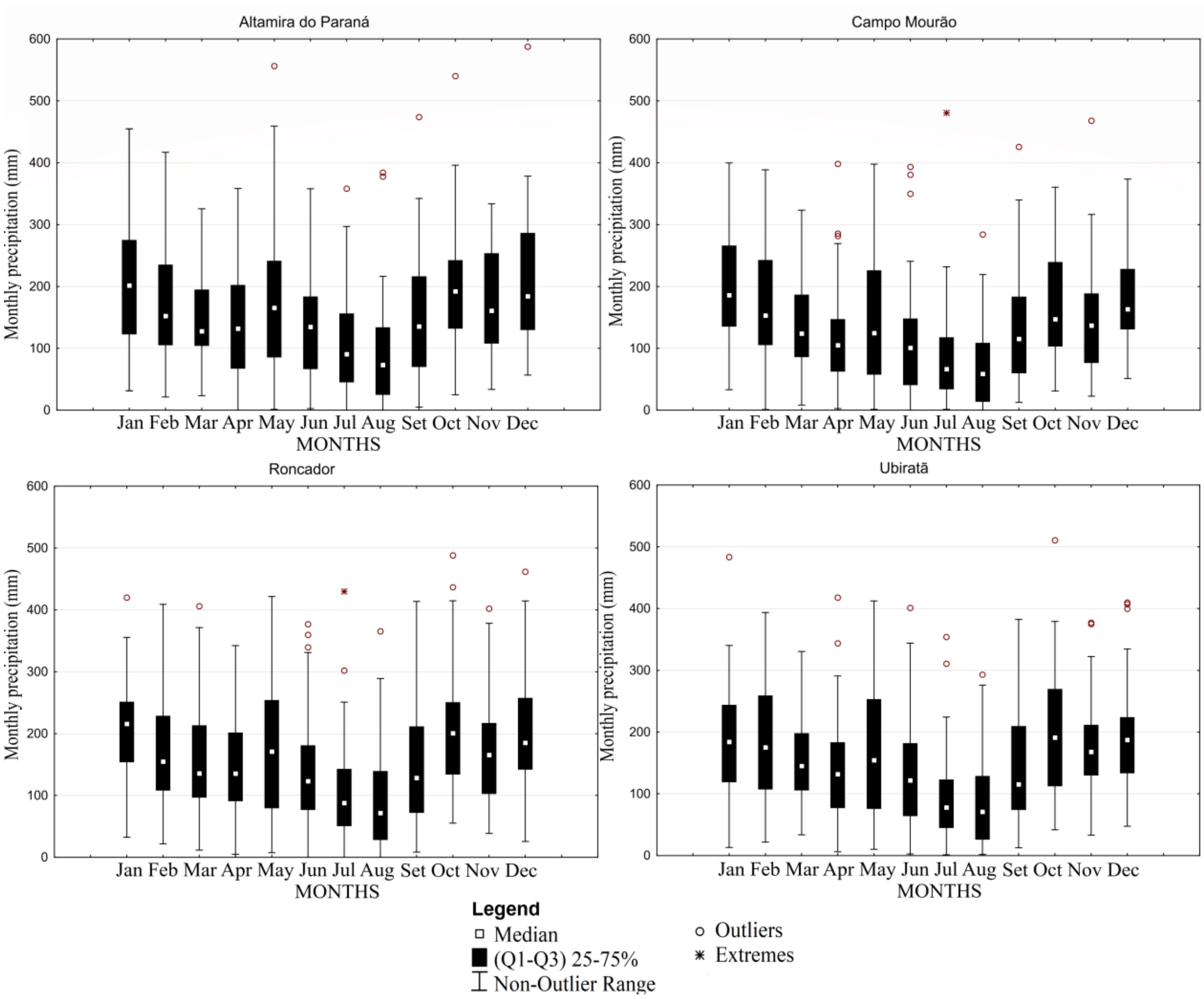
The Altamira do Paraná station showed a low interquartile range for all months compared to the others, the lowest in March with 89 mm of variation between Q1 and Q3. The highest rainfall recorded in December 1981 with 587 mm, and 25 % of the highest precipitation heights are above 276 mm for the same month and showing a variability from 263 and 454 mm, in January. The driest are in April, July and August with 0 mm of precipitation recorded, the verified precipitation height was 75 mm in 50 % of the years for August, even considering the location of the Southern area of MCOPR where the inclination of the topography towards instability aid to precipitation ocurrences.

It was verified a variation between Q1 and Q3 along the months analysed from the Campo Mourão station. In April, it was verified the value of 81 mm, the smallest interquartile range and 3 differing precipitation heights (269 mm; 281 mm; and 398 mm, respectively). The Q1 for August is the lowest in the series, with up to 25 % of the years showing less than 14 mm of precipitation, in addition, it was verified an extreme precipitation occurrence (480 mm), in July 2015.

In Roncador station it was verified a little variation in the interquartile range between months. July and August are the driest, with 25% of the years analyzed being concentrated below 50 mm and 29 mm, respectively; however, it was verified an extreme precipitation occurrence, a value of 429 mm in July 2015.

The months are different for the Ubiratã station, with February, May and October exhibited the largest and July and November the smallest variations between Q1 and Q3. Even though August is drier than July, as up to 25 % and 50 % of the years recorded lower precipitation heights, the 25% higher records were above, with a variation of 122 to 275 mm for the first and 110 to 224 mm for the second.

Figure 04 - Monthly variability of precipitation (from 1976 to 2019) at MCOPR.

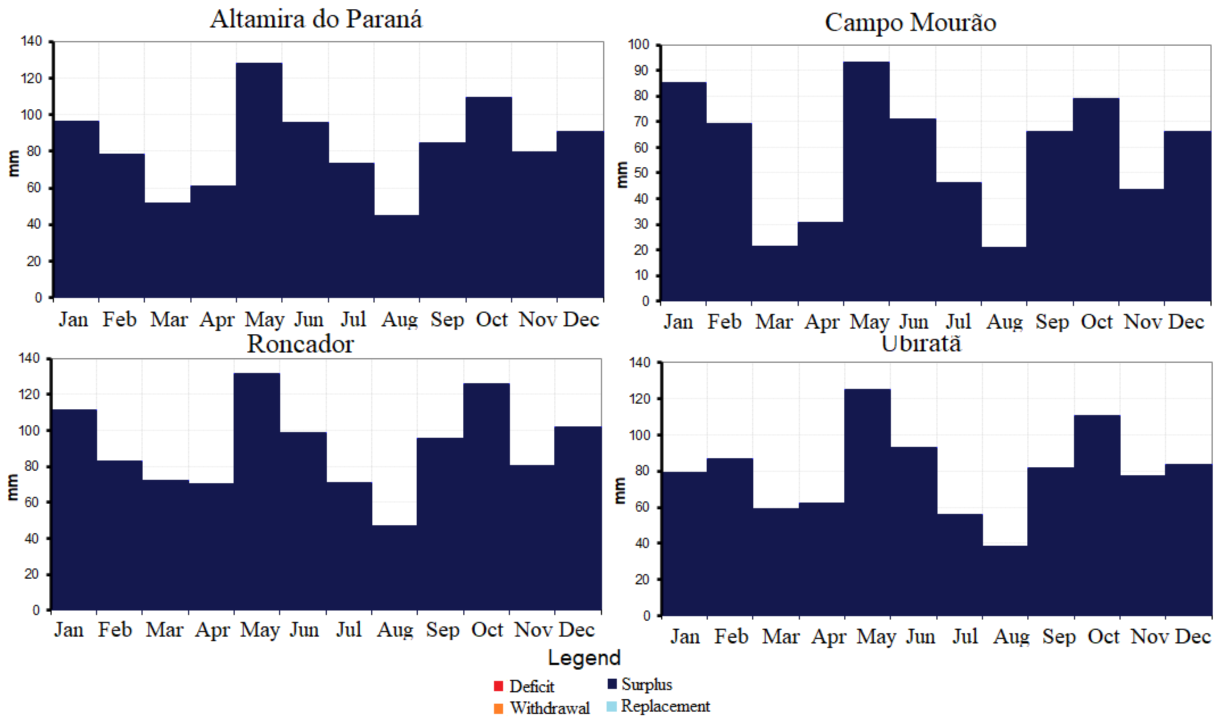


Source - ANA (2020). Organized by authors (2020).

The climatological water balance (CLIMWB) (Figure 05) for MCOPR was analyzed in order to verify the water surplus or deficit and the impacts on the soil, and consequently, for agricultural practice in the region, correlating the occurrence of precipitation, with temperature and evapotranspiration, as way to subsidize information for agriculture. As previously noted, there were very dry and rainy months and years; however, the water balance was positive for all months of the four stations verified.

Through the analysis of the water balance, the month of May it was verified as the most positive and that of August with the smallest surplus. Even though January is the rainiest in the previous analyses, May showed a greater balance, since the first fits in the summer of the southern hemisphere receiving more energy and occurring more evapotranspiration than in May; while it is in May that there is a significant precipitation and low temperature and evapotranspiration, in the transition between Fall and Winter (NITSCHE et al., 2019). August is a transition month between winter and spring in the region, starting to increase the temperature and evapotranspiration concomitantly with low rainfall, resulting in the smallest water surpluses for MCOPR.

Figure 05 - Average Climatological Water Balance (CLIMWB) (from 1976-2019) at MCOPR.



Source - ANA (2020). Organized by authors (2020).

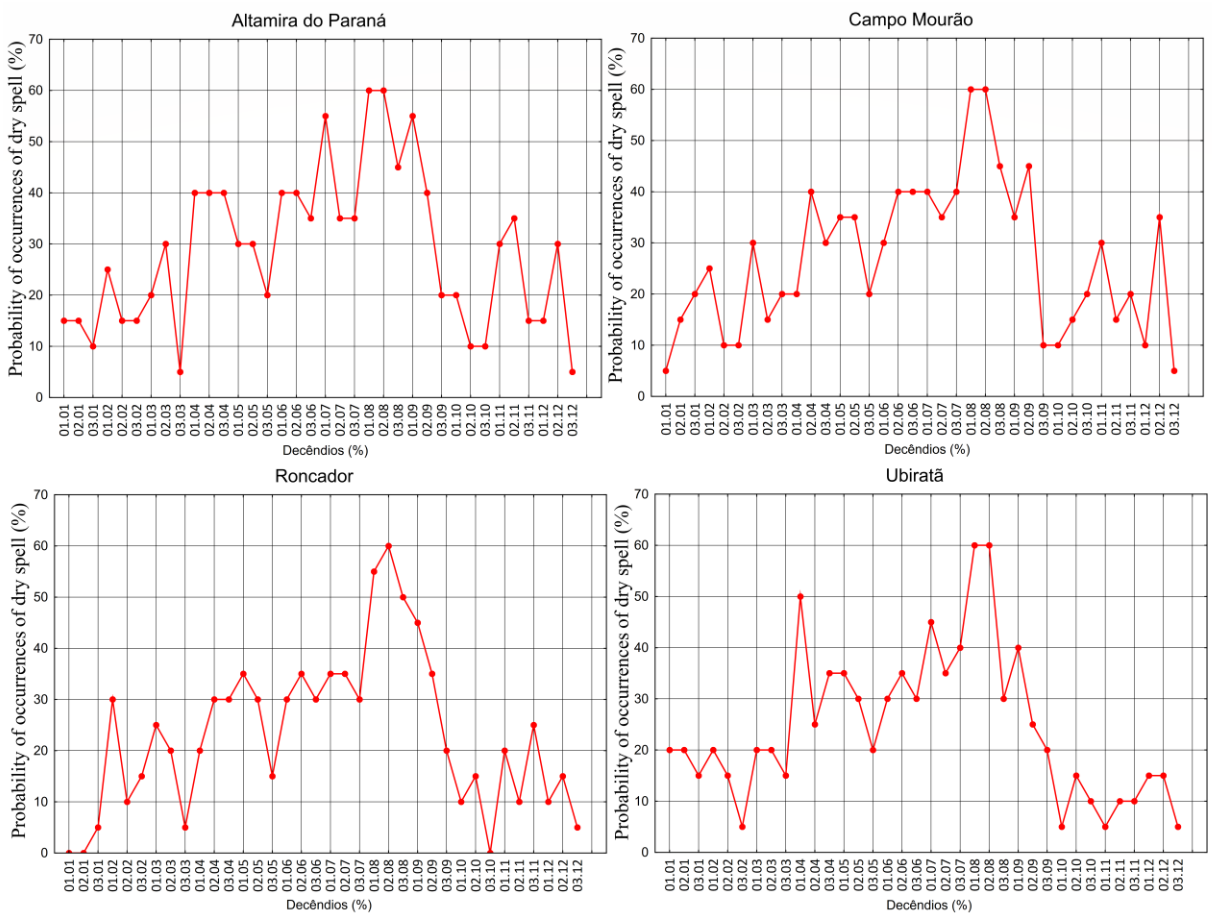
Campo Mourão stood out for recording in April and August the smallest water surplus of all stations, with 20 mm for both. In January and October Roncador exhibits greater surpluses than the others, due to the location to the Southeast, which aid the precipitation indexes, thanks to ascending slope of the topography.

In a distance of less than 100 km, in the Western of Paraná, Caldana et al. (2020) identified a significant change in the water balance. In the Guaíra and Foz do Iguaçu stations, the water balance showed negative values, with water deficit in the months of January and March. While in the São Miguel do Iguaçu and Toledo stations, the pattern is similar to that of MCOPR, with positive water balance extract along the year and with greater surpluses in the months of May and October.

The probability of dry spell (Figure 06) shows for all analysed stations, August exhibited a highest risk, with a 60 % probability of occurrence of dry spell. January and December were among the lowest percentages in all cases, coinciding with periods of heavy rainfall and water surplus from previous analyzes.

Roncador was the only one with records of 0 % probability of occurrence of dry spell, for the months of January and October. In Altamira do Paraná, July and November were also at high risk, verified 55 %. And April showed a high probability for Ubiratã (50 %).

Figure 06 - Probability of occurrences of dry spell during ten-day series (from 1976-2019) at MCOPR.



Source - IDR (2020). Organized by authors (2020).

Ferreira et al. (2020) verified the probability of occurrence of dry spell during the soybean crop cultivation, in the Western Mesoregion of Paraná state. As soybean cultivation begins in September, the researchers analyzed the ten-year series, from September to March. The analysis for the period showed similar results when compared to MCOPR, with a significant less probability to occurrence of dry spell from September to October; while it was verified fluctuations of 20% between November and January and a slight increase in February and March.

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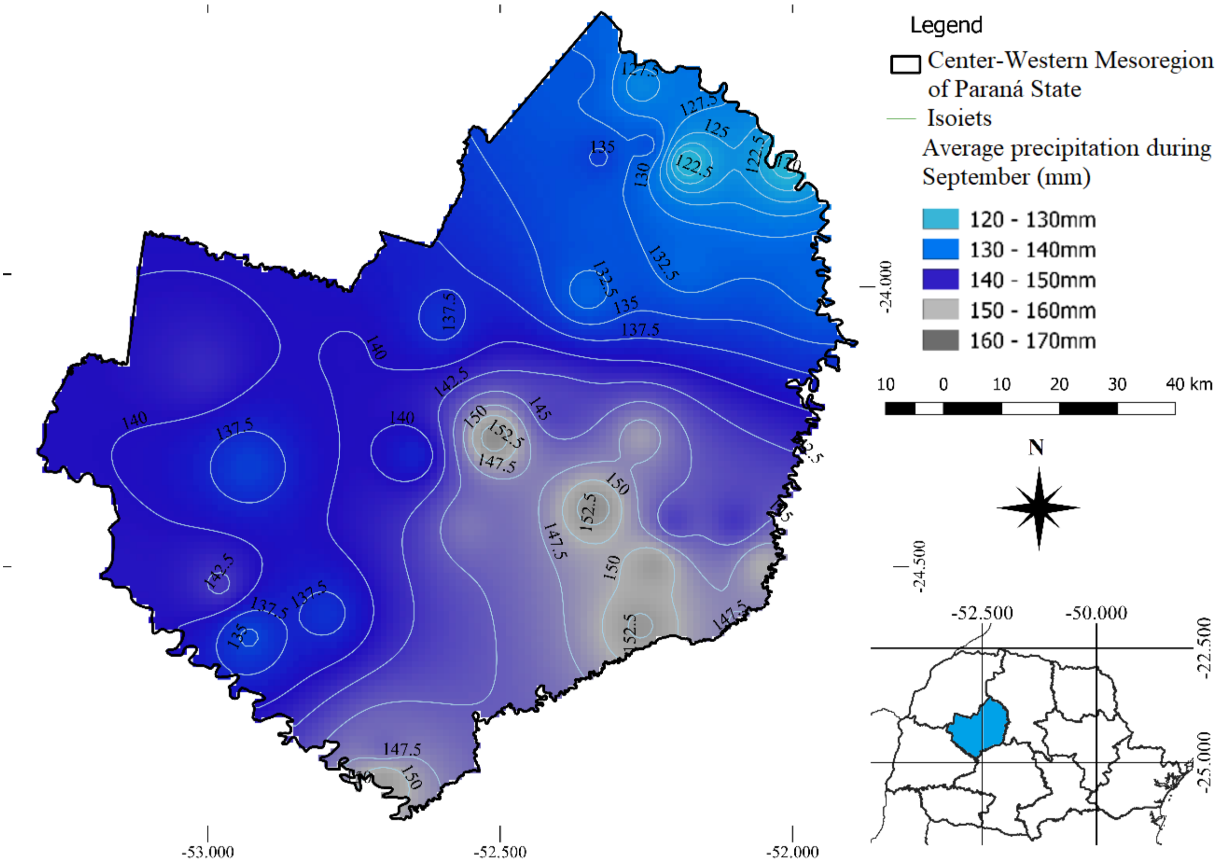
For the case study, were analyzed the average rainfall in September (Figure 07), in order to verify the historical series from 1976 to 2019 and to infer the precipitation variability in the MCOPR, in contrast and in isolation to September 2020.

The average for September was uniform with a maximum average of 154 mm and a minimum of 117.5 mm. The highest heights were recorded in the Southern and Southeast areas from the MCOPR, coinciding with the same areas of greatest annual average precipitation, exhibiting a variability from 125 to 150 mm. The lowest pluviometric heights also coincided with the annual average, registering a variation of 122.5 to 135 mm in the far Northern.

Figure 07 - Average precipitation during September (from 1976 to 2020) at MCOPR.



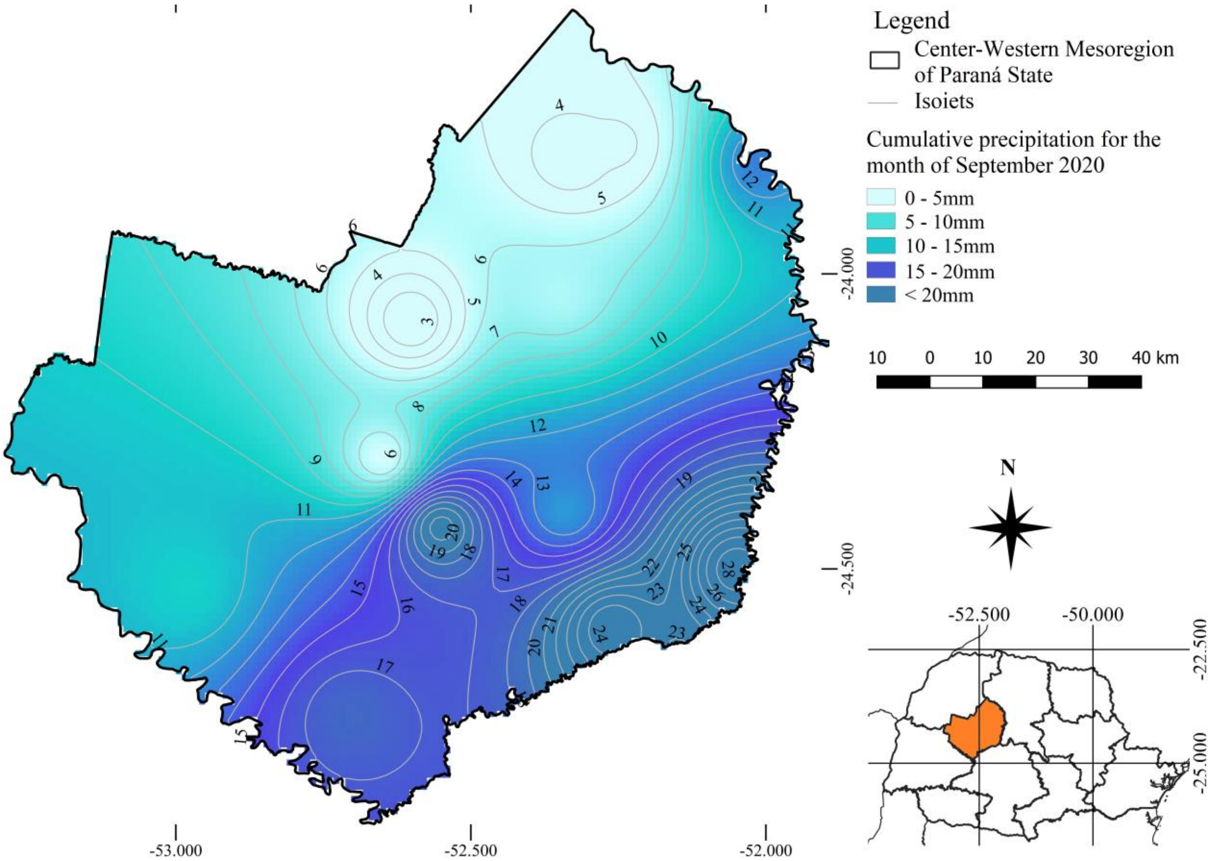
Source - ANA (2020); IDR (2020). Organized by authors (2020).

As noted, the entire region has recorded on average since 1976 at least 120 mm of precipitation during September. The scenario was quite different in 2020 (Figure 08), the Eastern and Southeastern regions from the Mesoregion were those with the highest precipitation verified, as in all previous analyzes, but with values much lower than the other findings.

The Roncador station showed 28mm, the highest record in MRCOP, while Campo Mourão and the entire Northern area showed precipitation between 3 and 6 mm, once the driest September since data have been recorded for this region. There was a reduction of more than 100 mm, in relation to the average, in the entire Mesoregion.

The month of September started with the performance of a mass of dry and hot air, which opposed an intense mass of cold air that acted on the South of Brazil and caused great instability and accumulated precipitation. The region had an average of approximately 200 mm (SIMEPAR, 2020) between August 23 and 31, well above the August average (60 mm - Figure 04). The atmospheric pattern has undergone drastic changes.

Figure 08 - Total precipitation for September (2020) at MCOPR.



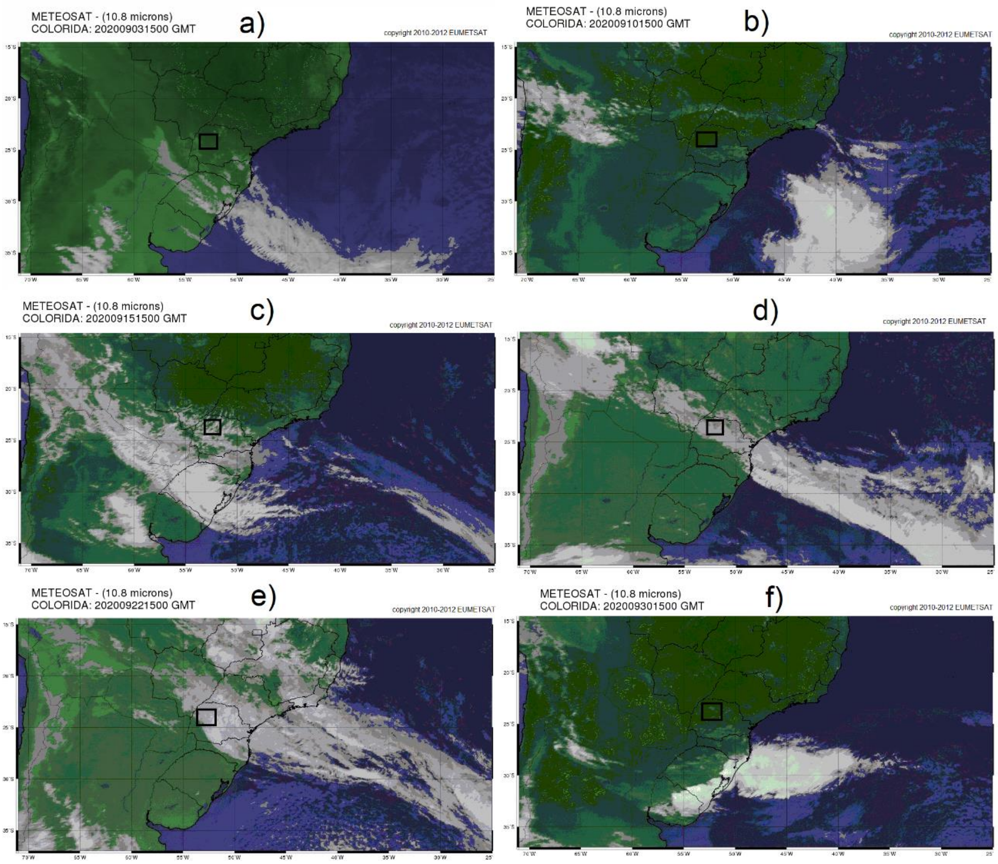
Source - ANA (2020); IDR (2020). Organized by authors (2020).

The great volume of precipitation was quickly lost with the advent of a mass of dry and hot air (Figure 09a) that settled from the states of Mato Grosso and Goiás to the interior of Paraná and Santa Catarina. This mass of air caused a great rise in temperature and a sharp drop in air humidity. This atmospheric pattern formed a block, which prevents the formation and advance of cold fronts, and consequently, events of precipitation. The cold air mass, which arrived in Rio Grande do Sul state in the first week of September (Figure 09a), forming great atmospheric instability and precipiation, but this blockade over Paraná prevents the cold front from advancing, making the front stationary in the Rio Grande do Sul until it advances into the ocean (SIMEPAR, 2020).

The MCOPR remained under the influence of this intense mass of dry and hot air until the 15th with temperatures above 35° C and humidity below 25 %, when the wind direction changed from the north (Figure 09b) (bringing dry, hot and with particles from the burning of the Brazilian Pantanal), to the Eastern (less heated and more humid air - Figure 09c). On day 18 (Figure 09d), there was a record of 0.6 mm rain in Campo Mourão and 2 mm (maximum in the region, in Roncador). After this small instability, the wind returned to the north, raising the temperature a lot and with a significant drop in humidity (SIMEPAR, 2020).

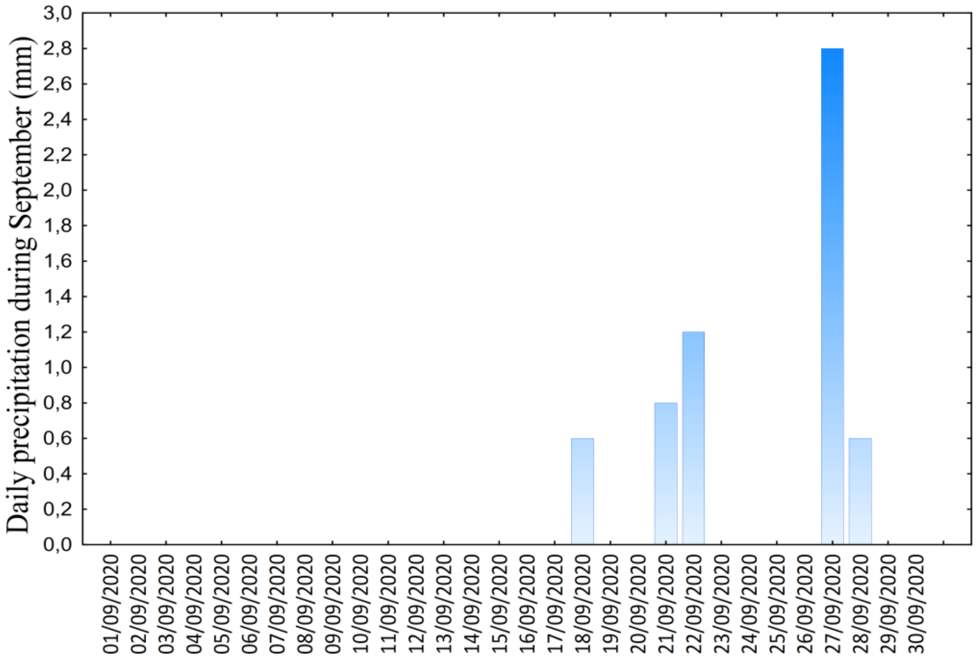
In Campo Mourão there was still rain on days 21 (0.8mm), 22 (1.2mm) (Figure 09e), 27 (2.8mm) and 28 (0.6). Totalling 6 mm accumulated (Figure 10), being less than half of the driest month in this location, which was 12.8 mm in 1988. Temperature records were also broken. The highest temperature record so far in Campo Mourão, was 39 ° C in 2011, on September 30, 2020 (Figure 09f) 40.3°C (SIMEPAR, 2020) was recorded in the same station.

Figure 09 - Satellite image from COLOR IR 9, extracted 3 p.m of the selected days for Brazilian Center-Southern.



Source: CPTEC (2020). Organized by authors (2020).

Figure 10 - Daily precipitation during September (2020) at MCOPR (From station of Campo Mourão).



Source - ANA (2020). Organized by authors (2020).

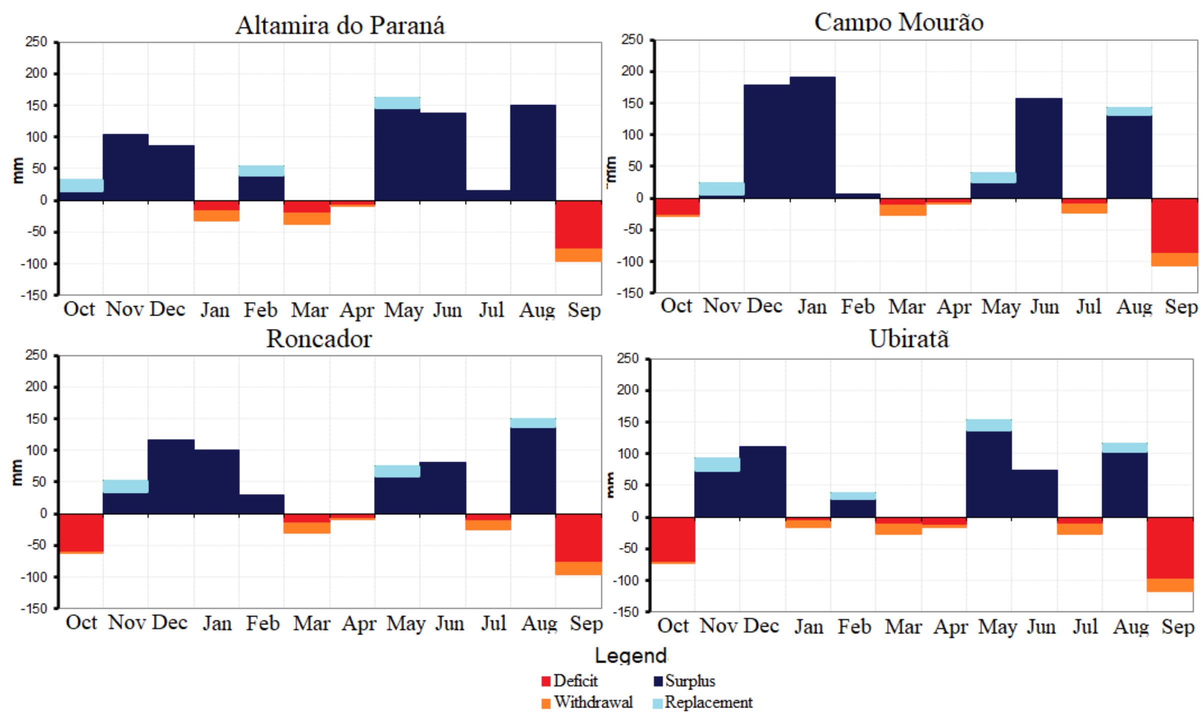
A factor that greatly interferes with the amount of precipitation in Paraná state, as in all of Southern Brazil, is the phenomenon El Niño-South Oscillation (ENSO), as identified by Terassi et al. (2018), analyzing the variability of the standardized precipitation index in the Northern Region of the Paraná state associated with the El Niño-South Oscillation Events among the key results, it was shown that the most intense events of El Niño and La Niña influenced the variability annual precipitation.

The events of El Niño of 1976, 1982, 1983, 1987, 1992, 1997, 1998, 2009 influenced to determine years of rain higher than normal climatological, while the events of La Niña of 1985 and 1988 coincided with the reduction of rains. However, a visual analysis demonstrated that the El Niño and La Niña events do not necessarily correspond to positive or negative rain anomalies in the study region, since the years of high rain and characterized by El Niño in 1997 / 1998 showed categories between moderately dry to extremely dry. It should be noted that the month of September 2020 is at the beginning of La Niña (NOAA / CPC, 2020).

As for drought with the synoptic look, Jacondino et al. (2019) performed the Analysis of Intense Dry Spell in the South Region of Brazil and Associated Synoptic Conditions; and identified the different magnitude over the cold seasonal period (May to September). The average magnitude is minimal in May and highest in August and September in RS and SC. The local incidence is also not homogeneous in magnitude, where localities in RS with the highest average magnitude are outside the Western region with the highest frequency of occurrence. There is a clear variable pattern from south to north in the magnitude of the phenomenon over the region, with more intense events over RS, decreasing for intermediaries over Santa Catarina and minimums in Paraná state. Although the work has not identified changes in the dry spell pattern for the month of September, as identified in 2020, future work can identify whether there is a significant trend for this month and can be included in the months with the greatest chance of dry spell.

The drought response observed in September 2020 can be seen in the limatological water balance (CLIMWB) extract for the last twelve months (Figure 11), quite different from the average (Figure 05). The last year had already had below average rainfall in several months, with a water deficit in the months of October (2019), March, April and June (2020). The only different pattern was observed in Altamira do Paraná, the Southernmost station in the mesoregion, which had a deficit in January instead of October.

Figure 11 - Climatic Water Balance (CLIMWB) from October (2019) to September (2020) at MCOPR.



Source - ANA (2020). Organized by authors (2020).

The worst scenario was in Ubiratã, with a deficit / withdrawal of soil water above 120 mm in September 2020. Even with the significant rains in August, the hottest-than-normal month (NITSCHE et al., 2019) linked to low rainfall caused rapid withdrawal and water deficit along the region.

The knowledge of the particularities of climate and soil of the region chosen for planting, assist in the choice of crop to be cultivated and aid the decision-making, reducing losses, however, it is should be noted that the occurrence of climatic changes can harm the potential productivity, as this factor comes from an event unexpected, which not even the slightest care can minimize the effects. According to the APROSOJA (Brazil, 2019), it is estimated that the drought losses of the 2018/2019 soybean crop will reach 16 million tons, with the state of Paraná being the hardest hit, with a loss of 30 %.

In addition to soybeans, corn and coffee were also affected by the irregular distribution of precipitation, in the Paraná state, according to the "Noticias Agrícola" website (2020), climatic instability has occurred in the state since February this year and despite expectations of good harvests from producers, the lack of water in the region has harmed the development of crops and consequently productivity.

Water is a primordial factor for the growth and development of every specie. In plants the water requirement varies according to the species metabolism rate and cycle, so it may require more or less water depending on the physiological stage in which it is found, due the water affects in all physiological process, as cellular functioning, nutrient transport and root absorption (TAIZ et al., 2017).

CONCLUSIONS

The annual precipitation at MCOPR exhibited well distribution annual distribution, with average values around 1,800 mm, however when analyzing the annual variability, it was identified that dry years, with values below 1,200 mm.

The same pattern is repeated with monthly rainfall, with months showing more than 500 mm between the rainiest and driest. All this variability has an effect on the water balance, on average; and every month has a positive extract, however, in dry years, the patterns are quite different, as in 2020, and especially during the occurrences of dry spells, in which months such as August, showed 60 % probability of occurrence.

Reflection of this great variability occurred in the year 2020, which with a series of data older than 40 years, exhibited the driest month in history, much attributed to the current atmospheric circulation with atmospheric blocks caused by the intense mass of hot air linked to the fires in the Brazilian Pantanal and Amazon.

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