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ANALYSIS OF PRECIPITATION AND INDIAN SUMMER IN PARANÁ STATE, BRAZIL – STUDY OF CASE IN APRIL 2021

Análise da Precipitação e de Veranico no Estado do Paraná, Brasil – Estudo de Caso do Mês de Abril de 2021

Análisis de lluvias y verano en el estado de Paraná, Brasil - Estudio de caso para el mes de abril de 2021

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Abstract: One of the key negative impacts of climate change are the fact of dry periods occurrences are becoming common. For this context, the objective of this study was to carry out the analyze of the precipitation variability in stations in the Paraná State, Southern Brazil, focusing on the month of April. For this, rainfall heights were analyzed, box plot graphics and probabilities were created to identify the regional precipitation behaviour, in addition to the graphical and satellite images of the April 2021 precipitation. It was identified that April 2021 was the driest in history, due to atmospheric blockages and dry air masses, which, despite being common this time of year in the Paraná State, were more intense this year, impacting the climatological water balance (CLIMWB), which had already been

negative across last year, the impacts were felt the most in Londrina and Cascavel, areas with a concentration of agronomic activities, which may register productivity losses due to the drought this month. A trend of reduced rainfall this month may be occurring, since when analyzing the series for decades, the last (2011-2020) had already been the driest in history, with the exception the meteorological station of Curitiba.
Keywords: Rains. Climatic risks. Extreme events.

Resumo: Episódios de seca estão se tornando cada vez mais frequentes no cenário de mudanças climáticas. Desta forma o objetivo deste trabalho foi analisar a variabilidade pluviométrica e a ocorrência de veranicos no Estado do Paraná, com enfoque para o mês de abril, em que foi realizado um estudo de caso para o ano de 2021. Para isso, foram analisadas as alturas pluviométricas, criou-se gráficos de box plot e probabilidades para identificar o comportamento pluviométrico regional, além da análise gráfica e de imagens de satélite das chuvas de abril de 2021. Pelo estudo de caso, identificou-se que abril de 2021 foi o mais seco da série histórica. E isso ocorreu, devido a atuações de bloqueios atmosféricos e massas de ar seco, que por mais que sejam comuns essa época do ano no estado, apresentaram maior intensidade nesse ano, causando impacto no balanço hídrico, que já vinha sendo negativo no decorrer do último ano. Os impactos foram mais sentidos em Londrina e Cascavel, áreas com concentração de atividades agrícolas, que podem registrar perdas de produtividade com a seca neste mês. Uma tendência de redução das chuvas neste mês pode estar ocorrendo, visto que ao analisar a série por décadas, a última (2011-2020) já havia sido a mais seca da história com exceção de Curitiba.
Palavras-chave: Chuvas. Riscos climáticos. Eventos Extremos.

Resumen: Los episodios de sequía se están volviendo cada vez más comunes en el panorama actual del cambio climático. Así, el objetivo de este trabajo fue analizar la variabilidad de las precipitaciones en las estaciones del Estado de Paraná, con foco en el mes de abril, en el cual se realizó un estudio de caso para el año 2021. Para ello se analizaron las alturas de precipitaciones. Se crearon diagramas de caja y probabilidades para identificar el comportamiento de las lluvias regionales, además del análisis gráfico y imágenes de satélite de las lluvias de abril de 2021. A través del estudio de caso, se identificó que abril de 2021 fue el más seco de la historia. Y esto ocurrió por bloqueos atmosféricos y masas de aire seco, que, a pesar de ser comunes en esta época del año en el estado de Paraná, fueron más intensos este año, impactando el balance hídrico, que ya había sido negativo durante todo el año pasado, los impactos fueron Se sintió más en Londrina y Cascavel, zonas con una concentración de actividades agronómicas, que pueden registrar pérdidas de productividad debido a la sequía de este mes. Puede estar ocurriendo una tendencia de disminución de las precipitaciones este mes, ya que al analizar la serie durante décadas, la última (2011-2020) ya había sido la más seca de la historia, a excepción de Curitiba.
Palabras clave: Lluvias. Riesgos climáticos. Cambios climáticos.

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1. INTRODUCTION

The conditioning and development of meteorological elements is not static, they show certain dynamics that can vary in magnitude and frequency, over time and from one place to another (BARRY; CHORLEY, 2009; GORDON, et al., 2016; SCORER, 1997), following territorial peculiarities at different scales of approach. These elements, of course, are objects of studies that seek to understand climate change and its recent effects (BOCCHIOLA et al., 2019; D'AGOSTINO; SCHLENKER, 2016; LIANG; GONG, 2017; PRĂVĂLIE et al., 2020; WANG et al., 2017). Analysing meteorological phenomena, climate change and its intensity exhibit negatively impacts the resilience of environments (BONFANTE et al., 2018), becomes notorious for determining improvements in the social and socioeconomic processes of human actions.

The occurrence of the indian summer is characterized by subsequent days without precipitation during the rainy season (AYOADE, 2007), with serious consequences for agriculture and water supply (ASSAD, 1994; SIFER et al., 2016; BAKO et al., 2020). Among the economic activities, agriculture is one of the most dependent on weather conditions (ANGELOCCI et al., 2002; CHAVAS et al., 2019), therefore, the occurrence of dry spells can have a direct impact, increasing water stress and harming the crops yields (FREITAS et al., 2014; KISAKA et al., 2015).

Precipitation is the most important element for tropical and subtropical areas, where its variable distribution affects crop performance (PEEL et al., 2007; SIFER et al., 2016). Water is of fundamental importance for all plant physiology processes, including root absorption, nutrient transport, thermoregulation and hydration, in addition, it is essential to maintain plant cell activity and its structure (BHATLA; LAL, 2018). The Paraná state has agriculture as a developed economic activity (FERREIRA et al., 2020). Thus, studies that show the occurrence of dry spells are fundamental for agricultural planning and help in decision-making, helping to make agriculture resilient and sustainable.

Although the Paraná state is one of the wettest in Brazil (CARAMORI et al., 2008), several studies suggest the occurrence of periods of drought in its interior (SANTOS et al., 2018; CALDANA et al., 2021; SALTON; MORAIS; LOHMANN, 2021). In the Western Mesoregion, Ferreira et al. (2020) identified a high probability of occurrence of periods of drought, between autumn and winter; Salton; Morais and Lohmann (2021) identified that periods of extreme and moderate drought may occur more frequently during La Niña, while periods of weaker drought under El Niño conditions, however, in this case, there is no trend of increasing or decreasing indian summer for the different regions; Caldana et al. (2021) pointed out that the analyzes of these climatological events are relevant for the planning and decision-making of agricultural management, since these events are responsible for losses or even crop failure.

Paraná state, South of Brazil, is in an area of climatic transition, with great variations in altitude and latitudinal effect, conditioning significant differences in its climatic variability (CARAMORI et al., 2008).

Thus, the objective of this work was to analyze the rainfall variability in meteorological stations in Paraná State, focusing on the month of April, in which a case study was carried out for the year 2021.

2. MATERIAL AND METHODS

2.1 Area of study

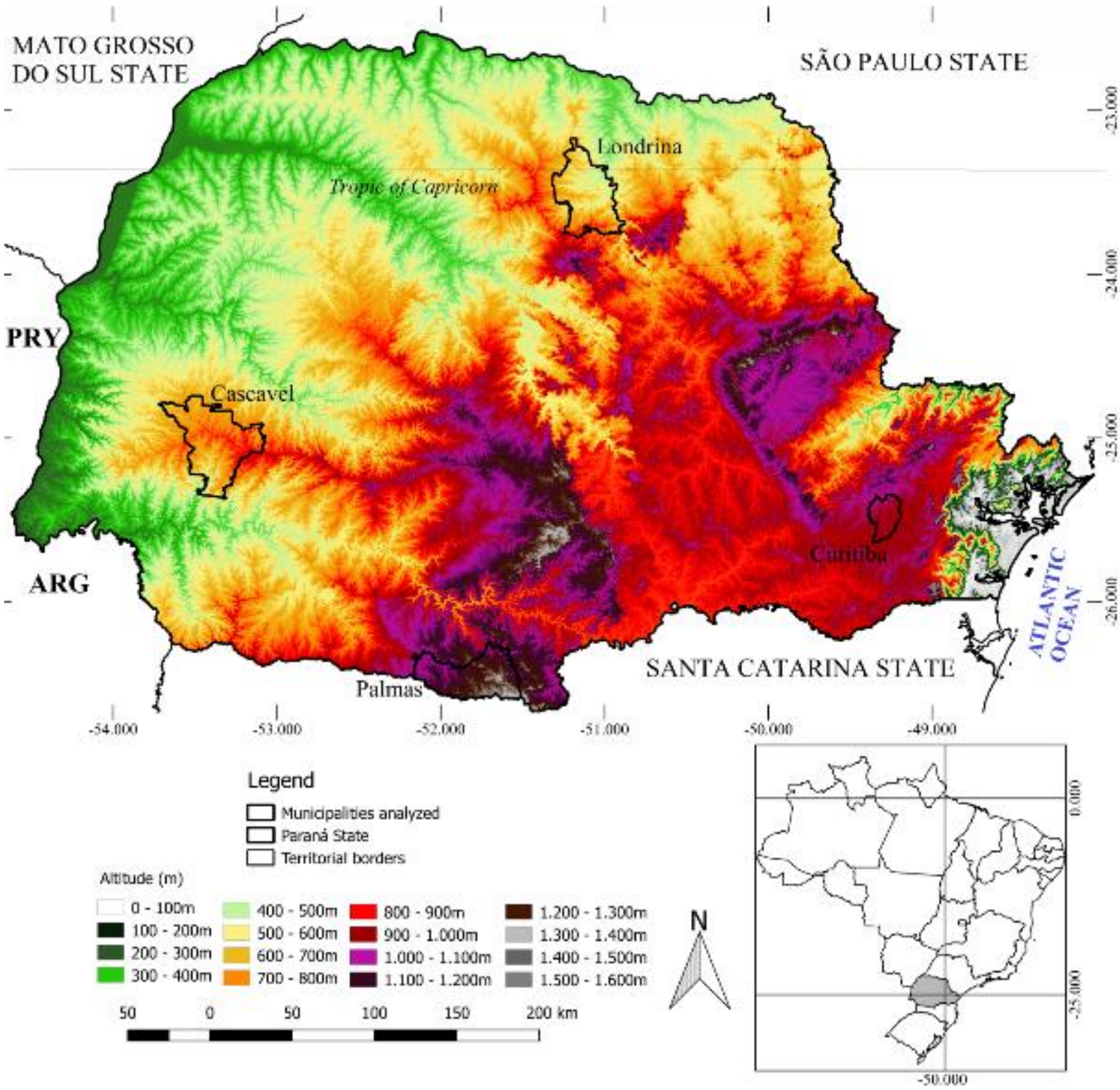
The Paraná state, located in South of Brazil, has an area of 199,315 km² (IBGE, 2020). The topography of Paraná shows a high variety: altitudes vary from 0 m, at sea level, in Far East of the state, to the shores of the Atlantic Ocean and reaches peaks of 1,200 m in its interior, and 1,800 m in Serra do Mar (Figure 1).

The climate of Paraná state, as its topography, exhibits significant variability due its considered as an area of climatic transition with the crossing of the tropic of Capricorn in the North of the state, in Londrina region, therefore, the latitudinal variation, interferes in the climate variability of the state (CARAMORI et al., 2008; CALDANA et al., 2019).

In the North, West and Coast regions, the climate classification "Cfa" predominates, with subtropical characteristics, with no defined dry season and hot summer, according to Köppen climate classification of 1936. The Center-South and East regions are classified in as "Cfb" of subtropical climate, without dry season and cold summer (NITSCHE et al, 2019).

The average annual precipitation varies from 1,000 mm in the far north of the state to 2,600 mm in the sea mountain, while the average air temperature varies from 14 °C in the mountains to 24 °C in the far northwest (NITSCHE et al, 2019).

Figure 1 - Spacialization of the meteorological stations and topography of Paraná state.



Fonte: authors (2021).

2.2. Statistical analysis

For the characterization of precipitation in Paraná state, were used data from eight meteorological stations, including the Instituto de Desenvolvimento Rural do Paraná (IDR-Paraná), Sistema Meteorológico do Paraná (SIMEPAR) and the Agência Nacional de Águas (ANA) (Figure 1 and Table 1), with a time frame from 1976 to 2020. In addition, data from April 2021 were used to carry out the case study.

Table 1 - Climatic information from the stations analyzed.

State Agency (data)	Station (Municipality)	Longitude	Latitude	Altitude	Average annual precipitation	Average annual temperature	Historical Series
SIMEPAR	Cascavel	-53.33	-24.53	660m	--	19,6°C	2000-2020
ANA	Rio do Salto (Cascavel)	-53.32	-25.12	606m	1.910,2mm	--	1976-2020
ANA	Curitiba (ANA)	-49.8	-25.25	985m	1.491mm	--	1976-2020
SIMEPAR	Curitiba (SIMEPAR)	-49.23	-25.44	929m	--	17,1°C	2000-2020
IDR	Londrina (IDR)	-51.10	-23.23	585m	1.637,2mm	--	1976-2020
SIMEPAR	Londrina (SIMEPAR)	-51.10	-23.23	585m	--	21,2°C	2000-2020
IDR	Palmas (IDR)	-51.59	-26.29	1.110m	2.129mm	--	1976-2020
SIMEPAR	Palmas (SIMEPAR)	-51.59	-26.29	1.110m	--	16,4°C	2000-2020

Fonte: authors (2021).

To study rainfall variability across these meteorological stations, graphics in Box Plot format were used, to analyze: the measure of its dispersions around the mean through standard deviation, the position of its median, that demonstrates where 50% of the data is located, its asymmetry and the presence of outliers (LEM et al., 2013; SCHNEIDER; SILVA, 2014). It is an effective method to analyze rainfall variability, due its exhibits extremes and outliers in historical series (DEVAK; DHANYA, 2014).

The box plots represent classifications of values, they are: median, outliers and extremes, and in addition 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; DA SILVA, 2014). Outliers are divided into outliers (values above the maximum, but not extremes) and extremes, with any values being considered, according to equation 1.

$$< Q3 + 1.5\ (Q3 - Q1) \text{ or } > Q1 - 1.5\ (Q3 - Q1) \quad (1)$$

The spatialization of these data was performed by interpolation, is an effective method for the spatial visualization of climate data (BERNDT; HABERLANDT,2018). To aid the study, were used isohyets or spatially filling the values to adjust the regression statistics and using the spatial interpolation algorithm Inverse Distance Weighted (IDW) (MUELLER et al., 2004). The maps were created using the Qgis Software.

The punctual data from meteorological stations were entered into the Qgis software and transformed into a raster file, with the aid of the IDW interpolator. This new file displays a smooth surface fitted to this point of interest data with pixel spatial resolution of 1 km by 1 km. After this procedure, isohyets and their values were inserted for better visualization of areas with similar rainfall and to regionalize them. The distribution of annual rainfall was also evaluated using a meteorological station per region.

The Shuttle Radar Topography Mission - SRTM, with a resolution of 30 m, was used to analyze the topographic influence. This method is necessary to spatialize and regionalize data for areas that do not have more accurate rainfall data.

Multiple linear regression equations were applied to spatialize mean rainfall data measured at meteorological stations. The applied equation is given by: y = a + b.lat + c.long + d.alt, where a, b, c, d are regression coefficients, and lat, long and alt represent latitude, longitude and altitude, respectively. This mathematical formula was applied in Arcgis geoprocessing software on the SRTM file, enabling the generation of maps with a spatial resolution of 30 m.

To identify the probability of occurrence droughts periods, the frequencies of the number of consecutive days with precipitation equal to or less than 1 mm day^{-1} during at least 10 days, were determined (MINUZZI; CARAMORI, 2011). Frequency analyzes were carried out by 10 days series (1-10/01, 2-11/01, 3-12/01, and so on). This procedure avoids the omission of consecutive ten-day periods without rain, which can occur when considering only the fixed ten-day periods 1-10, 11-20 and 20-30 of each month. We admitted rainfall only values above or equal 1 mm.

The Climatological Water Balance (CLIMWB) was obtained by the method of Thornthwaite and Mather (1955), using the equation with the values of meteorological variables (temperature and precipitation), and the available soil water capacity proportional to the effective depth of the roots of the second corn crop (72 mm according to the Climate Risk Agricultural Zoning). Being calculated for the period 2000-2021, thanks to the operating time of the stations with temperature data.

The monthly average precipitation data (extracted from monthly totals of each year) and the monthly average temperature (extracted from monthly averages of the daily values of each year) were considered.

Then, the potential evapotranspiration (PET) was calculated by the Thornthwaite method (equation 1). First, the standard potential evapotranspiration (PETp, mm month-1) was calculated using the empirical formula (equation 2 and 3):

$$\text{When: } 0 < Tn < 26{,}5°C \quad (2)$$

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

$$\text{When: Tn} \geq 26{,}5\text{ºCTn}^2 \quad (3)$$

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

Where: Tn - average temperature of month n, in °C; 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 (equation 4):

$$\text{I} = 12(0{,}2\ \text{Ta})^{1{,}514} \quad (4)$$

The exponent "a", being a function of I, is also a regional thermal index, and is calculated (equation 5):

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

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 6).

$$COR = \left(\frac{N}{12}\right)\left(\frac{NDP}{31}\right) \quad (6)$$

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 7):

$$Ih = \frac{EXC}{ETP}100 \quad (7)$$

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

2.3. Specific study of case

The genesis and identification of the system acting in the event of rain and the monitoring of daily meteorological conditions were carried out through METEOSAT satellite images provided by the Center for Weather Forecasting and Climate Studies (CPTEC). Images were collected every day and at 3 pm.

Then, analyzes of patterns and atmospheric circulation were carried out, and days 3, 10, 15, 18, 22 and 30 were extracted for the interpretation of the case study, as these showed changes in atmospheric circulation.

In addition, images were taken from the meteorological radar from the SIMEPAR, which is updated every 15 minutes to identify the type of instability and its displacement over the Paraná state.

To analyze the magnitude of the drought event, the monthly average rainfall in April and the 2021 accumulated were extracted to create maps using the IDW interpolator. In addition, CLIMWB from the last year was carried out to understand the impact of lack of rain on soil water conditions. In addition, a table of decadal averages was created to identify whether there is a reduction in rainfall in April in these locations.

3. RESULTS AND DISCUSSION

3.1. Analysis of precipitation and occurrences of indian summer.

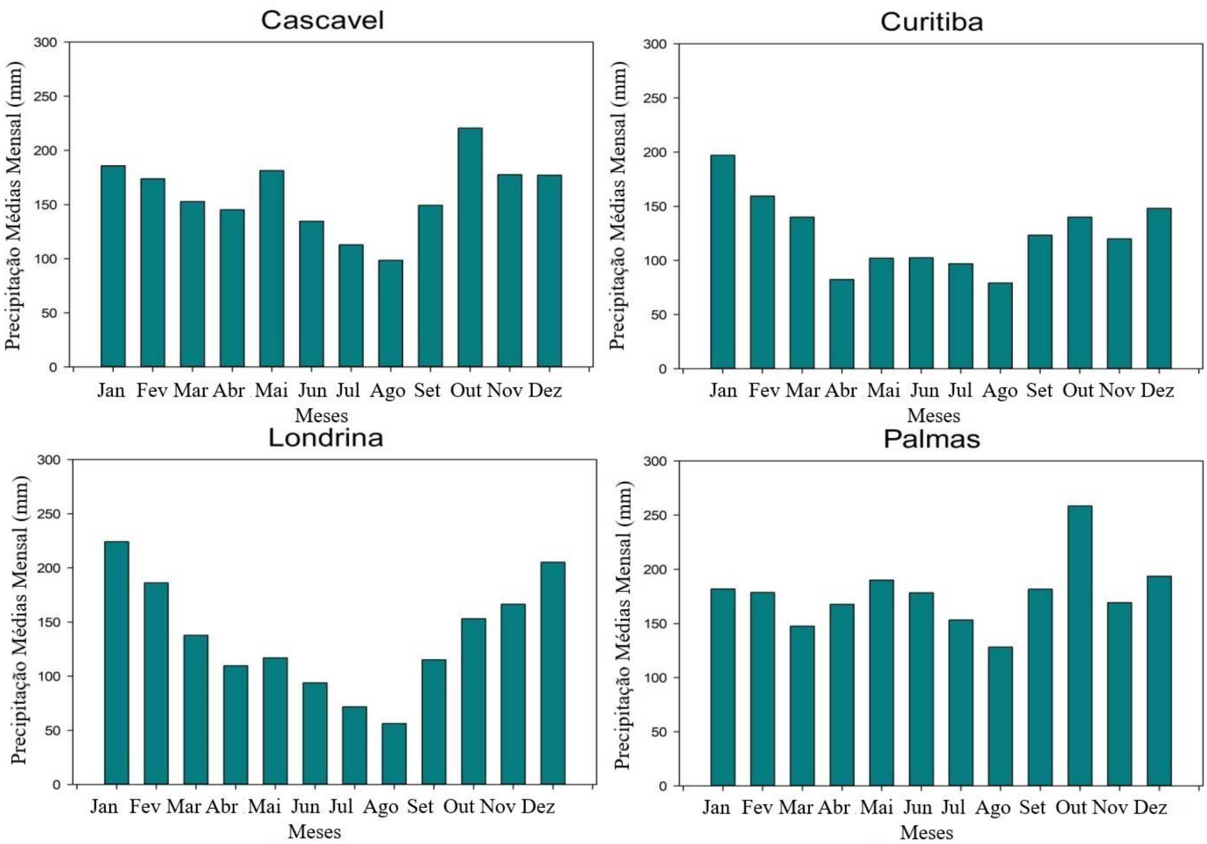
The precipitation in meteorological stations showed different distribution during the year. The Cascavel station, with an annual average of 1.910 mm (Table 1), had October as the wettest month, as well as in Palmas, while Londrina and Curitiba recorded the month of January.

This precipitation behaviour during the month of October was also identified across the west region of Paraná. Caldana et al. (2021) identified that the wettest month in the Paraná state (except for the Metropolitan Region of Curitiba) is January, while in the entire

The West of Paraná state and also de Midwest region showed wettest in October, due to instabilities formed at high temperatures in Paraguay that favour the advance of atmospheric systems over the Paraná state. The increasing of events of precipitation occurs due the South Atlantic Connvergence Zone (SACZ), from Amazon to South Atlantic, creating a great area of humidity in Brazil, from North do Southeast. It is should be noted that we can identified this climate phenomenon in center south of Amazon (Amazon and Para State), regions of Center-West and even in Southeast, as mentioned previously. In South of Brazil, the SACZ causes rainfall in Paraná State and Santa Catarina (BALICKI; ANDRADE; HORNES, 2020). The increasing temperature during seasons of spring-summer in October (MINUZZI; CARAMORI; BORROZZINO, 2011), associated with SACZ phenomenon (QUADRO et al., 2012) and convective systems (BORSATO; SOUZA FILHO et al., 2010), cause several storms and rainfall variability, as pointed out by Ferreira et al (2020) and instability during all Spring, in Paraná State.

On average, Curitiba is the driest station, with an annual average of 1,491 mm (Table 1), together with the wettest, in Palmas, with an average of 2,129 mm, recorded April (the object of this study) as the second driest month in the series (Figure 2), with means of 82.4 and 167 mm, consecutively. In Londrina (109.7 mm) and Cascavel (149 mm), april is only the ninth rainiest month.

Figure 2 – Monthly Average precipitation in the meteorological stations



Fonte: authors (2021).

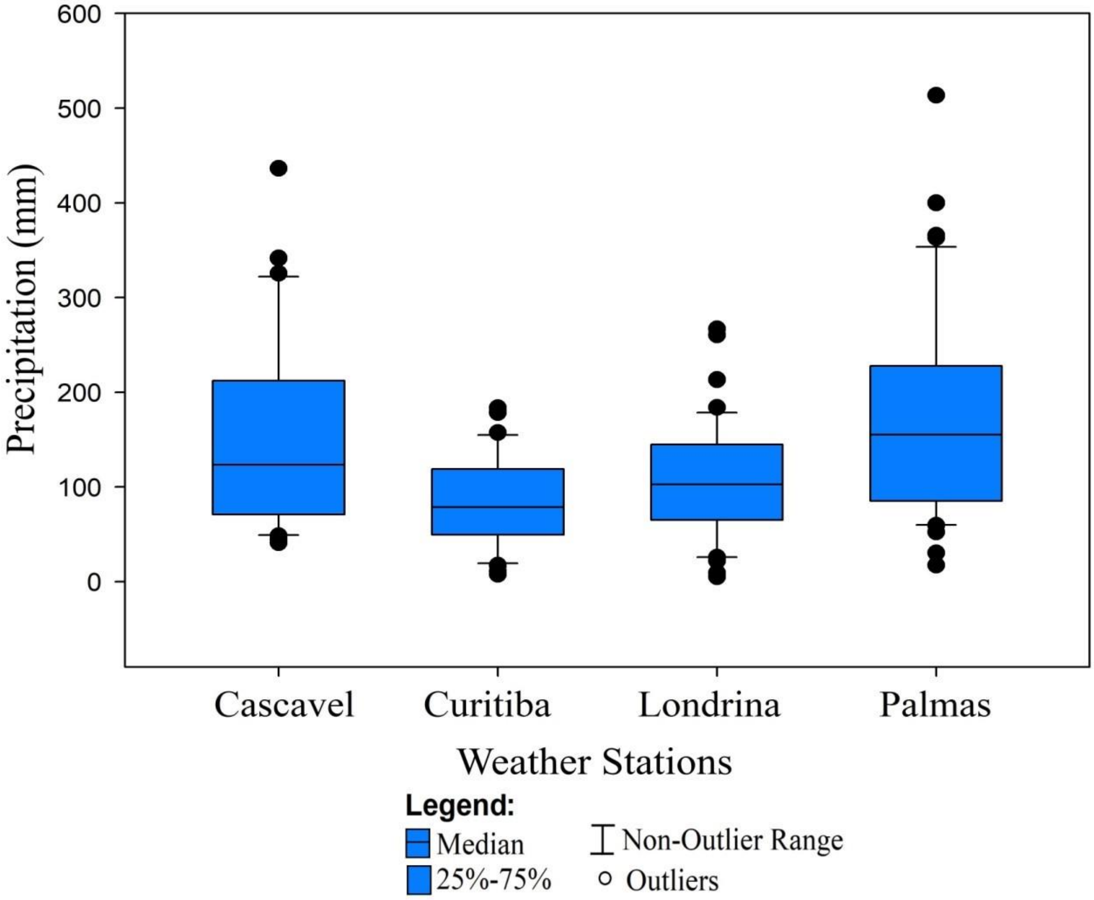
The variability in the month of April (Figure 3) was significant in Cascavel, with an interval between quartiles of more than 140 mm (67-209 mm) and a median of 120 mm. The occurrences of rainfall above 300 mm raise the monthly average (145.3 mm), there were seven occurrences in the analyzed period, three of which were outlier events. While the driest month of April, until the year 2020 was 41 mm in 1980.

A very different pattern was observed in Curitiba, with an interval between quartiles of only 50 mm (61-112 mm) and a median lower than the others (82 mm). There were also only two outlier events and none surpassing 200 mm, different from the other stations. The lowest rainfall record this month was in 1978 with 7.8 mm.

As the stations of Curitiba and Londrina did not exhibit monthly variation, with the difference between quartiles of 75 mm (67-142 mm) and a median of 105 mm. With six extreme events (outliers) and the driest April was in 2002 with 5.2 mm.

In Palmas, the place with the highest rainfall in April, the only event exceeding 500 mm was identified in 1998, a year with a strong influence of the El Niño phenomenon (CALDANA et al., 2020) with increased rainfall in all regions of the state (CAMILLONI; BARROS, 2000). There were 13 more events exceeding 300 mm, proving to be a very rainy month in the region in this area. The driest April occurred in 1996 with 17.2 mm.

Figure 3 – Box plot graphics to analyse the variability in April



Fonte: authors (2020).

We used Climatological Water Balance (CLIMWB) (Figure 4) to verify excess or deficit of water in the agricultural system to aid information for agricultural planning. As we can verify, the water balance is positive for all months of the four stations verified. As noted earlier, there were very dry and rainy months and years; however, the water balance was positive for all months of the four verified meteorological stations with the exception of August in Londrina, due this month is the driest of the year in Londrina.

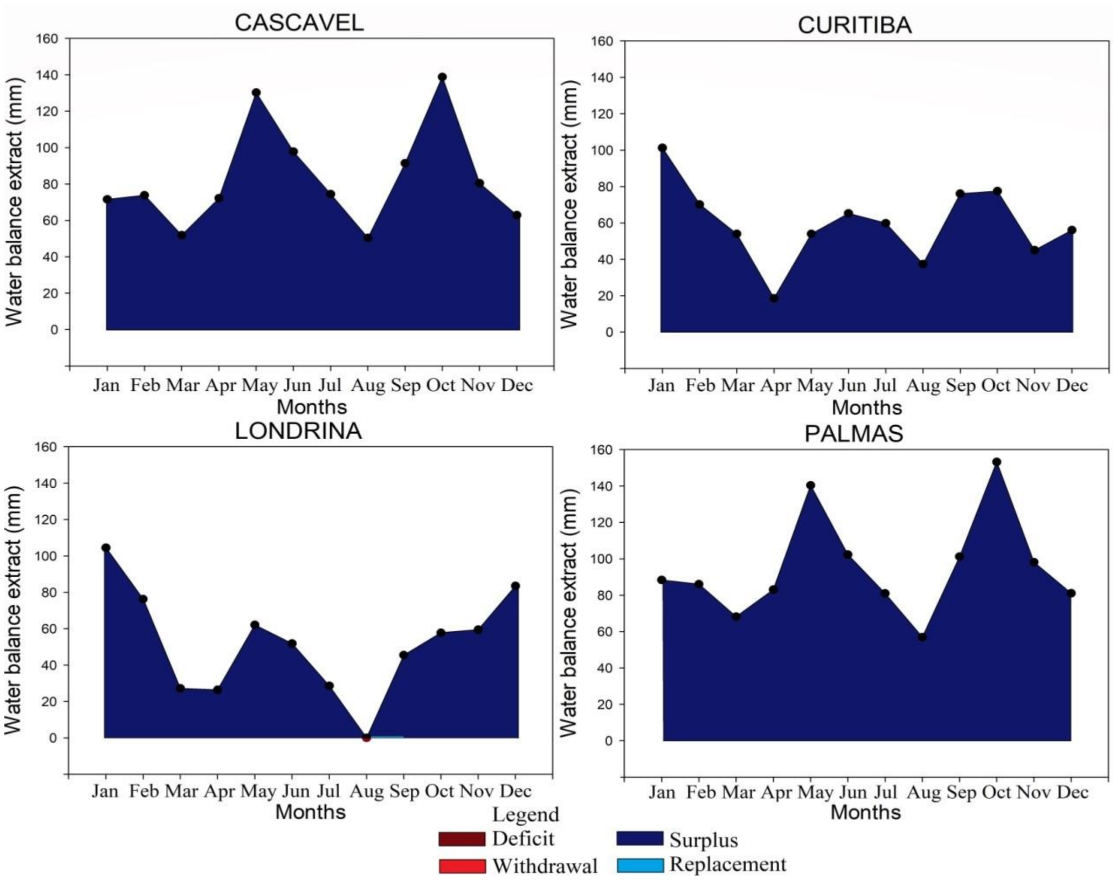
It was identified different moments from droughts periods to wet periods, from 1977 to 2012 (Ely, 2012). It was identified droughts periods from 1977 to 1981 (dry 2); wet periods were identified between 1982 and 1998 (wet 3) and droughts periods from 99 to 2012. From 2013 and so on were identified the beginning of wet period, with we check out variability, with correlations and identified climate tendencies.

As mentioned, Londrina was the only station to show a month with a negative water balance, the average occurrence is in August with 2 mm which, are already supplied in

September and returns to a positive balance in the following months. The month with the smallest extract of the water balance was August in Cascavel, Londrina and Palmas, and only in Curitiba it was in April, although it is still positive.

Even at a distance of 340 km, Palmas and Cascavel showed a similar water balance extract, however, with always higher values in Palmas.

Figure 4 – Climatological Water Balance (CLIMWB) (2000-2021)

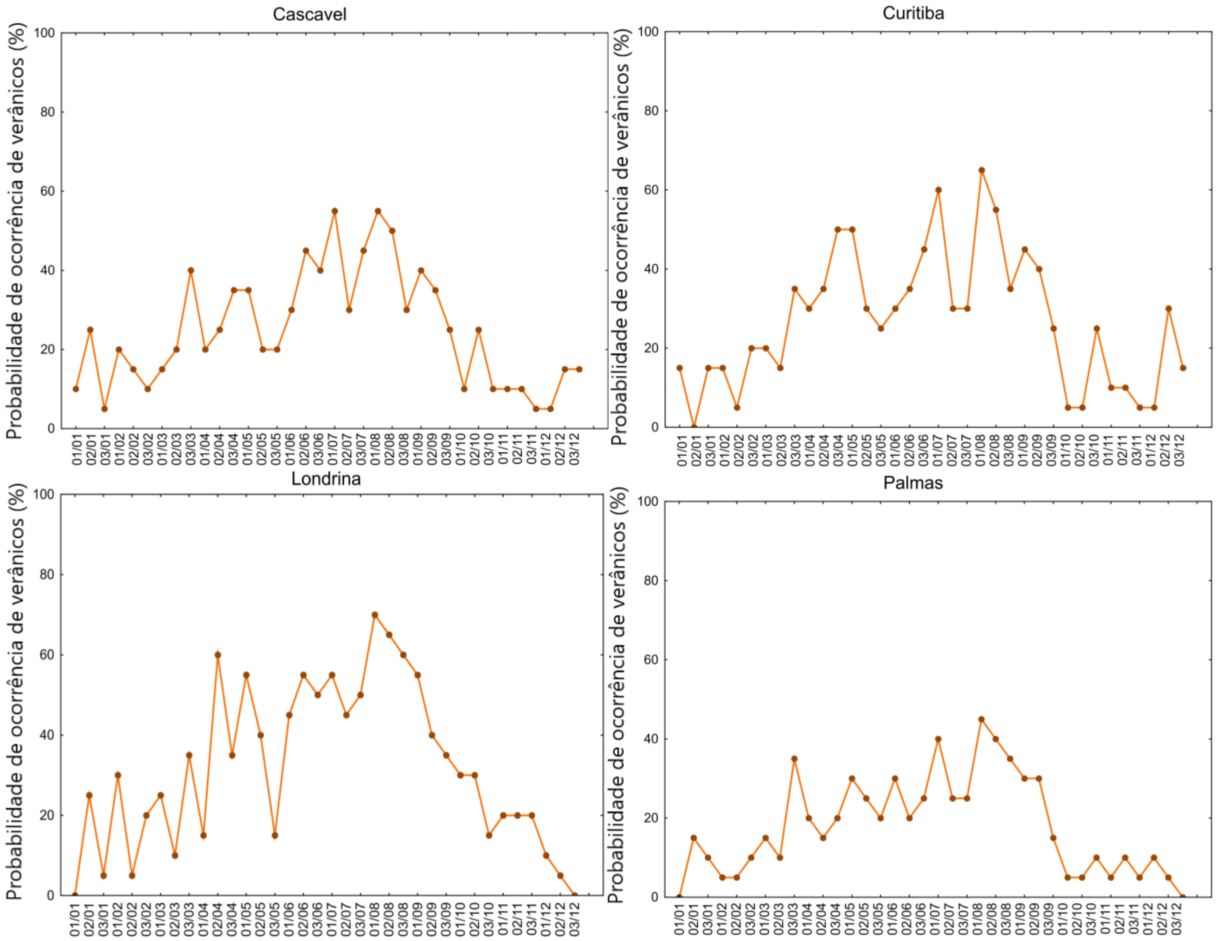


Fonte: authors (2020).

Despite showing every month with a positive extract of the water balance, the occurrence of indian summer is considered common across Paraná state, mainly in West (FERREIRA et al., 2020). Droughts periods cause negatively impact for economic activities, especially for soybean crop (FERREIRA et al., 2020).

As noted, even though Londrina shows average rainfall higher than the station of Curitiba, the distribution is not regular, with a much higher risk in summer, reaching a risk of 70% in the first ten days of August (Figure 05). The same occurs in April, even though it is the seventh month that it rains the most, the risk of Indian summer reaches 60 % in the first ten days. The same occurs in Curitiba, with a risk of 50 % on the 2nd and 3rd of April.

Figure 5 - Probability of occurrences of dry spell during ten-day series (from 1976-2020) in Paraná State.



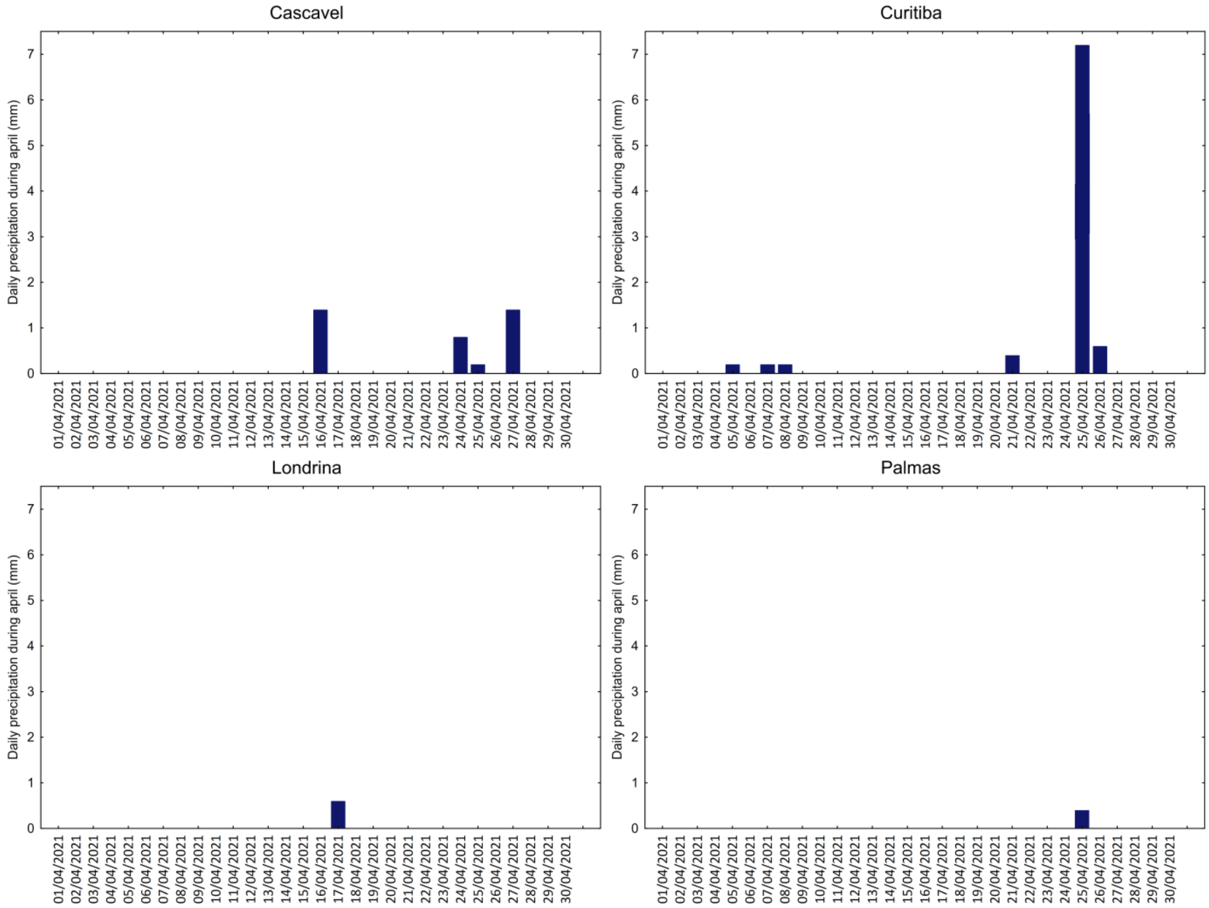
Fonte: authors (2020).

In Cascavel the peaks do not exceed 60 % and occur in the months of July and August. In April, the risk of Indian summer does not exceed 35 %. In Palmas the risk is lower than all the others, the peak occurs in August with 50 % and in April it does not exceed 20%.

3.2 Speficic Study For April (2021)

The daily precipitation in April 2021 was low in all analyzed stations (Figura 06). When observing the monthly precipitation in April during the historical series, the driest years in each stations were 41 mm in Cascavel (1980), 10.8 in Curitiba (2000), 5.2 in Londrina (2002) and 17.2 mm in Palmas (1996), making 2021 the driest April since 1976 in the analyzed stations of Paraná (Figure 03).

Figure 6 - Daily precipitation during April (2021) at Paraná

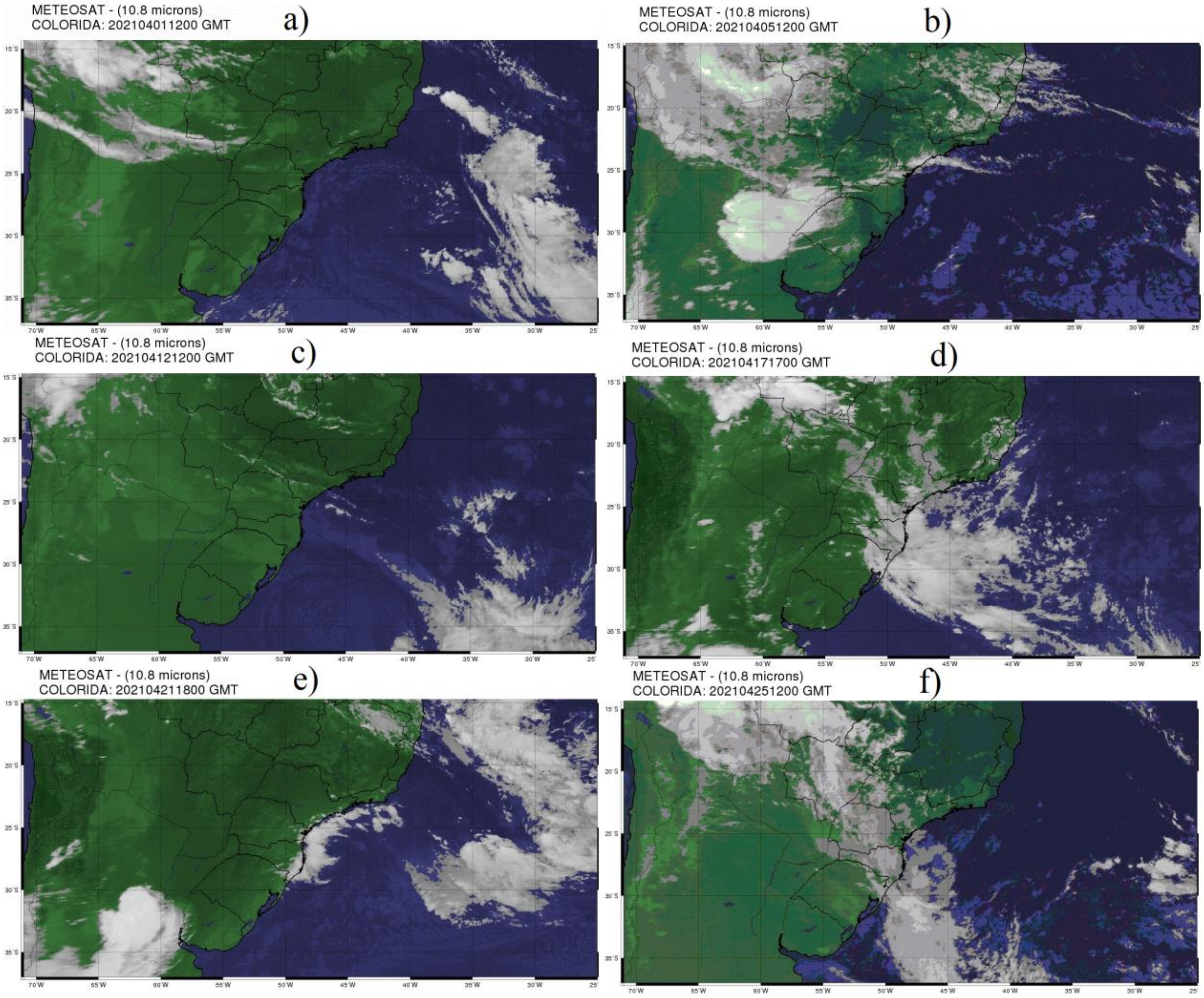


Fonte: authors (2020).

When observing the atmospheric scenario of the month (Figure 7), on the 1st (Figure 7a), as well as in most of April, there was a predominance of a dry and warmer air mass, not favouring the formation of rain. The winds were mostly from the northwest, bringing more heat from the tropical and equatorial regions of South America.

On days 5 and 12, the scenario began to change with the entry of cold fronts, which are already common at this time of year (Figure 7b). The one on the 5th, only advanced and brought rain to Curitiba, in the other meteorological stations there was no record. While on the 12th, there was no record of rain in any of the stations, largely caused by the presence of the dry air mass that predominated until then, there was only rain in isolated places in the state. Then, a new mass of dry and less heated air prevailed under Paraná (SIMEPAR, 2021).

Figure 7 - Satellite image from COLOR IR 9, extracted 3 p.m of the selected days for Brazilian Center-South.



Fonte: authors (2020).

On the 17th (Figure 7d), a new cold front entrance brought rain to the Cascavel and Londrina stations, it should be noted that the front acts first in these areas, given its preferential displacement across Paraná in the southwest-northeast and south-north directions, normally, this displacement is associated with an easterly wave system resulting from low pressure areas with instabilities (MONTEIRO, 1969; DOSS-GOLLIN et al., 2016). In the other areas, it is indicated that it had already weakened and did not bring instability when advancing by the areas to the east of the state towards the ocean.

Between days 21 and 30, with the exception of days 25 to 27 (Figure 7e), a dry and warm air mass returns to predominate about the state, with the exception of the coastal strip (SIMEPAR, 2021), with the displacement of moisture from the ocean, which did not advance beyond of the Serra do Mar do Paraná. In fact, the coast of Paraná was the only area in the state to record significant rainfall, according to data from SIMEPAR (2021) there were 233 mm in Guaratuba and 115 mm in Antonina.

From 25th to 27th there was an area of low pressure in Paraguay, a significant increase in cloudiness with some rains in the state, and the instability that generated more rain in the month, however, still being a Cold Front classified as a very weak system (SIMEPAR, 2021). The biggest registry was in Curitiba with 7.2mm.

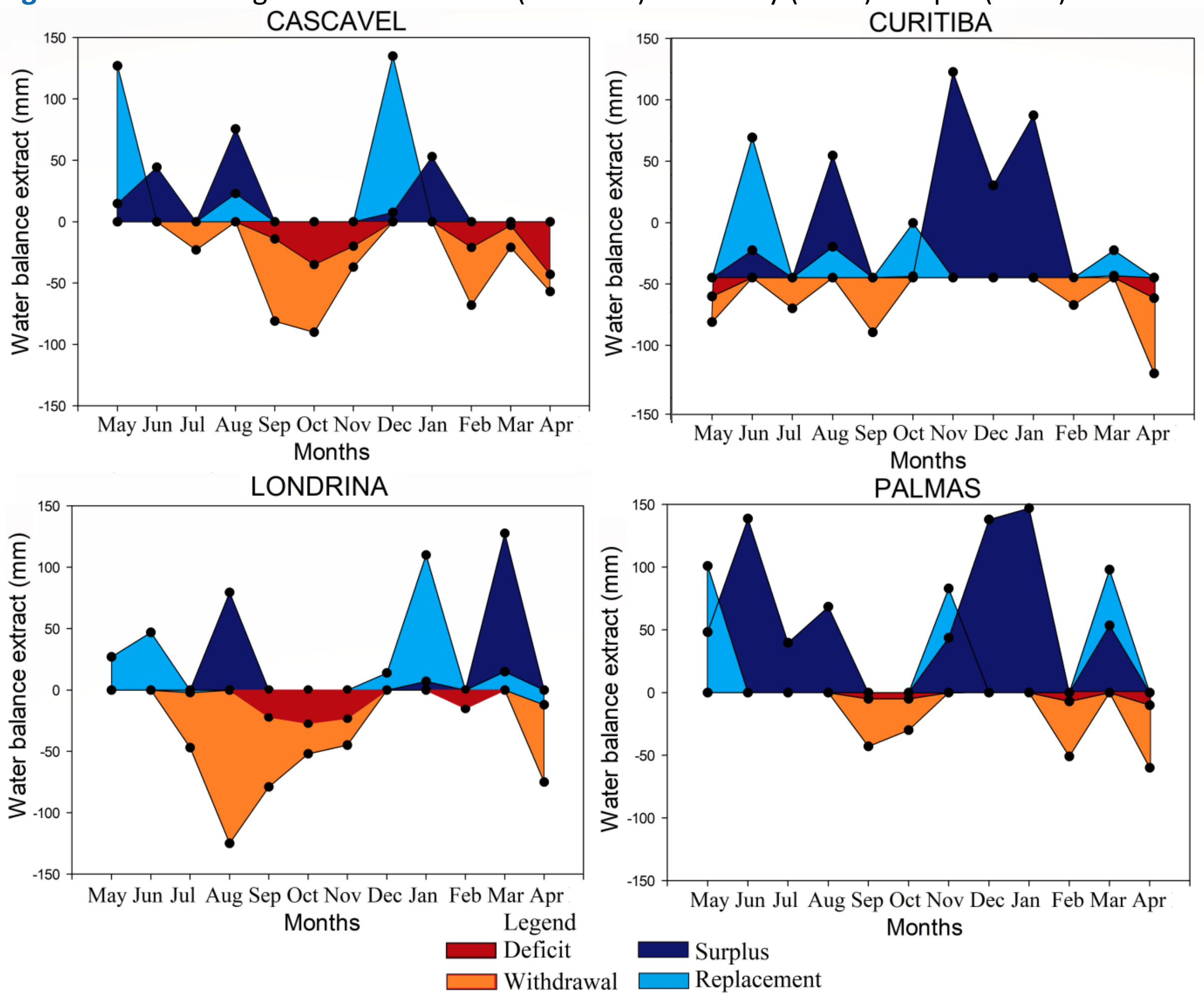
Other rainfall deficits have been recorded in Brazil in recent years, Caldana et al. (2021) identified that the month of September 2020 was the driest and hottest month in the Midwest Mesoregion of Paraná. Verifying satellite images, were identified the intense action of a dry air mass, favoured by the fires in the Pantanal and Amazônia that occurred in the same period (SIMEPAR, 2021).

As for drought with the synoptic gaze, Jacondino et al. (2019) performed the analysis of intense drought in the southern region of Brazil and associated synoptic conditions; and identified different magnitudes of drought across the seasonal cold period (April to September). The magnitude of average droughts is minimal in May and greater in August and September in Rio Grande do Sul (RS) and Santa Catarina (SC). The local incidence is also not homogeneous in magnitude, and the places in RS with the highest mean magnitude are outside the West region with the highest frequency of occurrence. There is a clear pattern of variables from south to north in the magnitude of the phenomenon over the region, with more intense events over RS, decreasing for intermediate over Santa Catarina and minimal over the Paraná state. Although the work did not identify changes in the drought pattern for the month of April, as identified in 2021, future work can identify if there is a significant trend for this month and can be included in the months with the greatest chance of drought.

Thus, even with the frequent entry of cold fronts that generate atmospheric instabilities across the Center-South of Brazil, in April, they are usually still weak, and with the presence of very dry and warmer air during much of the month, even with the entry of these systems, there was no significant rainfall throughout the month, making the month of April the driest in the historical series, and this had a direct impact on the regional water balance (Figure 8).

Differently from what was observed, in average standards of the CLIMWB the period that preceded the month of April showed several records of deficiency and removal of water from the soil, and not only in the month of April, the rainfall was already below in previous months.

Figure 8 - Climatological Water Balance (CLIMWB) from May (2020) to April (2021) at Paraná.



Fonte: authors (2020).

According to the extract of the water balance, it was identified that Curitiba and Palmas had the smallest impacts, but even so, with five and four months of water deficit, respectively, with the worst scenario occurring in the month of April. In Palmas the removal of water from the ground exceeded 50 mm and in Curitiba 100 mm.

In Londrina the worst scenario occurred previously, between June and November, with a peak in August with more than 120 mm of water removed from the ground and a deficit of 30 mm. This long period with CLIMWB showing water deficit may be repeated from April 2021 if it does not rain enough to replace what was lost in that dry month.

Cascavel, despite having lower values of water removal from the soil than Londrina, registered the highest values of water deficit, and unlike the others, the months of February and March, already registered negative CLIMWB, intensifying in the month of April, with that the water deficit reached 47 mm.

The scenario is even more alarming since the municipalities of Cascavel and Londrina have agriculture as the main activity developed and in a large part of their area, they plant corn at this time of year (BIAGIO et al., 2017). As a plant of tropical origin, corn requires during its cycle, heat and water available in the soil to develop (TEIXEIRA et al., 2020). Thus, the analysis of water availability in April for the corn crop is necessary since the second crop corn sowing time in the state of Paraná is between January and March, being the main one crop in this period, positioned after soybean cultivation in the state (MIRANDA et al., 2021).

The water deficit during the initial vegetative growth of maize crop causes a reduction in leaf area, solar radiation interception, stomatal conductance and leaf chlorophyll content, which results in a reduction in the efficiency of the photosynthetic rate, which can directly influence the crop yield (BERGAMASCHI et al., 2004)

The two municipalities that cultivate maize crop at this time of year are the ones with the greatest water deficit and will likely present negative results in productivity, and if this scenario indicates a future trend impact of climate change, it could make the crop as inapt for cultivation at this time of year for these locations. A pattern was identified when analyzing the average rainfall of the last decades, may represent future changes in regional agricultural planning (Table 2).

Table 2- Average rainfall for decades in April in stations in the Paraná State

Weather Stations	Average (1976-2021)	Average (1981-1990)	Average (1991-2000)	Average (2001-2010)	Average (2011-2020)
Cascavel	145,3mm	198,9mm	161,8mm	136,3mm	92mm
Curitiba	82,4mm	111,7mm	57,3mm	95,3mm	77,6mm
Londrina	109,7mm	138,9mm	108,1mm	87,3mm	83,3mm
Palmas	167,8mm	194,1mm	163mm	192,3mm	101,4mm

Fonte: authors (2020).

It can be observed that not only the year 2021, which was the driest in the historical series, but also the last decade showed a reduction in rainfall, demonstrating that there may be a negative trend in April 2021. With the exception of Curitiba, all other cities presented the last decade (2011-2020) as the driest in the historical series. Cascavel and Palmas recorded the most alarming values, with a reduction of approximately 50 mm of rainfall in relation to the average and 106 and 93 mm, respectively, in relation to the decade of 1981-1990.

4. CONCLUSION

It was concluded that April 2021 was the driest in the history series with rainfall between 0.6 and 8 mm in the analyzed meteorological stations of the Paraná state, due to the actions of atmospheric blockages and dry air masses.

The rainfall well below average this month impacted the water balance, which had already been negative over the last year, the impacts were felt more in Londrina and Cascavel, areas important for crops productions, especially soybean and corn, which may register yield gaps in this period.

A trend of reduced rainfall this month may be occurring, since when analyzing the series for decades, the last (2011-2020) had already been the driest in history, with the exception of Curitiba. And it exhibited alarming values of rainfall reduction, as in Cascavel with more than 100 mm in relation to the decade of 1981-1990 and 66 mm in relation to the average in Palmas.

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