ISSN: 2237-8642 (Eletrônica)

ANALYSES OF WATER BALANCE AND ANNUAL, SEASONAL AND MONTHLY PLUVIOMETRIC VARIABILITY IN PIONEER NORTHERN PARANÁ STATE MESOREGION, BRAZIL

CALDANA, Nathan Felipe da Silva - nathancaldana@gmail.com
Universidade Estadual de Londrina / UEL

FERREIRA, Luiz Gustavo Batista - luiz.gustavo@agronomo.eng.br
Instituto Agronômico do Paraná / IAPAR

SILVA, Iara da - iara@alunos.utfpr.edu.br
Universidade Tecnológica Federal do Paraná / UTFPR

SILVA, Marcelo Augusto Aguiar e - aguiaresilva@uel.br
Universidade Estadual de Londrina / UEL

Submetido em: 11/03/2020
Aceito para publicação em: 06/11/2020
Publicado em: 12/11/2020
DOI: http://dx.doi.org/10.5380/abclima.v27i0.72218

ABSTRACT: The precipitation variability has a key importance for all activities. The frequency of extreme events, such as droughts and intense rains, results in severe impacts on crops, urban activities, water resources, health and the environment on a local or regional scale. The estimation of the frequency, impacts and severity of these events is essential for planning human activities. The objective of this work was to analyze the rainfall variability and the water balance in the Northern Paraná state Mesoregion (PNPM) in the annual, seasonal and monthly time scales. For this, we used the annual, seasonal, monthly and daily time scales, from 1976 to 2018. It was used analysis using thematic maps with regionalization through interpolations and isohyets, box plot and dendogram. A large regional discrepancy in precipitation was identified in the analyzed mesoregion. In all the time scales analyzed in the region, there were alarming variations, which can bring perspectives for regional planning. We verified the Northwestern portion of the region, near to the municipality of Leópolis, had the lowest rainfall and the worst scenarios evaluated in the water balance, while near the municipality of Sapopema, showed more events of precipitation and less risk of drought occurrences. The average climatological water balance in the region exhibited a low deficit during the month of August, however, when testing scenarios of dry years, the entire region showed water deficiency throughout the year.

KEYWORDS: climate risk, climate extreme events, Paraná state

ANÁLISE DO BALANÇO HÍDRICO CLIMATOLÓGICO E A VARIABILIDADE PLUVIOMÉTRICA ANUAL, SAZONAL E MENSAL NA MESORREGIÃO NORTE PIONEIRO PARANAENSE, BRASIL

RESUMO: A variabilidade pluviométrica tem influência sobre as atividades humanas. A frequência dos eventos extremos, como secas e chuvas intensas, resulta em severos impactos nas práticas agrícolas, atividades urbanas, nos recursos hídricos, na saúde e sobre o meio ambiente em escala local ou regional. Dessa forma, a estimativa da frequência, impactos e severidades desses eventos são fundamentais para o planejamento das atividades humanas. Dessa forma, o objetivo deste trabalho foi analisar a variabilidade pluviométrica e o balanço hídrico na Mesorregião Norte Pioneiro Paranaense (MRNPP) nas escalas temporais anual, sazonal e mensal. Para isso, utilizaram-se as escalas temporais anual, sazonal, mensal e diária com o recorte temporal de 1976 a 2018. Para sua compreensão foram utilizados análises por meio de mapas temáticos com regionalização por meio de interpolações e isoietas, box plot e dendograma. Identificou-se, grande discrepância regional na precipitação na mesorregião analisada. Em todas as escalas temporais analisadas na região houve variação alarmantes, que podem trazer perspectivas para o planeamento regional. A porção noroeste da região, próximo a Leópolis, apresentou as menores alturas pluviométricas e os piores cenários testados no balanço hídrico, enquanto a porção alta, no sudoeste, próximo a Sapopema apresentou mais chuva e risco menor de seca. O balanço hídrico climatológico médio na região apresentou déficit baixo no mês de agosto, porém ao testar cenários de anos secos, toda a região apresentou deficiência hídrica durante todo o ano.

PALAVRAS-CHAVE: risco climático, eventos extremos, seca, Paraná..

1. INTRODUCTION

The understanding of climatic variability comes from both time and space scales. It is different from year to year, from decade to decade and century for century. The climate and the interaction with the environment is the result of a complex process that involves the dynamics of the atmosphere, solar energy, the oceans, average temperature, albedo and others (CONTI, 2005; CALDANA et al., 2019). A scientific consensus accepted the climate is changing. Several studies exhibited and analyzed the effects from the global climate change and the recent extreme events occurrences. It is should be noted that the climate change will continue to have an increasingly dramatic effect on the global environment, including increases in average temperatures and the frequency of heat waves (SILVA and SILVA, 2012; IPCC, 2013; SANCHES et al., 2014; AGOVINO et al., 2019).

This climatic variability exhibits key importance for almost all activities, due it is responsible for variabilities in elements, such as temperature, precipitation and frequency of extreme events, droughts occurrences and intense extreme precipitation, resulting in diverse impacts for the field and for urban areas (CALDANA et al., 2018). Several studies showed forms to reduce the climatic impacts for field and cities (LÓPEZ, 2018; MAIA et at., 2018; SOMBOONSUKE, 2018; PAILLER; TSANEVA, 2018 PERKINS et al., 2018; TSAVDAROGLOU, 2018; WOSSEN, 2018).

Even with the recent technological advances, the climate is still the one of the most prominent variable for the crops productions. Approximately 80 % of the variability of the agricultural production come from the climate, causing severe impacts on crops of significant expression (CARAMORI et al., 2008; CALDANA et al., 2019a). Regardless of the production process, technologies, investments and inputs that are applied in agricultural production systems, natural variables are the most significant and derived from the climate (AGOVINO et al., 2019; CALDANA et al., 2019). In this climate-production conjuncture, rainfall is the most important element, being the climatic attribute of considerable expression and significance for the regions of tropical and subtropical climate. Its regime and annual distribution and periods of extreme rainy and dry interfere in the various activities (PELL et al., 2007; CARAMORI et al., 2008; GELCER et al., 2018; MICHLER et al., 2018; SOMBOONSUKE et al., 2018; AGOVINO et al., 2019).

For the urban areas, natural disasters occur almost always due the extreme intensity of precipitation. With 59 % of records, flooding is a consequence of the extreme weather events (MARCELINO, 2007; CALDANA et al., 2018). Severe atmospheric instabilities cause large amounts of rain in a short period of time, and in addition, the low drainage and runoff linked to the occupation of inadequate areas aggravate the floods. For this context, studies which identify the frequency and intensity of these extreme events can be instruments to aid in decision - making and urban planning (HUANG et al., 2018; JAMALI et al., 2018; MUSTAFA et al., 2018; WOSSEN et al., 2018; BERTILSSON et al., 2019).

Thus, the objective of this work was to analyze the rainfall variability and the water balance in the Pioneer Northern Paraná state Mesoregion (PNPM) in the annual, seasonal and monthly time scales. For this, we used the annual, seasonal, monthly and daily time scales, considering the historical series from 1976 to 2018.

2. MATERIAL AND METHODS

2.1 AREA OF STUDY

The Pioneer Northern Paraná state Mesoregion (PNPM) is located in the Second and Third Plateaus of Paraná state, Brazil. Its area covers almost 16,000 km^2, which corresponds to about 7.9 % of the state territory. The region has 46 municipalities, including Cornélio Procópio, Santo Antônio da Platina and Jacarezinho, which are important municipalities for this area of the Paraná state (IPARDES, 2004).

The climate in the region of PNPM is Subtropical Humid Mesothermal (Cfa) with hot rainy summers (with values averaging 1,300 mm) and low frequency of frosts (NITSCHE et al., 2019). The temperature range goes from 22°C in the hottest months, and reaches 18°C during the coldest months.

2.2 DATABASE AND STATISTICAL ANALYSIS

We analyzed data of 42 years series (1976 to 2018) from 34 weather stations (Instituto Agronômico do Paraná - IAPAR) in PNPM region, showed in the Figure 01.

We used Box Plot to complement the analysis of rainfall variability and the detection of extreme. The key resource obtained in its use is to provide a quick view of the data distribution. If the distribution is symmetrical, the box is balanced with the median positioned in the center of the box. For asymmetric distributions, there is an imbalance in the box with respect to the median. The graphics were created using the R 3.6.1.® *software* (APPEL et al., 2011).

Box plots represent five classifications of values. Outliers are divided into discrepancies (values above what is considered maximum, but which are not extreme) and extremes, with any values greater than Q3 + 1.5 (Q3 - Q1) or less than Q1 - 1.5 (Q3 - Q1). The highs and lows are considered the highest values in the series, but they are not extreme or outliers. Inside the box, three quartiles are classified with 25 % of the data each, in addition to the median value, equivalent to the second quartile, or 50 % of the data (LEM et al., 2013). The data analyzed in the box plot were grouped by mobile semesters. For this analysis, we used a rainfall station in each region of the analyzed area: Bandeirantes, Leópolis, Sapopema and Tomazina.

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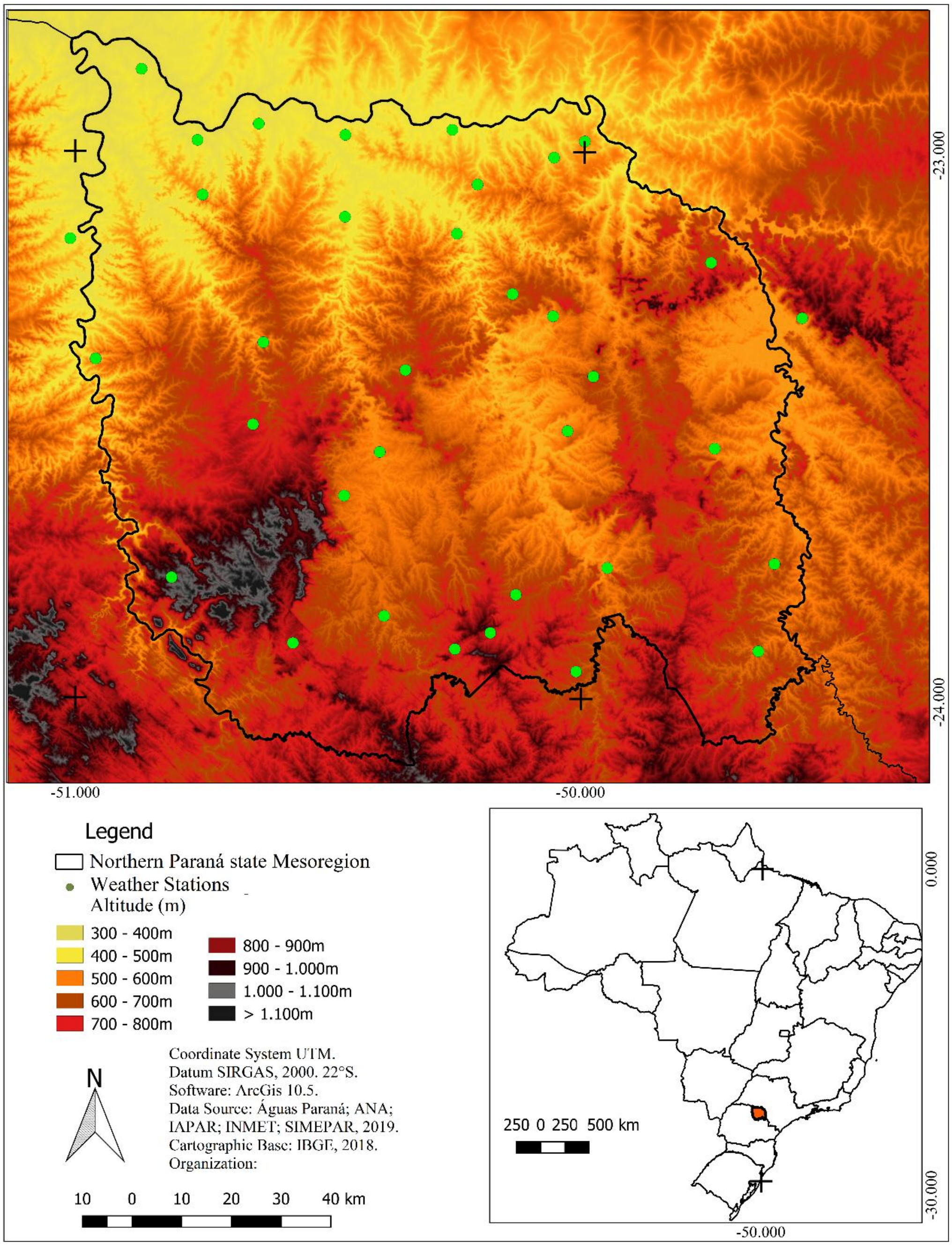

Figure 01 – Location of the weather stations. Org.: authors, 2020.

We used to identify similar characteristics between the stations studied, the complete linkage hierarchical grouping method. This method calculates the proximity between the sample groups. First, the algorithm determines the shortest distance between the points, thus building the distance matrix. In this study, was used the Euclidean Distance, which is obtained geometrically between two points in a Cartesian plane. From the grouping, the dendogram shown, in Figure 04, is obtained. For the calculations and construction of the dendogram (TEICH et al., 2012), we used the *software* R 3.6.1.

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Table 01 - Information on the weather stations used

Responsible institute	Weather Station (Municipality)	Longitude	Latitude	Altitude	Operating time
ANA	Amorinha (Ibaiti)	-50,25	-23,91	600 m	1976-2019
IAPAR	Bandeirantes	-50,21	-23,06	440 m	1976-2019
IAPAR	Cambará	-50,06	-23,01	450 m	1976-2019
ANA	Campo Alegre (Leópolis)	-50,76	-22,98	344 m	1976-2019
ANA	Cerro Leão (Assaí)	-50,96	-23,38	533 m	1976-2019
ANA	Conselho Zacarias (Santo A. da Platina)	-49,98	-23,41	603 m	1976-2019
ANA	Doutor Clóvis (Nova Fatíma)	-50,63	-23,35	818 m	1976-2019
ANA	Fazenda Flora (Cambara)	-50,00	-22,98	528 m	1976-2019
ANA	Guapirama	-50,03	-23,51	600 m	1976-2019
ANA	Ibiporã	-51,01	-23,16	484 m	1976-2019
ANA	Japira	-50,13	-23,81	660 m	1976-2019
IAPAR	Joaquim Távora	-49,57	-23,30	512 m	1976-2019
ANA	Jundiai do Sul	-50,14	-23,26	500 m	1976-2019
ANA	Leópolis	-50,75	-23,08	445 m	1976-2019
ANA	Nossa Senhora Aparecida (Andirá)	-50,26	-22,96	423 m	1976-2019
ANA	Paranagi (Sertaneja)	-50,87	-22,85	365 m	1976-2019
ANA	Patrimônio do Café (Ibaiti)	-50,18	-23,88	730 m	1976-2019
ANA	Pintos (Carlópolis)	-49,74	-23,54	563 m	1976-2019
ANA	Ribeirão Claro	-49,75	-23,20	728m	1976-2019
ANA	Ribeirão do Café (Pinhalão)	-50,01	-23,95	750 m	1976-2019
ANA	Ribeirão do Pinhal	-50,35	-23,40	600 m	1976-2019
ANA	Santa Amélia	-50,25	-23,15	471 m	1976-2019
ANA	Santa Maria do Rio do Peixe (Congoinhas)	-50,47	-23,63	531 m	1976-2019
ANA	Santana do Itararé	-49,62	-23,75	543 m	1976-2019
ANA	Santo Antônio da Platina	-50,06	-23,30	520 m	1976-2019
ANA	Santo Antônio do Paraíso	-50,65	-23,50	670 m	1976-2019
ANA	São Joaquim do Pontal (Itambaraca)	-50,47	-22,97	402 m	1976-2019
ANA	São José da Boa Vista	-49,65	-23,91	550 m	1976-2019
ANA	Sapopema	-50,57	-23,90	764 m	1976-2019
ANA	Terra Nova (São Jerônimo da Serra)	-50,81	-23,78	989 m	1976-2019
ANA	Tomazina	-49,95	-23,76	483 m	1976-2019
ANA	Três Cantos (Leopólis)	-50,64	-22,95	904 m	1976-2019
ANA	Triolândia (Ribeirão do Pinhal)	-50,40	-23,55	800 m	1976-2019
ANA	Uraí	-50,47	-23,12	458 m	1976-2019
ANA	Usina Figueira (Figueira)	-50,39	-23,85	526 m	1976-2019

Source - ANA e IAPAR (2020); Org.: authors, 2020.

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We used rainfall data (from the monthly totals of each year) and the monthly average temperature (from the monthly averages of the daily values of each year). Then, the potential evapotranspiration (PET, mm) was calculated according to the Thornthwaite method (THORNTHWAITE and MATHER, 1955) with the help of the spreadsheet developed by Rolim, Sentelhas e Barbieri (1998). First, the standard potential evapotranspiration (PET.month^{-1}) was calculated using the empirical formula:

$$\text{For: } 0 < Tn < 26.5\ °C \quad 1)$$

$$\text{PET} = 16\left(10\frac{\text{Tn}}{\text{I}}\right)^{\text{a}} \quad 2)$$

$$\text{For: Tn} \geq 26.5\ °\text{CTn}^2 \quad 3)$$

$$\text{PET} = -415\,85, + 32\,24, \text{Tn} - 43.0\,\text{Tn}^2 \quad 4)$$

where Tn is the average temperature of month *n* (*n* = 1 is January, *n* = 2 is February, etc.) in °C, and I is an index that expresses the heat level of the region.

The value of I depends on the annual temperature cycle, integrating the thermal effect of each month, and is calculated using the formula

$$\text{I} = 12(0.2\ \text{Ta})^{1514}. \quad 5)$$

The exponent "a", being a function of I, is also a regional thermal index, and is calculated using the expression

$$a = 0.49239 + 1.7912 \text{ x } 10^{-2}\, I - 7.71 \text{ x } 10^{-5}\, I^2 + 6.75 \text{ x } 10^{-7}\, I^3. \quad 6)$$

The PET value represents the total monthly potential evapotranspiration that would occur under the thermal conditions of a standard 30 day month, and with a 12 hour photoperiod (N) each day. Therefore, PET should be corrected for N and the number of days in the period (PEREIRA et al., 2002).

$$COR = \left(\frac{N}{12}\right)\left(\frac{NDP}{31}\right) \quad 7)$$

In addition, we used the average climatological water balance and a dry series of years scenario to identify the severity of rain events below normal in the region. For this procedure, we used data from the weather stations from the municipalities of Bandeirantes, Leópolis, Sapopema and Tomazina.

3. RESULTS AND DISCUSSION

The average rainfall in the Pioneer Northern Paraná state Mesoregion (PNPM) showed a significant discrepancy (Figure 02). At the far Western area of the Mesoregion, in the areas with higher altitudes (Figure 01) the minimum values are 1,600 mm, while in the Eastern, Central and Southern regions exhibited maximum values of 1,400 mm.

The average rainfall showed great similarity with the altitude (Figure 01), with the lowest area with an average altitude of 300 to 500 m, close to the Itararé River and bordering the São Paulo state, with lower precipitation heights, while the highest region of the 900 to 1,100 m basin represents the highest rainfall.

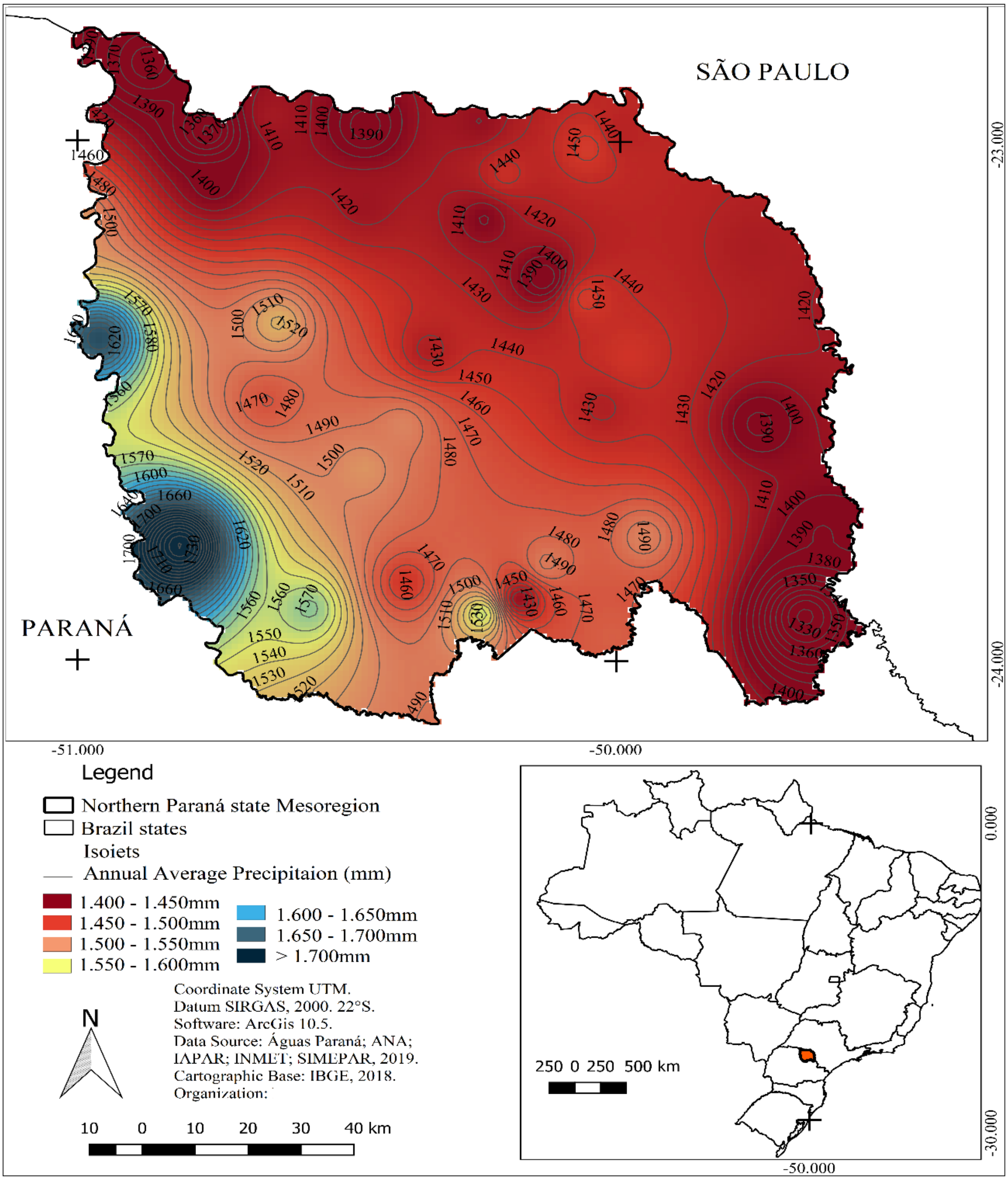

Figure 02 - Annual average pluviometric distribution in Pioneer Northern Paraná state Mesoregion (PNPM). Org. Authors (2020)

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For the Paraná state, precipitation in the continental influence the three ways of formation that interfere with its regional distribution: cold fronts, convective systems and MCC - Mesoscale Convective Complexes (CALDANA, et al., 2018; CALDANA et al., 2019; CALDANA and MARTELÓCIO 2019). First, the cold fronts, which are characterized by the encounter of the Polar Air Mass with the continental hot air mass; with the advent of humidity they generate strong atmospheric instability, which can lead to the formation of cumulunimbus and lead to the formation of severe storms, which may be accompanied by strong gusts of wind and precipitation with hail, or even light to moderate rain, but lasting days, if this becomes stationary (BEREZUK and SANT'ANNA NETO, 2006; BEREZUK, 2017; CALDANA et al., 2018; CALDANA et al., 2019). These operate predominantly during the Fall, Winter and early Spring and are responsible for the high rainfall in the region.

The Polar Air Mass has a trajectory favored by the channel of the Paraná River and later the Iguaçu River, advancing throughout the Paraná state (CALDANA, et al., 2018; CALDANA et al., 2019; CALDANA and MARTELÓCIO 2019). The cold fronts are identified in satellite images by a great line of instability that advances in the Paraná state in the Southwest - Northeast direction. (BEREZUK and SANT'ANNA NETO, 2006; BEREZUK, 2017; CALDANA et al., 2018; CALDANA et al., 2019). It is should be noted that the topography in the Center-Southern areas from the Mesoregion exhibited an abrupt rise, from 400 to 1,000 m (Figure 01); this shock with the topography can bring more events of precipitation in the highest areas of the Mesoregion, near to the municipalities of Tamarana and Mauá da Serra. For the entire Northern area of the Mesoregion, it has descent from the altitude in the Southwest-Northwest and South-North directions, not contributing to the friction of the air mass with the topography, and not favoring the increase of precipitation.

While the MCC, which operate throughout the year, but predominantly in the Spring and Summer (DURKEE et al., 2009). MCCs are identified in satellite images by their approximately circular shape and by a wide area of storm coverage. They are defined as a cluster of cumulunimbus covered by a dense cirrus layer, and are also convective cloud systems, with rapid vertical and horizontal growth over a period of 6 to 12 hours. Depending on their intensity, they can create several nuclei with the formation of storms and hail. Their displacement, through Paraná state, is normally in the Western - Eastern direction, coming from Paraguay and northern Argentina (TREFAULT et al., 2018; CALDANA et al., 2018; CALDANA et al., 2019). It is worth noting that the altitudes of most of the region do not increase in the Western-Eastern direction, not contributing to the friction of the system with the relief (Figure 01). The only areas that rise from the topography in this sense are the regions over 1,000 m. Convective systems are differentiated from MCC by the lesser spatial coverage, formed by the process of heat transfer by conduction that occurs in intense vertical movements, thus leading the rapid condensation process and the formation of Cumulunimbus, which can also intensify with the friction with the topography (CALDANA, et al., 2018; CALDANA et al., 2019; CALDANA and MARTELÓCIO 2019).

We verified that the Sapopema station, located in the area with the highest altitudes, exhibited the highest average rainfall (Figure 04). The median of this station was 1588 mm, the highest recorded among those analyzed. The station also showed large discrepancies, identifying the highest and lowest annual rainfall, being 2,115, in 2009, and 911 mm, in 1984, respectively, the latter identified as the influence of a strong La Niña, and in these periods in the South of Brazil, there is less rain for that region (CALDANA et al., 2019).

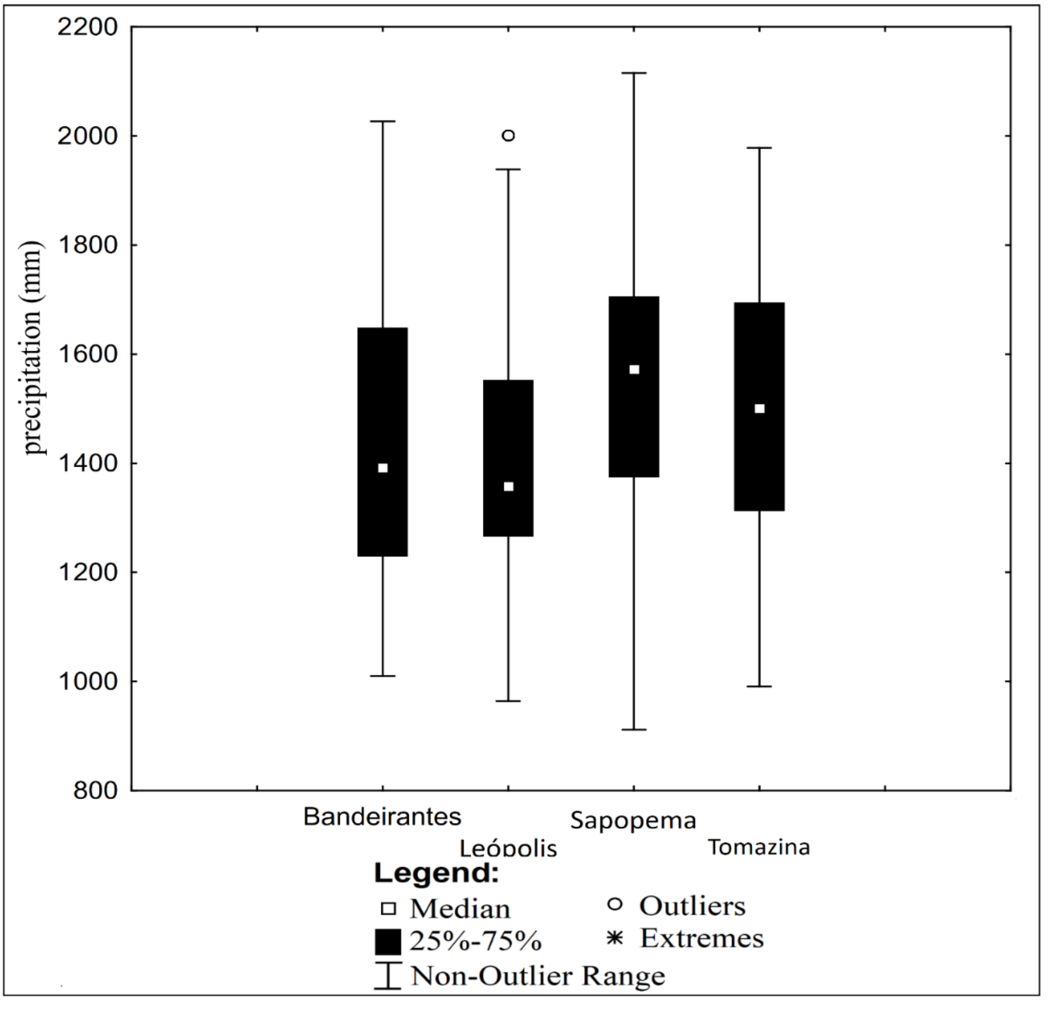

Figure 03 - Annual pluviometric variability in Pioneer Northern Paraná state Mesoregion (PNPM). Org: Auhtors (2020).

At Bandeirantes and Tomazina stations, we verified the largest discrepancies between Q (quartiles), the median of these stations were 1,388 and 1,443, respectively. There were no discrepancies, and in Bandeirantes the second highest annual rainfall was identified, with 2027 mm in 1982, identified in the El Niño period, which is usually the rainiest in South of Brazil.

As the station with the lowest median 1,351 mm, Leópolis showed the only discrepancy in the analyzed annual series, being 2,001 mm in 2015, this year was identified as the influence of El Niño, more once as a rainy year (CALDANA et al., 2019).

The key climatic elements for the annual precipitation, in Paraná State, is the phenomenon ENSO - El Nino South Oscillation, according to the literature (CAMILLONI and BARROS, 2000; CALDANA et al., 2019). It is should be noted that the, during the El Nino, occurs more events of precipitation, while for La

ISSN: 2237-8642 (Eletrônica)

Nina is inverse. In conditions of ENSO neutrality can occur periods of higher precipitation in Brazilian Southern, due the reduction in the atmospheric blocking, while in the Tropical area of the South America the air increase to Western (lower atmospheric pressure) shows tendency to down above the cold water (higher atmospheric pressure). As a consequence, has no clouds and precipitation in this region (RAO and HADA, 1990; BERLATO et al., 2005; ANDERSON et al., 2018). This factor justifies the higher precipitation in a few analyses during the period of ENSO neutrality in the region.

For seasonal precipitation (Figure 04), a distribution similar to annual precipitation was identified, with Sapopema with the highest rainfall and Leópolis with the lowest. Average rainfall heights reduce during the year, occurring at peak levels in the Summer, with a fall towards Fall, reaching the negative peak in the driest Winter and increasing again in the Spring.

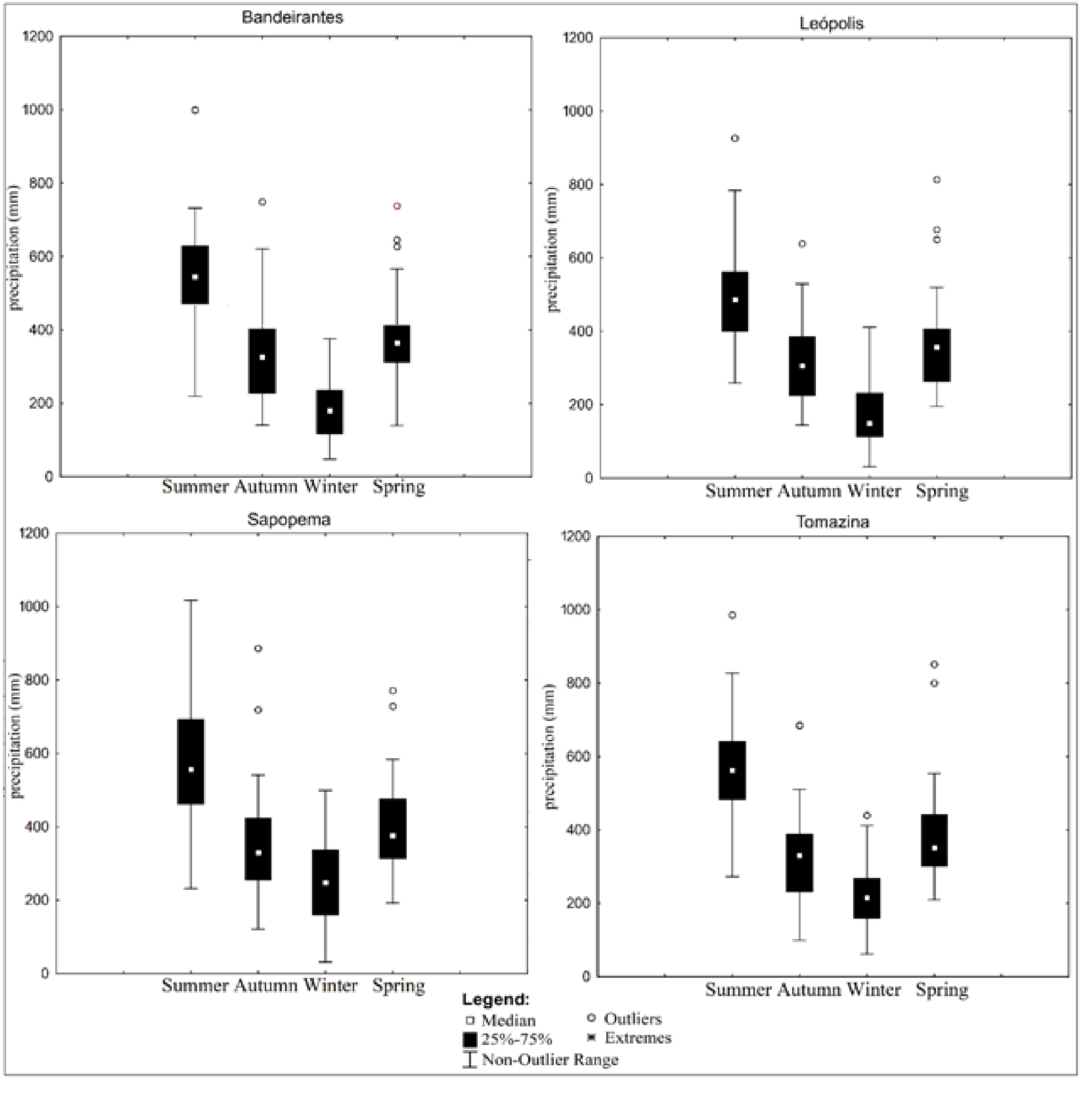

Figure 04 – Seasonal pluviometric variability in Pioneer Northern Paraná state Mesoregion (PNPM). Org: Authors (2020).

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In municipality of Sapopema, we verified significant variation, during the Summer, between quartiles (430-653 mm) and between maximum and minimum values (210-1.042 mm), even though it was the rainiest season, it showed values lower than the median of the driest winter season (242 mm), in addition, it was the one with the least discrepant values in the 43 years analyzed, with only four values concentrated in the transition seasons, Fall and Spring.

In municipality of Bandeirantes, the same pattern of seasonal distribution of precipitation was identified as in the Sapopema station, but with less significant discrepancy due to the difference between quartiles in the diagrams. Six outliers were identified in the series, with a highlight in the summer exceeding 1,000 mm. The Tomazina station presented medians and outliers similar to that of Bandeirantes.

Monthly (Figure 05), the stations exhibited significant variation and discrepant extreme events. The distribution of precipitation is similar to the seasonal one, with the highest pluviometric heights verified at the Sapopema station and the lowest in the municipality of Leópolis.

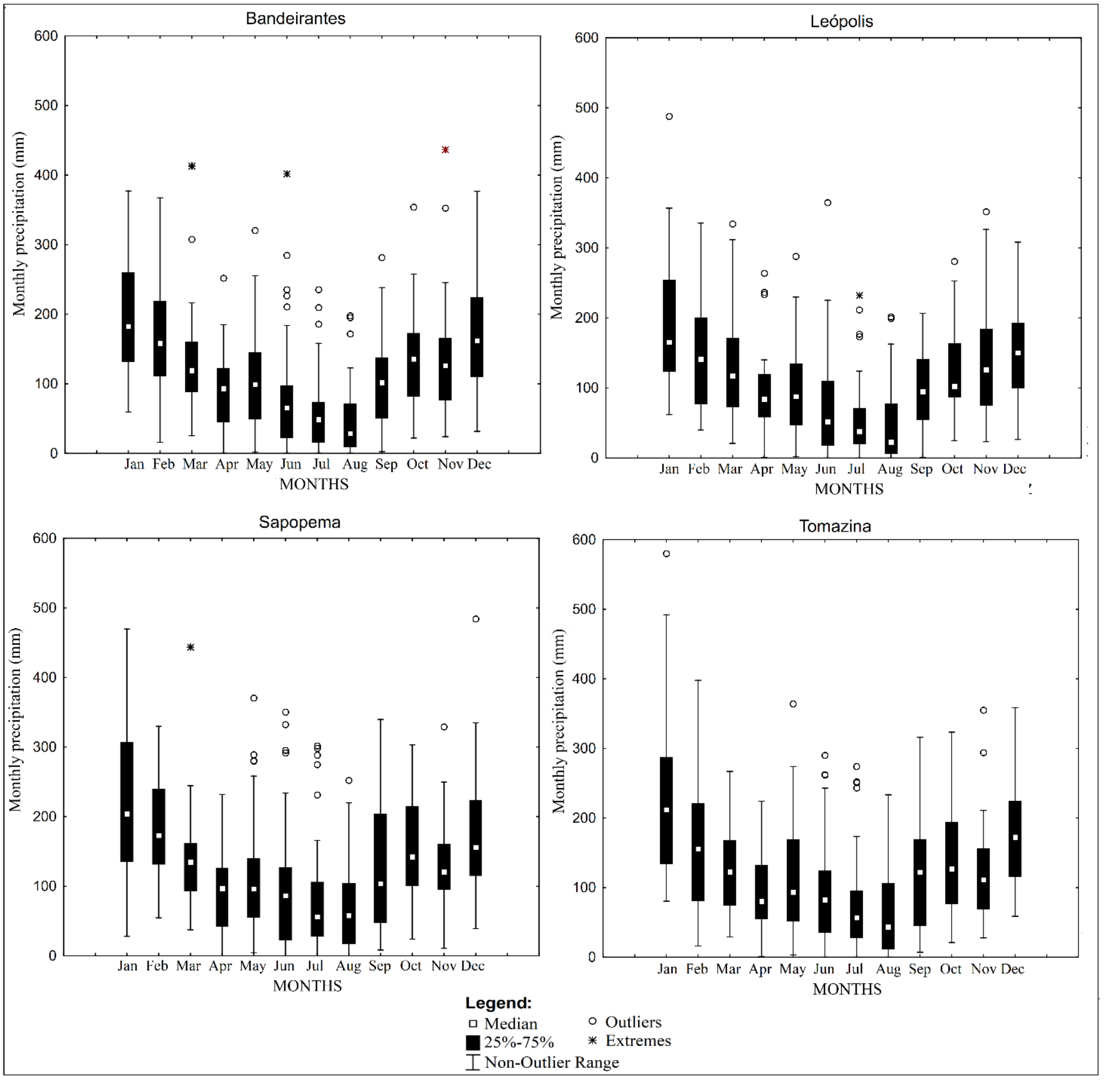

Figure 05 - Monthly pluviometric variability in Pioneer Northern Paraná state Mesoregion (PNPM). Org: Authors (2020).

The rainiest month in the analyzed weather stations was January, the median precipitation in that month exceeded 200 mm in Sapopema and Tomazina, in the latter, the highest monthly rainfall recorded in the region, with 580 mm, still occurred, and again verified as the period strong influence of El Niño in an extreme event in the region (CALDANA et al., 2019).

In the four seasons analyzed, the frequency of months without rain was also identified, mainly between April and August, with all the minimum values of the box plot classified at 0 mm. The month of August is still the driest in the region, with the lowest medians, and in some cases, being less than 50 mm, a factor that can also be identified through the water balance (Figure 06).

The average climatological water balance exhibited discrepant values in the region (Figure 06). At the Sapopema and Tomazina station, located in the highest altitudes in the region, with variation from 900 to 1000 m (Figure 01), there was a water surplus during all months in the mean of the analyzed series. The months of January and February had the highest surpluses, while March, April and August had the lowest, almost to the limit range to determine water deficiency.

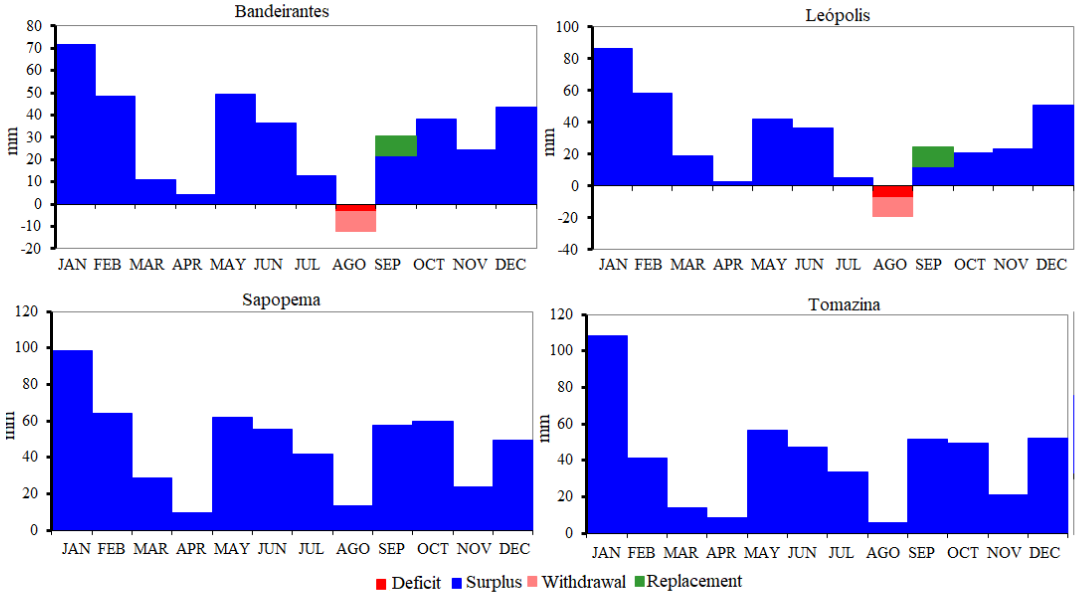

Figure 06 – Water balance in Pioneer Northern Paraná state Mesoregion (PNPM). Org: Authors (2020).

At the Bandeirantes and Leópolis stations, located in the northeast and northwest of the region, respectively, with altitudes close to 400 m, they showed regular water balance, with little water withdrawal from the soil in August, reaching water deficit values of 10 mm, being replaced in the month of September.

The winter months, due to the lower average temperatures in the region (NITSCHE et al., 2019) and lower pluviometric heights showed the greatest risks of a deficit period in the region, as verified at the Figure 04.

However, water deficiency can occur throughout the year in the region (Figure 07) in dry years it is possible to observe higher rates reaching more than 90 mm between deficiency and withdrawal of water from the soil in Tomazina in April, in the year of 2018. In this season, there was a big deficit in the month of February and during much of the winter and early summer following.

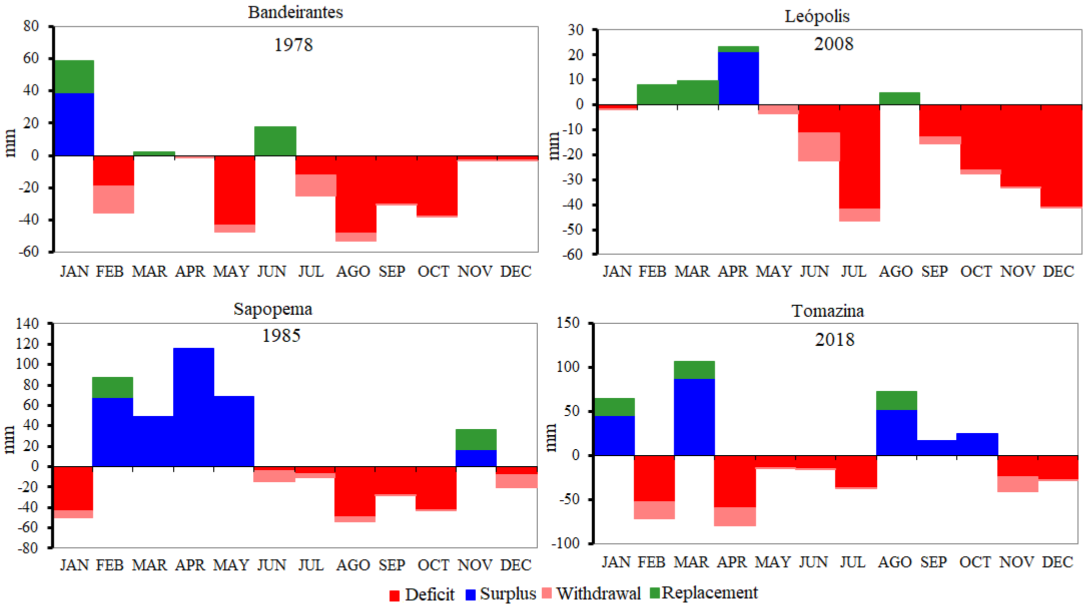

Figure 07 - Water balance of the driest years in Pioneer Northern Paraná state Mesoregion (PNPM). Org: Authors (2020).

At the Bandeirantes station, there was water deficiency in almost the whole year, the only month to show a surplus was January. In the months of March and April, there was little water replacement in the soil, but in the following months there was a deficiency again. In Sapopema there was the smallest water deficiency scenario, the biggest deficit happened in January, which when it rains little, coupled with high temperatures and high evapotranspiration (NITSCHE et al., 2019), worsens water availability in the soil.

While in the municipality of Leópolis was verified a significant deficiency during the Winter, which was extended until the end of the year, and probably, at the beginning of the following year, the only month to show a surplus was April, having already been lost the following month. Figure 08 shows the tree diagram obtained for the 1976 to 2018 annual precipitation data set, of the 34 rainfall weather stations located in Pioneer Northern Paraná state Mesoregion (PNPM).

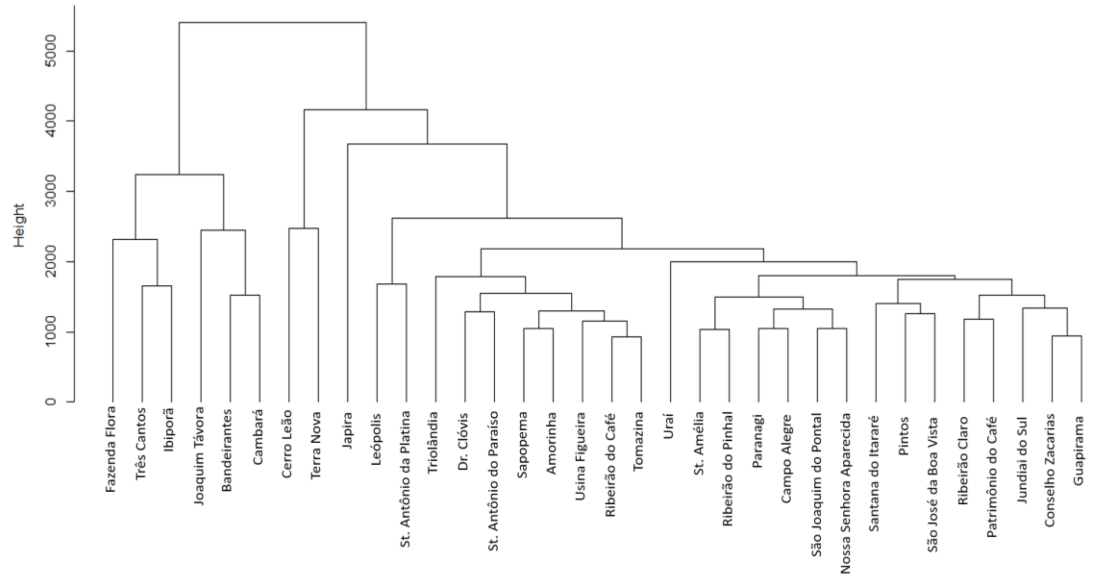

Figure 08 - Dendogram of the weather stations in Pioneer Northern Paraná state Mesoregion (PNPM). Org: Authors (2020).

From the graph it can be seen that there are two key axes of similarity in the rainfall pattern. The first comprises six stations and the second to the others, and the second group also has some subdivisions according to the differences between the seasons.

The great territorial extension of the area and, therefore, the varied characteristics of the topography of the region together with the climatic dynamics in the region constitute the significant differences between the measurement posts used in the analysis.

4. CONCLUSIONS

• The average annual rainfall in the region exhibited a significant discrepancy, showing the variability from 1,200 to 1,800 mm in a low distance.

• It was verified great variation for the annual variability, in the data series analyzed as records, from 900 to 2,100 mm.

• For the monthly precipitation, January was identified as the rainiest month, while the Fall and Winter months showed periods with no precipitation.

• The Northwestern region from the Mesoregion, near to municipality of Leópolis, showed the lowest rainfall and the worst scenarios tested in the water balance, while the Southwest, near Sapopema, exhibited rainy periods and less risk of drought occurrences. The average climatological water balance in the region exhibited a low deficit during August, however, when testing scenarios of dry years, it showed water deficiency throughout the year.

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ISSN: 2237-8642 (Eletrônica)

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