RAINFALL VARIABILITY AND ANALYSIS OF DROUGHTS PERIODS RISKS DURING THE SOYBEAN CROP (*Glycine max L.*) IN THE WESTERN OF PARANÁ STATE, BRAZIL

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ABSTRACT: Although the recent scientific and advances technologies, the climate is still one the key variables for soybean yield (Glycine max L.), the main crop cultivated in Brazil and Paraná State. Droughts periods are potentially harming for soybean yield. For this context, studies which identify the frequency and intensity of droughts periods are relevant to the agricultural planning and contribution to decision-making in the field. The objective of this study was to evaluate the rainfall variability and to determine the frequency of droughts periods, aiming to verify the risks of soybean cultivation in the Western of Paraná State, Brazil. For that purpose, were used meteorological data from 48 stations, distributed along the Western of Paraná State, from 1976 to 2018. It was used Box Plots to analyze the rainfall variability, in addition, were analyzed annual and monthly averages and moving 10-days scales to verify the rainfall variability and the frequencies of droughts periods occurrences, from September to March, period of the soybean cycle. It was used the Climatological Water Balance (CLIMWB) during the soybean cycle in Western of Paraná State, according to the method of Thornthwaite and Mather. It was verified rainfall variability, however, all the weather stations exhibited sufficient rainfall for the soybean cultivation requirements. The Southern area, of the Western of Paraná State, showed the highest average rainfall, while the Northern area, the lowest. The frequencies of droughts periods per moving 10-day periods exhibited a maximum of 35 % between the months of September and March. It was verified periods with the lowest risk during the month of October, followed by December 10 to January 5. The highest risks of droughts periods occurrences are concentrated during September, period where the soybean is sown, in the Western of Paraná State. The Climatological Water Balance was favorable for soybean cultivation. It was concluded there is not considerable risks for soybean crop cultivation, in the Western of Paraná State.

KEYWORDS: rainfall variability; agricultural planning; droughts periods, climatic risks.

VARIABILIDADE DE CHUVAS E ANÁLISE DE RISCOS DE SECAS DURANTE O CICLO DA SOJA (Glycine max L.) NA REGIÃO OESTE DO PARANÁ

RESUMO: Mesmo com avanços científicos e tecnológicos, o clima está entre as principais variáveis no desempenho produtivo de uma cultura agrícola, sendo assim, componente crucial por sucesso ou quebra de safras de soja (Glycine max L.). Períodos secos são potencialmente prejudiciais para um sistema de produção agrícola. Nesse contexto, estudos que identifiquem a frequência e intensidade desses eventos são fundamentais para tomadas de decisão no campo. O objetivo desse estudo avaliar a variabilidade de chuvas e determinar a frequência de riscos de secas, visando dessa forma analisar potenciais riscos para o cultivo de soja na Região Oeste do Paraná. Os dados de chuva foram obtidos a partir de 48 estações distribuídas no Oeste do Paraná, entre os anos de 1976 a 2018. Para a análise de variabilidade de chuvas foram utilizados Box Plots. Foram analisadas a variabilidade das chuvas nas escalas anual, mensal e decendial e as frequências de ocorrência de períodos secos de 10 dias de setembro a março e ≥ 20 dias durante o ano, além do Balanço Hídrico Climatológico (BHC) nos meses de cultivo de soja no Oeste do Paraná, de acordo com o método proposto por Thornthwaite e Mather. Verificou-se que a região Oeste do Paraná apresenta totais de chuvas satisfatórios para a soja. A porção sul, da Região Oeste do Paraná, apresenta as maiores médias de chuvas, enquanto a porção norte, as menores. As frequências de períodos secos por decêndio móvel mostraram máximo de 35 % entre os meses de setembro e março na região. Os períodos com menor risco são durante todo o mês de outubro, seguido de 10 de dezembro a 5 de janeiro. Os maiores riscos de secas concentram-se no mês de setembro, período no qual a soja é semeada. O Balanço Hídrico foi favorável para o cultivo de soja no Oeste do Paraná. Foi concluído de que não há riscos consideráveis para o cultivo da soja, na Região Oeste do Paraná.

PALAVRAS-CHAVE: variabilidade nas chuvas; planejamento agrícola; períodos secos, riscos climáticos.

INTRODUCTION

Although the agricultural technological and scientific advances, the climate is still one of the most important variables for crops productionThe most significant natural variables for yield come from the climate due it is responsible for 80 % of crops productions variability, thus, accepted as a key factor for physiology of production (CARAMORI et al., 2008; FAO, 2014; SANT'ANNA NETO, 2015; CARAMORI et al., 2016).

Rainfall are the most important element for tropical and subtropical areas, where its variable distribution affects the crops performance (PELL et al., 2007; MICHLER et al., 2018). The water has a key importance for all plant physiology processes, including root absorption, nutrient transport, thermoregulation and hydration, in addition, is essential to maintain the vegetal cellular activity and its structure (BHATLA; LAL, 2018).

Studies which identify occurrences of droughts contribute for decision-making and establish an appropriated agricultural planning and management, for example, the moment for sowing, necessities of irrigation and cultivar choice (PATHMESWARAN et al. 2018; WIRÉHN, 2018; SANTI et al., 2018; DE SOUSA; DE OLIVEIRA, 2018; DE SOUZA et al., 2018; TAYT'SOHN et al., 2018; AGOVINO et al., 2019).

Cultivated during the Spring-Summer, between September and March, the soybean crop is the main agricultural activity for Brazil and Paraná State. Several studies have focused on water deficit of soybean and the yield impacts

(FARIAS et al., 1997; PEDERSEN; LAUER, 2004; FARIAS et al., 2007 STÜLP et al., 2010; ALVARES et al., 2013; SENTELHAS et al., 2015; BATTISTI et al., 2017; GARCIA et al., 2018; ZARO et al., 2018; ADEBOYE et al., 2019; AKHTAR et al., 2019; BENCKE-MALATO et al., 2019; NÓIA and SENTELHAS, 2019).

The objective of this study was to evaluate the rainfall variability and to determine the frequency of droughts periods occurrences, during the period of soybean cultivation, aiming to verify the risks of soybean cultivation in the Western of Paraná State, Brazil.

MATERIAL AND METHODS

CHARACTERIZATION OF AREA OF THE STUDY

The Western of Paraná State has a population around 1 million inhabitants, and the key economic activity is agriculture (IBGE, 2018). In this region, soil occupation occurred rapidly, from 1950 to 1980 the area increased and in this process, the short cycle crops, such as cassava and rice, were substituted by crops such as wheat, soybean and corn. Nowadays, the Western of Paraná State as a key relevance for crops productions of Paraná State, and the municipalities of Cascavel and Toledo stand out with soybean annual production around 200,000 tons, according to the Figure 1 (MEDEIROS, 2018).

The climatic classification of the Western of Paraná State is Cfa, according to the Köppen climatic classification, characterized by irregularities on rainfall distribution (NITSCHE et al., 2019; MINUZZI; CARAMORI, 2015; JACONDINO et al., 2018).

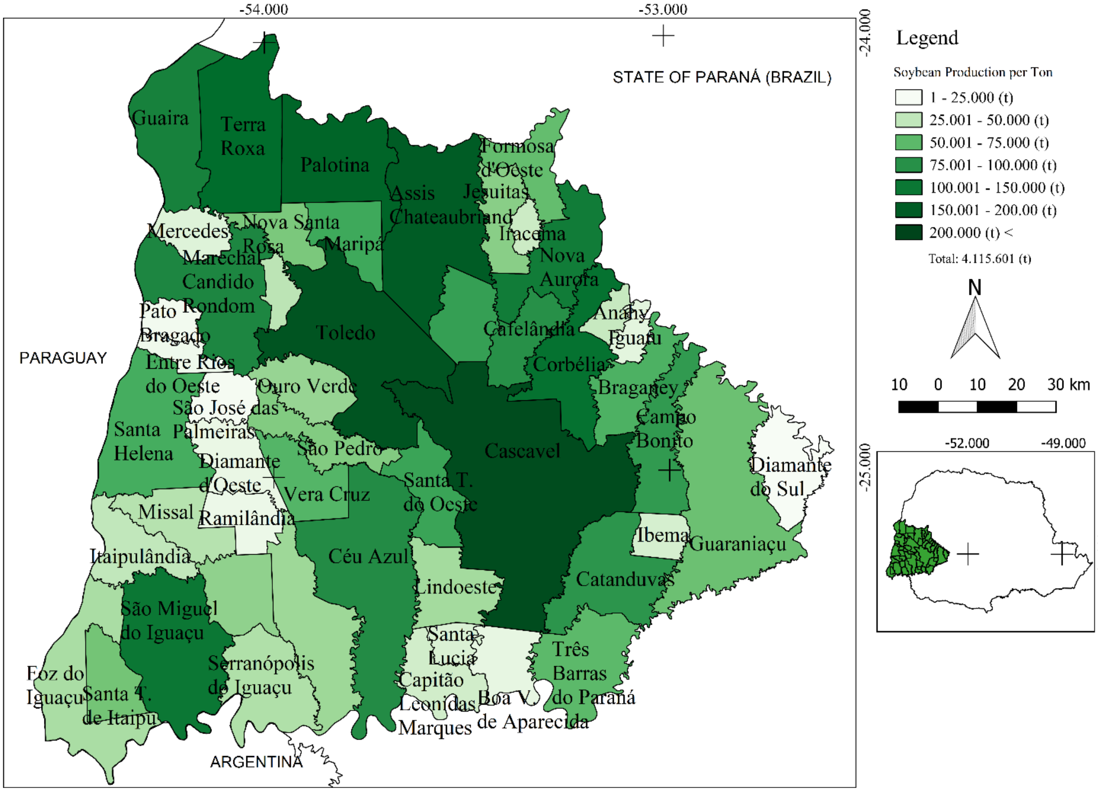

Figure 1 - Soybean production in the Western of Paraná State, Brazil. Source: DERAL (2019).

METHODOLOGICAL PROCEDURES

For this, were used database from 48 weather stations from the Instituto Agronômico do Paraná (IAPAR), Instituto das Águas Paraná (ÁGUAS PARANÁ), Instituto Nacional de Meteorologia (INMET), Agência Nacional das Águas (ANA) and Sistema Meteorológico do Paraná (SIMEPAR). The weather stations are distributed along the Western of Paraná State (Figure 2), with homogeneous periods of daily data observation, from 1976 to 2018. Altimetric data were used to identify possible geographic factors that interfere with regional rainfall distribution due the regional topography ascends from the Northern, Southern and Western, to the Center-Eastern direction with altitudes around 100-200 m to 800-900 m.

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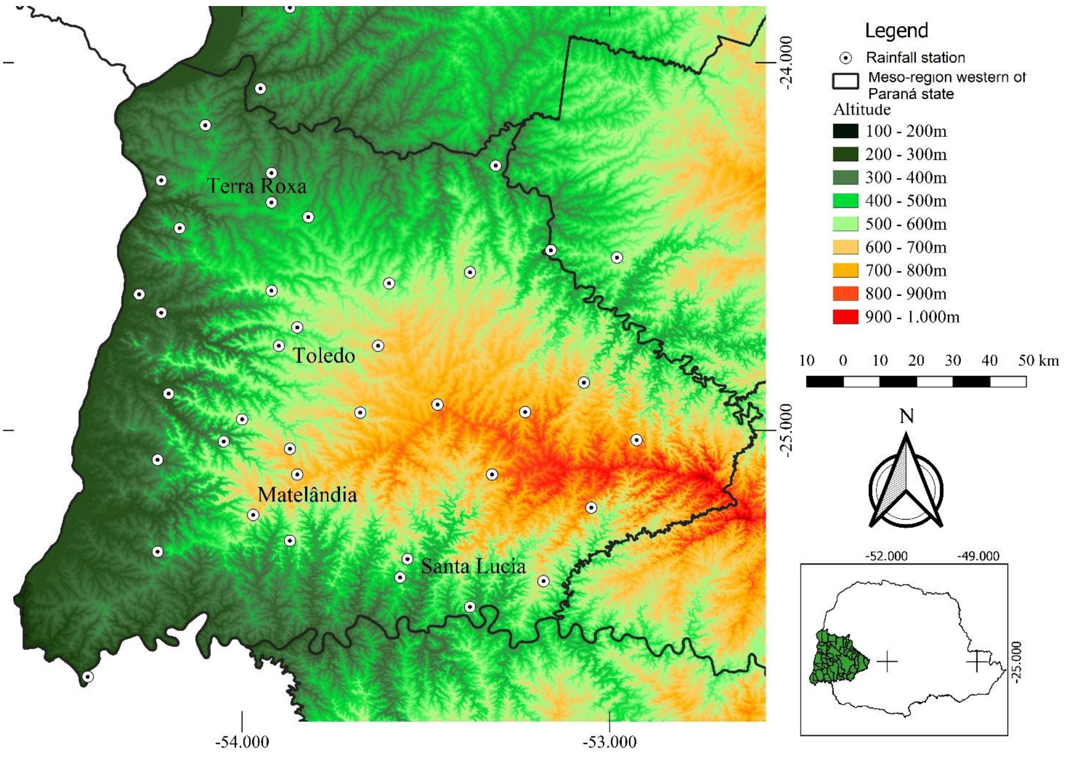

Figure 2 - Hypsometry and location of the Meteorological Stations in Western of Paraná State, Brazil. Source**:** ANA; ÁGUAS PARANÁ; INMET; IAPAR (adapted).

The spatial rainfall data of the area of the Western of Paraná State were represented by interpolation using the Inverse distance weighted (IDW) algorithm, which is an appropriate method for the spatial representation of rainfall data (MUELER, 2004). The maps were created using the Qgis *softwar*e. For this procedure, the maps were transformed into a raster format, generating a fine mesh of grid cells (pixels) which add a numerical value. Each pixel of the generated images has a spatial resolution of 1 km x 1 km (ELY; DUBREUIL, 2017). The nearest neighbors have an average distance of 20 km and were interpolated with a distance of 2.0.

The rainfall variability was explored by Box Plot or box diagram charts. This procedure is recommended to provide a quick view of the data distribution. If the distribution is symmetrical, the box is balanced with median equals to the mean and positioning in the center. For asymmetric distributions there is an imbalance in the box in relation to the median (SILVESTRE et al., 2014, p.27). The graphics were created by the program *Statistica® software*.

The Box plots represent five values of classification. The outliers were divided into the discrepant (values above the maximum considered but not extreme) and extremes, considered as values greater than Q3 + 1.5 (Q3 - Q1) or lower than Q1 – 1.5 (Q3 - Q1). In the box, three quartiles with 25 % of the data are classified, in addition to the median value, equivalent to the second quartile, or 50 % of the data (LEM et al., 2013, SCHNEIDER; DA SILVA, 2014). The average and extreme values are defined by each station analyzed, according to the data series.

The analysis of Box plot was applied to the rainfall data from the stations of the of Matelândia, Santa Lucia, Terra Roxa and Toledo (Figure 2). It is should be noted that the weather stations were chosen due the data series exhibited the most variabilities of rainfall, however, this is not meaning the other weather stations do not showed variability, thus, these stations were chosen only for exhibit in Figure 2. Also, according to the Figure 2, each municipality (Matelândia, Santa Lucia, Terra Roxa and Toledo) has four weather stations analyzed.

ANALYSIS OF DROUGHTS PERIODS

This analysis consisted on the verification of the probabilities of consecutive days without rainfall. For this, were admitted rainfall with at least 1 mm (ZARO et al., 2018). The following methods aiming to identifiy droughts periods occurrences were analyzed:

a) Consecutive periods of 10 days without rainfall: The soybean is cultivated from September to March, in the Western of Paraná State. Droughts periods were identified in a sequence of ten days without rainfall, during the soybean cultivation. Analyzes were established by a moving 10 days scales, such as September 1st to 10th; September 2nd to 11th; September 3rd to 12th and so on.

b) Periods ≥ 20 days without rainfall: Also during the soybean cultivation in Western of Paraná State, were made descriptive analysis of the mean that had 20 days or more without rainfall, total of days over 20 days without rainfall, and error and standard deviation. In addition, were calculated the frequencies of droughts periods and the adjustment of the largest annual droughts periods to distribution of extreme values, whose probability density function f (X) and the cumulative probability function F (X), according to the mathematical formula showed below (ASSIS et al. 1996; COSTA et al., 2009):

$$f(X) = \frac{1}{\beta}\ e^{-\frac{x-a}{\beta}}\ e^{-e^{-\frac{x-a}{\beta}}}$$

$$F(X) = \frac{1}{\beta}\ -e^{-\frac{x-a}{\beta}}$$

Where X is the random variable, ɑ is the parameter that controls the position of the curve on the axis of the abscissa and β is the parameter that controls the curve dimensions, given a constant shape.

For this study was used the Lieblein method to estimate ɑ and parameters and the Kolmogorov-Smirnov adhesion test, as described by Assis (1996) and Costa et al. (2009). The trend line was performed with the non-parametric Mann-Kendall method and calculated using Past software, from the set of statistical tests (including the Mann-Kendall).

This test has a purpose to identify whether in a given series of data analyzed there is a time trend of statistically significant change (SALVIANO et al, 2016). For this study, the significance tested was 95 %. The weather stations from the municipalities of Matelândia, Santa Lucia, Terra Roxa and Bom Princípio (Toledo) were used as models.

The Climatological Water Balance (CLIMWB) was obtained by the classical method of Thornthwaite and Mather (1955), considering the equation with the values of several meteorological variables and the Available Water Capacity (AWC) proportional to the effective depth of the roots of the analyzed species. Were considered the monthly average rainfall data and the monthly average temperature. The potential evapotranspiration (PET) was calculated according to the Thornthwaite method.

The Available Water Capacity (AWC) used was 20 %, according to the Zaro et al. (2018). The researchers used this value in five points of clayey soils. This value is correct, according to the Vermeiren and Jobling (1997). Different from the previous analyzes, data of temperature average, evapotranspiration and precipitation were used, being necessary data to complement the analyses. For this, were used the weather stations from the municipalities of Assis Chateaubriand, Cascavel, Foz do Iguaçu, São Miguel do Iguaçu and Toledo.

RESULTS AND DISCUSSION

RAINFALL DISTRIBUTION

Discrepancies in annual rainfall average in the Western of Paraná State (Figure 3), were verified. For the far areas of the Mesoregion (Northern and Western), the minimum values are 1600 mm, while in the Eastern, Central and Southern areas, of the Western of Paraná State, exhibited maximums of 1950 mm.

Rainfall variabilities in different altitudes were observed. For areas from 100 m to 300 m, near to the Paraná River, were observed lower rainfall average, while for the areas from 450 m to 800 m, highest rainfall average. The factor that justifies this discrepancy is the abrupt ascent of the regional topography, in addition, the topography from the Southern, Northern and Western areas of the Mesoregion exhibited an abrupt rise, from 200 to 900 m.

Rainfall is affected by different factors, including continentally, topography forms, altitude and the displacement of systems. The cold fronts are characterized by the encounter of the polar mass air with the mass of continental hot and humid air. This can generate strong atmospheric instabilities, often with formation of cumulonimbus and severe storms, accompanied by strong gusts of wind and hail rainfall. In the Western of Paraná State, these phenomena occur during the Fall, Winter and Spring (CALDANA et al., 2018; NITSCHE et al., 2019; CALDANA et al., 2019a; CALDANA et al., 2019b).

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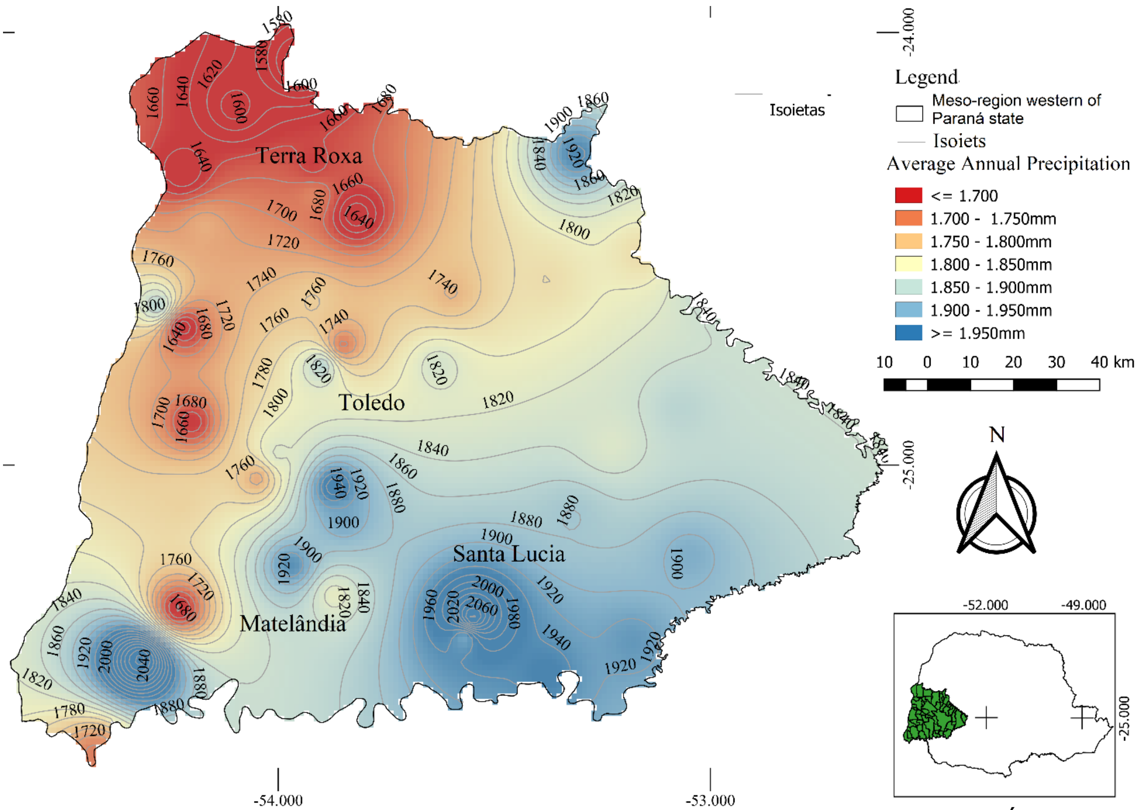

Figure 3. Annual rainfall average in Western of Paraná State. Source**:** ANA; ÁGUAS PARANÁ; INMET; IAPAR.

The Convective Systems and the Mesoscale Convective Complexes (MCC), which operate during the year, however, predominate in the Spring and Summer, in the Western of Paraná State. The MCC are identified using satellite images by their approximately circular shape and by a wide area of storm coverage. They are defined as a cluster of cumulonimbus covered by a dense layer of cirrus, and convective cloud systems with rapid vertical and horizontal growth over a period of 6 to 12 hours.

Depending on their intensity, they can create multiple nuclei with storm formation and hail. Its displacement is normally in the direction Western - Eastern, coming from Paraguay. The shape of the topography, mountainous areas and altimetric rise over short distances contribute to the elevation of warm and humid air, strengthening this system and causing more rainfall in these areas. The convective systems differ from these by the smaller spatial extent, forming several rainfall nuclei. The topography also contributes to the formation and intensity of the Convective System, influencing the rainfall variability (TREFAULT et al., 2018; CALDANA et al., 2018; CALDANA et al., 2019a). For Sobral et al. (2018) in higher areas (topography), are higher concentration of rainfall.

As mentioned, the Convective Systems and MCCs operate along the year in the Southern region of Brazil but predominantly in the Spring and Summer seasons (CALDANA et al., 2018; CALDANA et al., 2019). Their displacement along the Paraná State is normally in the Western - Eastern direction, coming from Paraguay (TREFAULT et al., 2018; CALDANA et al., 2018; CALDANA et al., 2019a).

Convective systems, on the other hand, are differentiated by the smaller spatial scope, formed by the process of heat transfer by conduction that occurs in intense vertical movements, leading to the rapid condensation process and the formation of Cumulunimbus (CALDANA et al., 2018; CALDANA et al., 2019). In both cases, precipitation is generally short-lived and of high intensity, as a consequence, there are rainfall variabilities (TREFAULT et al., 2018).

The Paraná State is located into a climatic transition area (NITSCHE et al., 2019). This contributes to the discrepancies of temperature and, consequently, of pressure, influencing the displacement of the systems (CARAMORI et al., 2001; CALDANA et al., 2018). Due the far distance from the Oceans Atlantic and Pacific, the Western of Paraná State do not suffer maritime influence.

According to the analysis of Box Plot graphics (Figure 4) it was possible to verify a significant discrepancy between the rainfall heights at the Matelândia station, when compared to the others. The interval between Q1 and Q3 was 1.290 mm to 2.195 mm. Was observed the median was 1,975 mm and the maximum value was 3.006 mm, the highest annual rainfall recorded in the series of the analyzed stations.

Even with a maximum rainfall lower than the Matelândia station, the medians of Toledo and Santa Lucia stations exhibited similar when compared with Matelândia, with 1.860 and 1.805 mm, respectively. The maximum values verified were 2.620 and 2.610 mm, respectively.

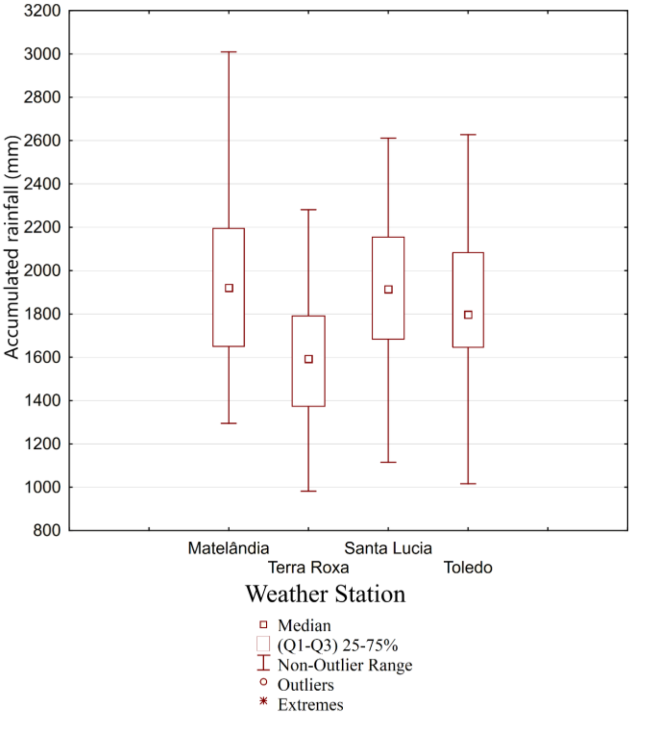

Figure 4 - Annual rainfall variability in the Western of Paraná State.

The Terra Roxa station exhibited values with relative dispersion for the others. The median was 1.602 mm and the maximum and minimum values ranged from 2.260 to 960 mm, respectively. The latter was the lowest annual rainfall recorded among the analyzed stations. The interval between Q1 and Q3 of Terra Roxa station was 1.798 to 1.385 mm, respectively. Even with the discrepancy verified in between localities, the Western of Paraná State exhibited appropriated rainfall distributions, during of period for soybean cultivation.

Salton et al. (2016) studied the climatology of rainfall in Paraná State. They identified similar patterns of rainfall distribution, due they verified greater rainfall average, especially during the Springer - Summer, period where the soybean is cultivated, in the Western of Paraná State.

Regional climatic peculiarities, influenced by cloudiness and radiation, and mainly by the dynamics of atmospheric circulation for the different seasons, cause different local configurations in the quantity, distribution, duration and intensity of rainfall, as identified in Western of Paraná State.

The monthly variability of the rainfall during the soybean cycle (Figure 05) exhibited similar distribution. The Matelândia station showed six discrepant values, one at the bottom of the Box Plot. In December, an extreme value of 505 mm was identified. The medians of these months ranged from 160 mm (September) to 195 mm (October).

The Santa Lucia station showed five discrepant values in the upper part of the Box Plot, three in the month of January and one in November and December, and a lower value in January. It was observed two rainfall heights below 20 mm monthly in February and December, being the months exhibited the greatest variability, with oscillation of 16 to 470 mm.

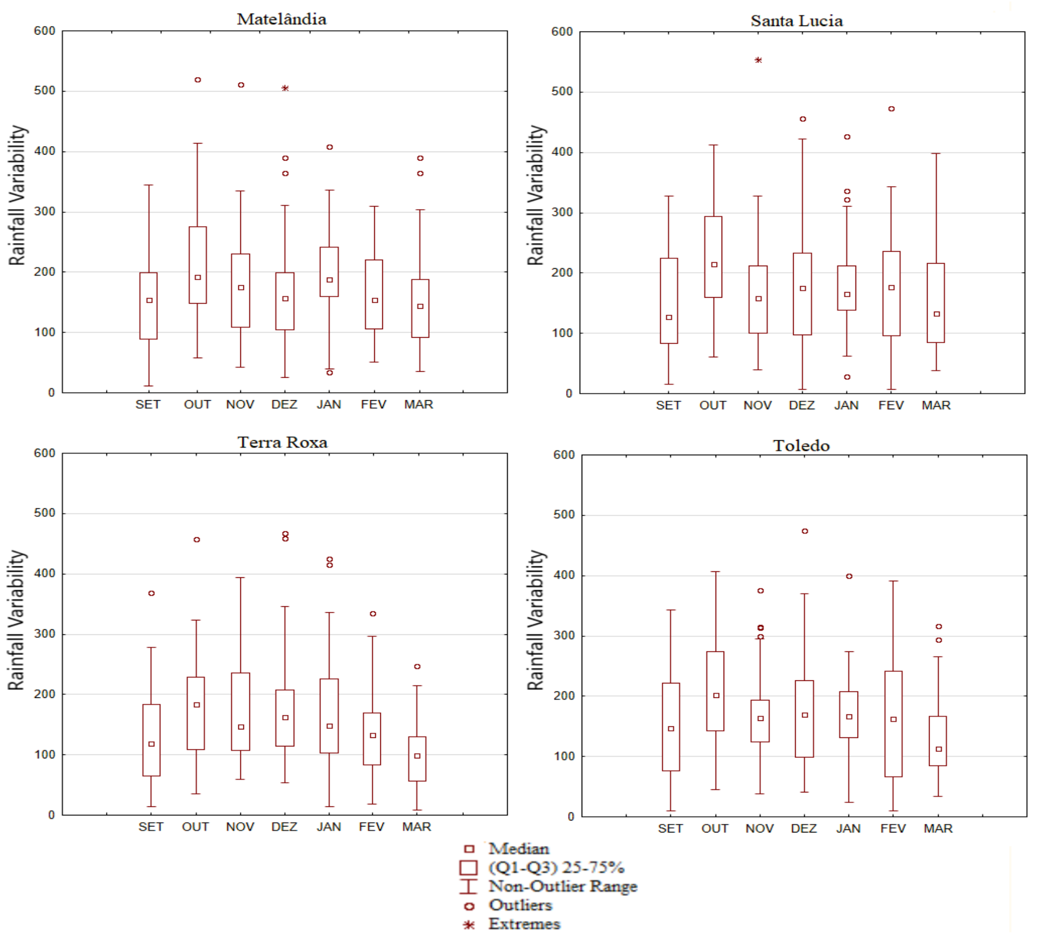

Figure 5 - Rainfall variability during the cycle of soybean crops in Western of Paraná State.

The Terra Roxa station showed five discrepant values, all in the superior part of the Box plot, being one in the month of October, one in February and two in December and one in January, and also exhibited the lowest rainfall values, with medians of all months below 180 mm, while the Toledo station showed five discrepant values, all in the part superior of the Box Plot, during the months of November, December and January. Only the month of October had a median of over 200 mm, while in the lower part, in February, showed 13 mm, the lowest value of monthly rainfall.

The medians remain in all scenarios above 100 mm, and in a few months, over 200 mm, but there is a risk of rainfall with discrepant values such as in the lower part of the Box Plot in Matelândia and Santa Lucia, or, monthly rainfall less than 20 mm, as observed in all weather stations, mainly in September.

The 10 days scales of rainfall (Figure 6) exhibited variation and numerous discrepant or extreme values. The accumulation of consecutive days without rainfall can be determinant for the growth, development and soybean yield, in the Western of Paraná State. The 10 days scales analysis exhibited a significant rainfall variability, as for example in the December 3/11, varying from 0 to 312 mm. With the exception of Terra Roxa, the December 01/09 presented the

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lowest median in the region. As of October, even with expressive variability, the 10/10 ,10 days scales exhibited medians greater than 50 mm, suggesting expressive rainfall regularity.

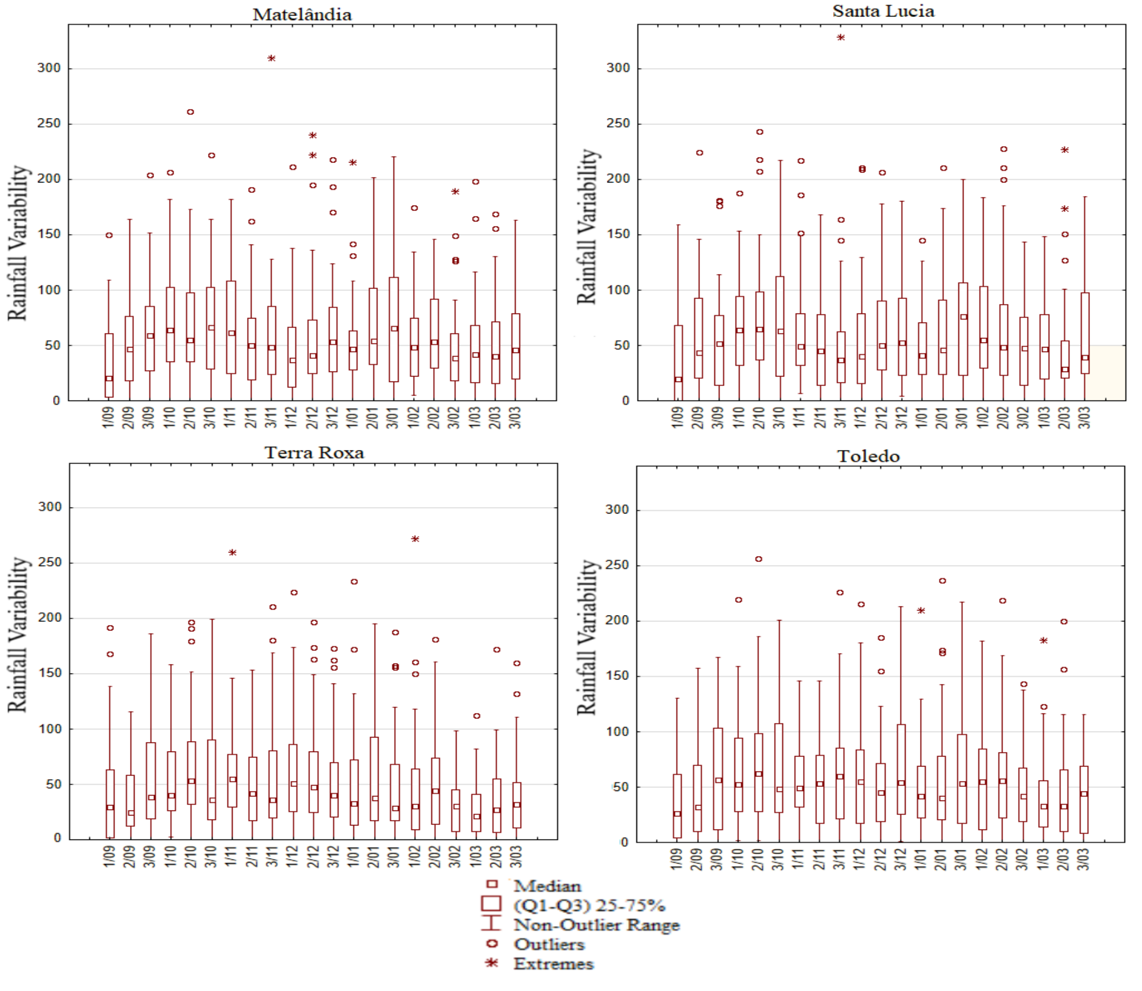

Figure 6 – Decendial (10 days scales) rainfall variability of the soybean cycle months in the Western of Paraná State**.**

For the soybean crop reproductive stages, if the water deficiency coincides with flourish critical stages (R2) and developing of the grains (R5), the soybean yield can be harmed, even can occur crop failure, if the water deficiency was severe on the mentioned stages. Thus, ten consecutives days without rain is determinant for soybean crop performance (FEHR; CAVINESS, 1977; KADHEM; SPECHT; WILLIAMS, 1985; FARIAS et al., 1997; FARIAS et al., 2007; BOARD; KAHLON, 2011; YEE-SCHAN et al., 2013). To aid the best comprehend, the development stages of soybean are represented according to the Figure 7.

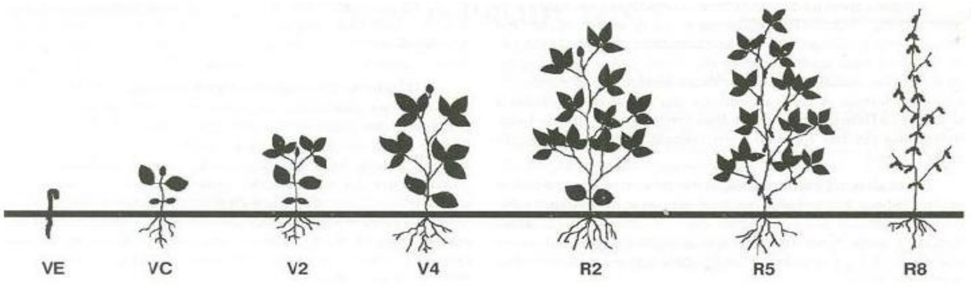

Figure 7 - Cycle of soybean, where V are vegetative stages and R are the reproductive ones. Source: Iowa State University, Special Report, n.53, 1988).

ANALYSIS OF DROUGHTS PERIODS

10 Consecutive Days Without Rainfall

The relative frequencies of moving 10 days droughts periods (Figure 8) exhibited variation from 3 % to approximately 35 %, between the months of September and March in Western of Paraná State. The periods with the lowest risk are in the month of October, followed by December 10 to January 5. The higher risks of occurrences of droughts periods are concentrated during the first half of September, with peaks above 30 %.

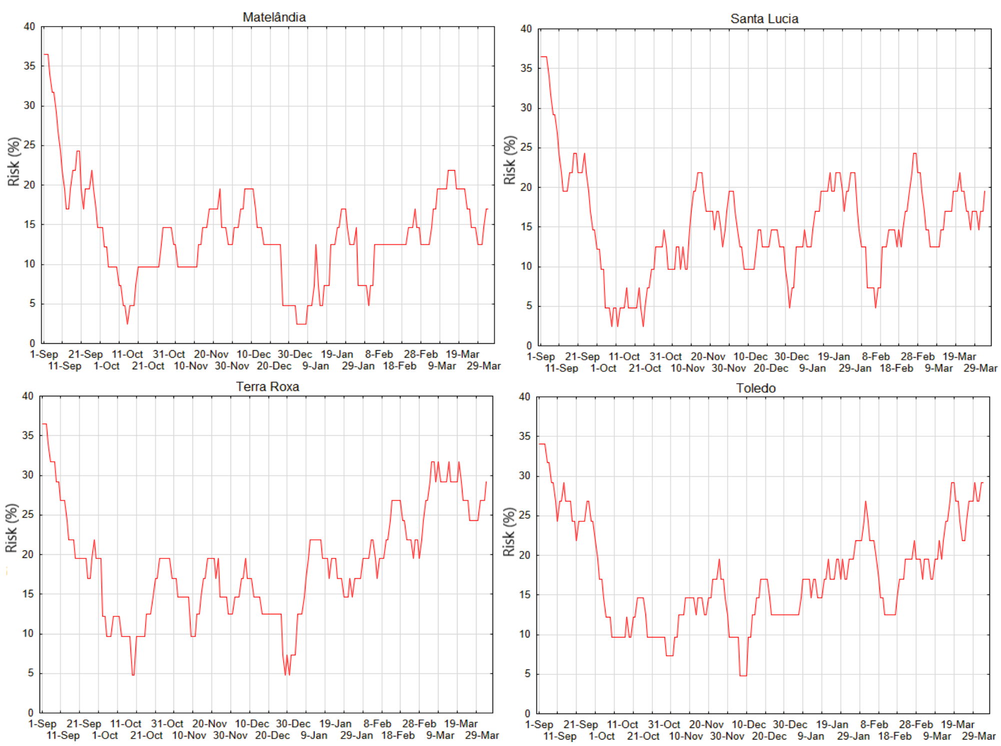

Figure 8 - Occurrences frequency of droughts periods, in decendial between September to March in Western of Paraná State, Brazil.

From December to January soybean is in the reproductive stages in this region. As mentioned, the phases of flowering, formation of grains the soybean has considerable necessity of water. During these two months, the risk varies from 5 to 25 %, however, is lower than in the months of November, February and March. During the month of January, were verified few occurrences of 10-day droughts periods, highlighting the Terra Roxa station with a significant risk, while the stations of Santa Lucia and Matelândia showed the lowest frequencies.

During the second half of January there is a risk of droughts periods, ranging from 10 to 20 %. The risk increases during February and March; however, this is coincident to senescence and harvest of the soybean crop.

Periods ≥ 20 days without rainfall during the year

Most years have at least a period of 20 consecutive days without rain (Figure 9). The station with more occurrences annually was Terra Roxa with 106 events between 1986 and 2017. Only the year 2000 did not have at least 20 days without rain in this locality. It was not possible to identify trends of increase or decrease of these occurrences in the relatively short period of data analyzed.

It is should be noted that the analyses of periods ≥ 20 days without rainfall during the year was created as annual, even though the soybean crop is cultivated only during September-March, were made the annual rainfall average, in order to evaluate the entire rainfall distribution for the area of this study. As we made the analysis of 10 days only during the cycle of the soybean crop due to show precisely the droughts periods during the soybean crop. Then, for this analysis we decided to show all the months, not only during the cycle, then it was possible to verify before the sown and after the harvest and even during the Winter. Thus, only the 10 days' analysis were sufficient to verify the droughts periods occurrences, and the analysis of 20 days it is just to aid the holistic comprehend the behavior of the rainfall in the Western of Paraná State.

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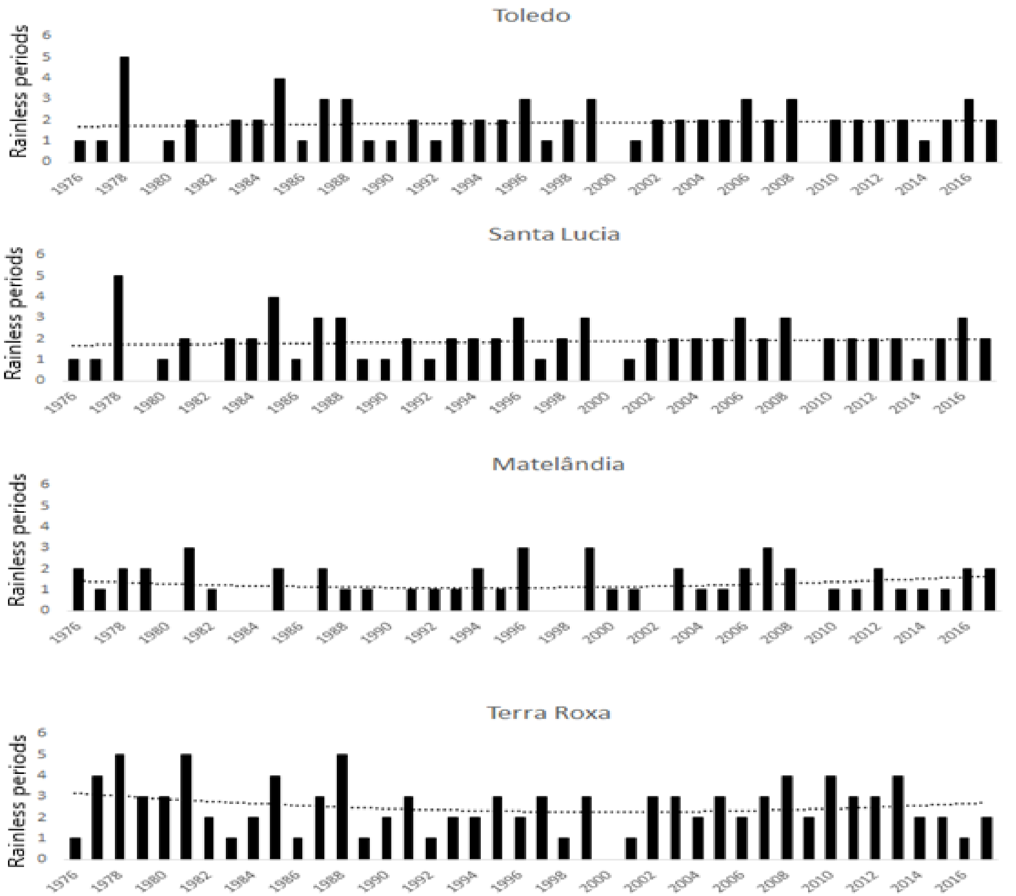

Figure 9 - Occurrences at least consecutives 20 days with no rainfall in Western of Paraná State, Brazil.

The station with the lowest number of occurrences was Matelândia, with 53 occurrences during the analyzed series. Four years in the series were identified without any rainfall within 20 days.

The distribution of consecutives days under extremes droughts was identified even in the region with registered high rainfall heights. The risk of reaching at least 20 days without any rainfall is about 80 %, while for the other stations is 90 %. It was found that none of the stations analyzed exhibited a risk for soybean cultivation, considering the average (Figure 10).

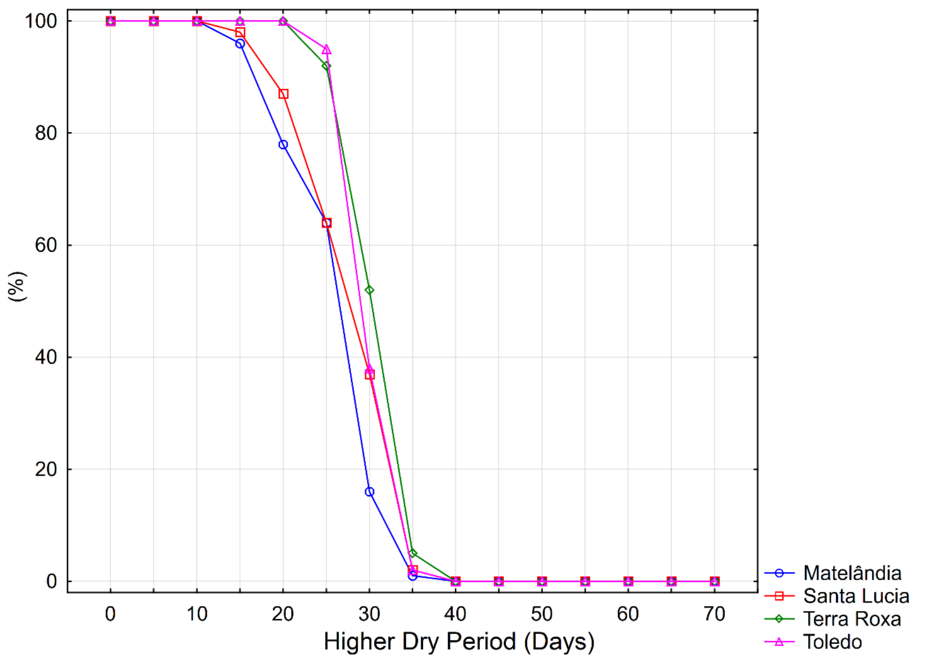

Figure 10 - Cumulative probability of the largest annual droughts periods, in the Western of Paraná State, according to the distribution of the extremes.

The risk tends to zero for durations of 30 to 40 days without rainfall. These occurrences were few in the period that the soybean crops are in the field at Matelândia station, used as an example (Table 01). Three of the occurrences were in March, a late harvest period, exhibiting no risk for soybean cultivation. Soybean can produce with a maximum water deficit of 60 mm throughout the cycle (DEBIASI et al., 2013). One of them, being the most severe one, occurred practically throughout the month of September, with accumulated precipitation of 1.1 mm, indicating once again the importance of adjusting the sowing period for the month of October.

Table 1 - Date of occurrence with no rainfall registrations at Matelândia station, during the soybean cycle in the field, September to March (Rainfall < 1 mm. day^{-1}).

Data	Year	Total Rainfall (mm)
January 09 to 28	1978	0mm
January 10 to 31	1982	0mm
February 23 to March 17	1987	0mm
March 06 to 28	1988	8.6mm
March 08 to 31	2002	0mm
November 13 to December 02	2008	0mm
November 23 to December 30	2011	4.7mm
September 01 to 29	2017	1.1mm

Authors (2020)

The Climatological Water Balance (CLIMWB) during the soybean cycle, in the Western of Paraná State is showed in Figure 11. For this, were admitted during the year per yield, from 1976 to 2018. Thus, were verified only in Guaíra has two months with water deficit and Foz, in March. For the other stations, the extract were favorable for soybean crop production in the Western of Paraná

State. It is should be noted that the purpose of the CLIMWB is to show the periods of sufficient quantity of water for soybean production, in the Mesoregion Western of Paraná State, aiming to aid the best time to sown and the technical information.

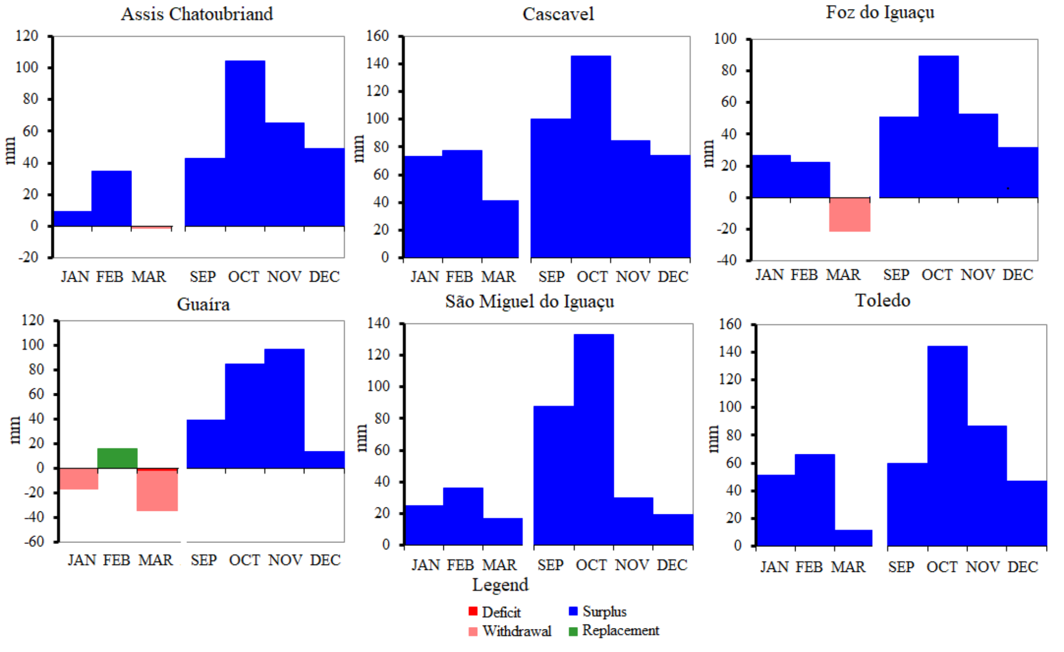

Figure 11 - Climatological Water Balance (CLIMWB) in the Western of Paraná State.

As an example of Terra Roxa station, the Guaíra station located in the far Northern of Western of the Paraná State and in the driest area, was the one that exhibited expressive risks due the deficit verified was 57 mm, not reaching the maximum of 60 mm. However, the greatest deficit occurs during the month of March, a period in which the soybean crop is in senescence and ready to be harvested, in addition, this is can be good for the soybean due the rainfall harms the harvest. For the other areas of the region, the water balance extract was favorable.

Caldana et al. (2019c) studied with a fragment of the Western region, in the Basin of Paraná River III. The authors analyzed the agrometeorological variables of the region for climatic aptitude for cultivation. According to the researchers, the rainfall is sufficient for the plants requirements in this region. Even not analyzing year by year as the present study, the region exhibits a regular rainfall distribution, even if events with no rainfall registrations occur. Zaro et al. (2018) carried out an interannual analysis of soybean and corn productivity in relation to the water deficit in the Paraná State, however, they reduced the cultivation period only for the months of November to February.

This study demonstrates the importance of agricultural planning of the soybean crop in the Western of Paraná State, aiming to reduce risks and obtain the highest yields, contributing for decision-making. There is a need to adapt the sowing moment, always aiming at the most regular rainy period, corresponding to the month of October. The knowledge of the regional climatology, rainy periods and risks of droughts periods, is fundamental to minimize the harmed yield and even risks of crop failure.

FINAL CONSIDERATIONS

The average rainfall is sufficient for soybean crop production, in the Western of Paraná State. However, the rainfall distribution is not regular both in the annual scale and in shorter periods during the crop cycle. Only the weather stations, located in municipality of Terra Rocha, showed risks of consecutive droughts periods, higher than the other weather stations analyzed. The Water Balance was favorable for soybean cultivation, in the Western of Paraná State.

During the soybean crop cycle, the highest droughts risk occurs during September. Sowing in October, the critical stages of flowering and developing of the grains occurs between December and January, thus, there is not considerable risks of droughts periods occurrences for the critical stages.

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