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Climate Trends in Bom Jesus, soybean production region in Piauí

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ABSTRACT
Climate is still the main responsible for soybean yield variations, exerting a limiting action on these agricultural systems. In the cerrado "savannah" of Bom Jesus, this crop has shown a growth in cultivated areas over the years, however, productivity does not follow the same rhythm, going through oscillation periods. Although cultivation is aggregated to high technology, the crop is highly vulnerable to climatic adversities. Thus, the objective of this study was to analyze possible trends in meteorological variables that could influence soybean yield in the municipality of Bom Jesus (Piauí). Daily meteorological data were used for the variables: precipitation, maximum and minimum temperature and air diurnal thermal amplitude from 1974 to 2014. The statistical Mann-Kendall test was applied in order to analyze variation trend in climatological time series of the variables under study. As regards variability of the agrometeorological elements, a significant negative trend for precipitation in the months of June and October and a significant positive trend in the month of December was observed from the indicated results, which detected changes in the local climate patterns. It was also possible to identify statistically significant positive trends in the maximum temperature, for all the months that are part of the soybean cycle (November - April). The identified results may be used to elaborate planning strategies to choose the best sowing time for soybean crop in the municipality of Bom Jesus (PI), in order to minimize the vulnerability of the crop productive system to climatic risks.

Keywords: agrometeorology, climatic variability, Mann-Kendall

Introduction

In Brazil, great part of the states of Maranhão, Tocantins, the southwestern portion of Piauí and northwestern Bahia (called the MATOPIBA1 region) are considered the main frontier for new agribusiness investments in Brazil (Anderson et al., 2016). Piauí's cerrado or savannah is located in this region, which has been showing a marked potential for expansion of grain production. Among the soybean-producing municipalities in Piaui, Bom Jesus stands out, currently concentrating a large part of the Piauí's cerrado grain production.

Over the years, the Brazilian Institute of Geography and Statistics recorded annual average growth around 44.2% of soybean cultivated areas in the cerrado or savannah of Bom Jesus. However, even though these areas are growing at a steady pace, due to the use of technologies, the adoption of genetic materials with greater productive potential, the use of soil management practices and the increasing qualification of rural producers, there have been fluctuations in productivity. In this sense, Ferreira & Rao (2011) emphasize that agricultural activities are always exposed to fluctuations in their incomes due to the occurrence of variations in meteorological elements. For the case of soybean, the climate and its variability is preponderant in productivity, being considered the main risk factor for the success of the crop development (Rio et al., 2015).

For the studied municipality, precipitation is the main source of water for soybean crop, since the cultivation is of the dry land type. Thus, considering the damages caused by climatic adversities, there are few corrective measures that can be taken as a way out to the producers, without adding values to the cost of production, and, therefore, the

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detection of changes in the records of meteorological variables is of great importance for decision makers to establish preventive strategies by means of climate change impacts on soybean productivity.

In this perspective, the present study starts from the premise that the behavior of the meteorological variables is the main limitation for soybean yield potential in the study area, being the hardest one to control, due to periodicities related to natural climate variability, which in many circumstances are difficult to predict. Therefore, the objective of this research is to analyze the possible trends in meteorological variables that may influence soybean yield in Bom Jesus (PI).

Material and Methods

The municipality of Bom Jesus (PI) is located in the microregion called Alto Médio Gurguéia (09 ° 04'28 "S, 44 ° 21'31"W, 277 meters above mean sea level). Its territorial area is 5,469,181 km2. The municipality climatology presents two well-defined seasons: a rainy one, which goes from October to April, and a dry one, which lasts from May to September. The average rainfall is 1,093.4 mm annually. The mean annual temperature is 26.2 ° C, ranging from 19 ° C in July to 35.7 ° C in September (Ramos et al., 2009).

For the development of the study, daily meteorological data from the period 1974 to 2014 were analyzed from the variables: precipitation, maximum and minimum temperature and diurnal air thermal amplitude by the meteorological station of Bom Jesus-PI (09 ° 06'S, 44 ° 07'S 'W, 331 m altitude) belonging to the National Institute of Meteorology (INMET) from 1974 to 2014.

The choice of these variables is strictly related to their influence on soybean yield, which in its turn was based on studies by Berlato et al. (1992) and Ferreira & Rao (2011). Cunha et al. (1998) pointed out that among the necessary environmental conditions to obtain high yields, water availability is outstanding, since it constitutes a factor that depending on its distribution along the stages of the crop can cause productivity fall or gain. At the maximum water requirement stage (average stage) the plant lacks a demand of 7 to 8 mm / day of water, which in its turn will be decreased after this period. Throughout the soybean cycle, the plant demands a total water need ranging from 450 to 800 mm / cycle to obtain maximum yield, which in its turn will depend on climatic conditions, crop management, type of cultivar, and cycle duration (Embrapa Soja, 2008).

Another meteorological variable considered determinant for the development process of soybean crop is air temperature. Soybean crop has a better adaptation to air temperatures in the range of 20°C to 30°C, and its development is small or null at 10°C or lower temperatures, considering in this perspective an ideal temperature around 30°C (Farias et al., 2007).

The non-parametric Mann-Kendall test (Mann, 1945; Kendall, 1975) was used to analyze the trend of variation in the climatological time series of the previously mentioned variables, referring to the 1974-2014 period. Based on several studies that use statistical methods for the verification of climatic variations, it is worth mentioning the studies by Sneyers (1975), considered to be the first ones to apply the Mann-Kendall test to identify climatic variability and trends. Later Goossens and Berger (1986) indicate the efficacy of the Mann-Kendall test compared to other usual techniques used to detect abrupt climate change. According to them, besides identifying the change, the method detects the approximate location of its start date.

Still in consonance with the effectiveness of the Mann-Kendall test, studies by Yu et al. (2002) mentioned that it is recommended by the WMO for the detection of climatic variations, since it is considered the most appropriate for this type of diagnosis. Obregón Párraga (2003) cites the advantage of using this test in his study because it uses the relative magnitude of the series values filtering extreme values.

Results and Discussion

Table 1 shows the results of trend analysis of the total and monthly maximum precipitation values using the Mann-Kendall test (Z), in which it is possible to identify the trend for reduction in total precipitation with statistical significance in the months of June and October. However, it is worth noting that this reduction trend observed in June is not a relevant concern for agricultural production since it occurs in the dry season (June) and in the dry-rainy transition period (October). On the other hand, it is possible to observe the trend for significant increase at probability level 10% for the monthly total of December (beginning of the rainy season). Similar results were obtained by Blain (2011) in Campinas (SP), although the climates of Campinas-SP and Bom Jesus-PI are quite different. In addition, the results were consistent with the study by Oliveira et al. (2014), which reveal the increase in the seasonality of precipitation over the Brazilian Northeast.

According to Embrapa Soja (2008), considering the local agricultural calendar, the table of favorable conditions for the seed germination, the trend for rain reduction in the transition period and its increase in the rainy season, that is, the delay of the rainy season, it is suggested that an experimental study be carried out in the analyzed area, with the purpose of proposing the best season for sowing, aiming to meet the soil water requirements for the good development of the crop. Still on Table 1, analyzing the trend for maximum precipitation values, it is possible to verify negative trend of this variable in the months of June (dry period) and October (dry-rainy transition). For the months of January (rainy season) and

November (beginning of the rainy season), the trend for decrease in monthly precipitation maximum values presented only a 10% significance level.

Specifically, the decrease of maximum precipitation values in January (beginning of flowering) may not be so detrimental to soybean cultivation, as it is known that the development of soybean crop can be affected by both water deficit and excess. Among the soybean stages, the reproductive (medium) stage is the most sensitive to soil water excess (Barni, 1973, 1978; Bergamaschi & Berlatto, 1973 and Schöffel et al., 2001).

The results of the Mann-Kendall test for the monthly maximum temperature series (Table 2) indicated a positive trend in the months of December, January, February (rainy season), March, April, May (transition), June, July, and November (beginning of the rainy season). The results are consistent with similar analyzes performed in the state of São Paulo (Blain, 2011), Minas Gerais (Ávila et al., 2014) and Paraná (Ferreira & Rao, 2011). Considering the results found in the present research, it was verified that soybean cultivation is increasingly exposed to the condition of higher temperatures, a fact that can cause physiological damages which may affect future productivity. Moreover, raising the maximum temperature will provide faster degree-day accumulation resulting in shorter crop cycle length (Mavi and Tupper, 2004).

Table 2 shows a negative trend for the minimum temperature in the months of December, February (rainy season), March, April (transition), September, October and November (beginning of the rainy season). The results were consistent with the study by Salvador (2014), when analyzing the climatic variabilities of rainfall and temperature in the MATOPIBA region. In the agrometeorological approach, it is expected that this decrease will not have adverse effects on soybean crop, since it is in the recommended range (between 20°C and 30°C) for the development of the crop, according to Embrapa Soja (2008).

Based on the Mann-Kendall test, it was possible to identify a positive trend for the variable diurnal thermal amplitude (Table 2) in all months of the year, except in the months of July and August. From the agroclimatic point of view, the increase in diurnal temperature range may be detrimental to the crop, especially if such increase is associated with the maximum temperature rise, considering that for the crop, the increase in diurnal temperature is more striking than in nocturnal (Ferreira, 2010). On the other hand, this increase implies the need for less time for the crop to accumulate the thermal requirement (degrees-day) needed to complete its cycle.

Table 1 – The application of the non-parametric Mann-Kendall (Z) test to the cumulative monthly precipitation values and accumulated daily maximum values of Bom Jesus (PI) from 1974 to 2014.

	Accumulated values			Maximum values		
month	Test Z	p-value	Slope (mm)	Test Z	p-value	Slope (mm)
Jan	0,12	0,8941ns	0,123	-1,74	0,0543+	-0,600
Feb	-0,54	0,5839ns	-0,519	-1,56	0,1157ns	-0,459
Mar	0,78	0,4282ns	0,870	0,31	0,7442ns	0,129
Apr	-0,30	0,7531ns	-0,345	-0,14	0,8796ns	-0,065
May	1,03	0,2956ns	0,250	0,78	0,4273ns	0,104
Jun	-2,26	0,0236*	0,000	-2,26	0,0236*	0,000
Jul	-0,73	0,4643ns	0,000	-0,69	0,4885ns	0,000
Aug	-1,61	0,1067ns	0,000	-1,61	0,1067ns	0,000
Sep	-1,17	0,2409ns	-0,006	-0,78	0,4295ns	0,000
Oct	-2,59	0,0092**	-1,717	-2,55	0,0103*	-0,695
Nov	-1,48	0,1359ns	-1,611	-1,64	0,0993+	-0,363
Dec	1,82	0,0670+	1,362	0,82	0,4024ns	0,246

ns non significant; + 10% significance level; * 5% significance level; ** 1% significance level

Table 2 – Mann-Kendall non-parametric (Z) test in the monthly series of the Maximum, Minimum and Amplitude average values of Bom Jesus (PI) from 1974 to 2014.

	Maximum			Minimum			Range		
Mês	Test Z	p-value	Slope (mm)	Test Z	p-value	Slope (mm)	Test Z	p-value	Slope (mm)
Jan	3,58	0,0001***	0,075	-1,51	0,3095ns	-0,031	3,95	< 0,001***	0,122
Feb	4,89	< 0,001***	0,100	-2,16	0,0236*	-0,035	4,59	< 0,001***	0,145
Mar	3,90	< 0,001***	0,078	-2,69	0,0043**	-0,053	4,32	< 0,001***	0,133
Apr	3,97	< 0,001***	0,083	-2,25	0,0236*	-0,034	3,80	0,0001***	0,112
May	3,04	0,0011**	0,071	-0,14	0,9710ns	-0,003	3,37	0,0006***	0,091
Jun	3,33	0,0008***	0,073	1,01	0,2455ns	0,021	3,02	0,0016**	0,081
Jul	2,59	0,0126**	0,049	1,53	0,1955ns	0,022	1,66	0,0836+	0,042
Aug	1,21	0,2041ns	0,013	-0,70	0,4679ns	-0,014	1,66	0,0926+	0,038
Sep	0,65	0,4991ns	0,013	-3,68	< 0,001***	-0,053	3,20	0,0003***	0,074
Oct	1,81	0,0673+	0,035	-3,63	0,0002***	-0,064	4,50	< 0,001***	0,095
Nov	2,09	0,0488*	0,041	-2,23	0,0145*	-0,045	4,21	< 0,001***	0,091
Dec	3,00	0,0015**	0,056	-2,34	0,0183*	-0,032	4,30	< 0,001***	0,108

ns non significant; + 10% significance level; * 5% significance level; ** 1% significance level; ***0,01% significance level.

Conclusions

Based on the Mann-Kendall test results, significant negative trends were observed in the accumulated monthly precipitaion values in the months of the dry period and the transition period (dry-rainy), as well as a positive trend in the rainy season (December).

Significant positive trends at probability level 5% were detected for the maximum temperature in all months, except in August and September, and at probability lever 10% for the month of October.

Significant reduction trends in minimum temperature values were detected in the months of December, February (rainy season), March, April (transition), September, October and November (transition).

Significant positive trends were detected at probability level 5% for air diurnal thermal amplitude in all analyzed months, with the exception of July and August, with significant trends at level 10%.

The results of the present study may be taken into consideration in the conduction of planning measures for defining the best sowing season for soybean cultivation in the municipality of Bom Jesus (PI), aiming at reducing the vulnerability of the crop production system to climatic risks.

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