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Influence of rainfall variability on bean production (*Phaseolus vulgaris* L.) in a municipality of Brazilian semiarid

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ABSTRACT

Brazilian semiarid region is marked by the constant incidence of droughts periods, which are climatic events responsible for great disorders for agricultural production, an activity traditionally based on subsistence agriculture. The study aimed at analyzing the evolution of bean production in the municipality of Itaporanga, Paraíba State, Brazil, between 2005-2015, associating these results with local rainfall. It was performed the Principal Component Analysis. Six years of the 11-year series presented a value of annual precipitation lower than the historical mean of the municipality (838 mm). The crop area with beans in the municipality ranged from 5,560 hectares in 2006 to 150 hectares in 2013. There were large variations in the amount of bean production, with values ranging from 2 to 1,985 tons. The PCA recorded a value of 92.4% of explanation in the first two axes and demonstrated a strong correlation between the analyzed variables with the precipitation. Confirming that proper pluviometric indexes are determining factors on bean production in Itaporanga, Paraíba State, Brazil.

Keywords: Agriculture, drought periods, economic damages.

Introduction

Brazilian Northeast has its history and development directly linked to climate inconstancy, where drought events have always been an obstacle to the population located in this region. These drought periods have been reported since the beginning of Portuguese colonization (Santos et al., 2012). Drought period is not only a phenomenon restricted to the Northeast region, its occurrence being reported in several parts of the planet (Dettinger & Cayan, 2014; Allah et al., 2017; Church et al., 2017). It is influenced by several factors, such as physiographic characteristics and meteorological parameters. In inhabited regions, it generates material and human damages and, additionally, brings social, ecological and economic problems (Silva et al., 2013).

In Brazilian semiarid region, the availability of water is a limiting factor for human activities. This area is characterized by high-temperature oscillation and irregularity of precipitation, factors that, in shallow soil conditions and technological backwardness, lead to periodic water scarcity, reduction of food production and animal husbandry (Sobrinho & Sousa, 2016). This scenario is further aggravated by high poverty in which a large part of the population lives, high illiteracy rates, low socioeconomic indicators and strong, productive infrastructure (Teixeira & Pires, 2017).

In this context, agricultural activities in this region are directly influenced by the climatic uncertainties. Thus, rainfall irregularities lead agriculture to become a risk activity (Brito et al., 2012). In drought conditions, losses related to production reach significant levels and undermine

the local economy (Santos et al., 2012). However, even in years of normal precipitation, according to the mean rainfall, its distribution may focus on a single period, resulting in water stresses for both human and agricultural systems (Lindoso et al., 2013).

The effects of drought on agricultural production generate series of complications in the field, ranging from the abandonment of activity to rural exodus, which is mainly due to the departure of the rural population in search of better living conditions in the cities, attracted by its supposed better life and income opportunities (Casagrande & Souza, 2012). In regions where human activities that generate economic resources are based on agriculture, there are few or no other alternative sources of income (Sá et al., 2015).

In addition to climate problems, the agriculture in the semiarid region is still largely practiced on conditions of low technological apparatus. It is characterized by subsistence crops, which are important for most of the agricultural income and contribute to perpetuating the inequality cycle in the region. These temporary crops are the basis of family farming (Lima et al., 2016) and one of the main source of income.

Bean (*Phaseolus vulgaris* L.) is practically cultivated in all the municipalities of Paraíba State, Brazil. It belongs to the Fabaceae family, standing out because it has pods and seeds with high nutritional value, constituting itself as one of the main foods of Brazilians. It adapts to medium fertility soils and a wide variety of climatic conditions and can be developed in almost all agricultural areas of the planet (Souza et al., 2016). However, in regions where rainfall is a scarce or poorly distributed factor, it is possible to obtain significant yield loss results, as well as to obtain grains with low quality if the crop is submitted to a deficit or water stress in its phases (Soares et al., 2016).

Irrigation techniques are still a distant reality in semiarid of Paraíba State, Brazil. Agricultural exploitation in these areas is highly dependent on the occurrence of rainfall, so variations cause severe damage to the agriculture (Francisco et al., 2016). Mostly planted in the rainfed system, the development of bean crop is extremely dependent on the interactions between its phenological phases and the weather and climate conditions. Therefore, the final yield of these plantations in this management system depends on the amount, distribution and intensity of precipitation (Menezes et al., 2015).

In a scenario of marked climatic change, linked to a region highly dependent on agriculture, the study of the impact of droughts on agricultural production is of utmost importance for production strategies, such as the selection of varieties that require a smaller amount of water in their productive cycle, as well as for the adoption of more efficient techniques of cultivation (Silva & Silva, 2016). This study aimed at analyzing the evolution of bean production in a municipality located in the semiarid of Paraíba State, Brazil, associating these results with local rainfall.

Material and Methods

The municipality of Itaporanga (7º18"14"S and 38º09"00" O) is in part geographically known as Sertão mesoregion of Paraíba State and Piancó Valley microregion. The territorial area is, approximately, 468 km², with an altitude of 291 m (IBGE, 2010). At the beginning of the 1990s, the main agricultural crop of the municipality was cotton, but due to the attack of pests such as the bollworm (*Anthonomus grandis* Boheman), other species, especially corn and bean, began to occupy large cultivated areas (Moreira, 1997).

According the classification of Köppen, the municipality presents an Aw type climate - hot and humid with summer-autumn rains. The climatological mean is 838 mm annually (AESA, 2017). However, precipitation irregularities are standard, with the occurrence of years with an insipid rainy season. The mean temperature is, approximately, 26.5°C with relative humidity ranging from 75 - 85% (Sousa et al., 2007).

Data of bean cultivation in Itaporanga, Paraíba State, Brazil, from 2005 to 2015, was obtained through the Municipal Agricultural Production - Temporary Crops database from the Brazilian Institute of Geography and Statistics (IBGE), using the Automatic Recovery System (SIDRA). The values of rainfall in the same period were obtained from the website of the Executive Agency of Water Management of Paraíba State, Brazil (AESA).

Aiming to analyze the influence of the precipitation on bean crop production variables, the Principal Component Analysis (PCA) was performed. This type of analysis consists of an exploratory multivariate technique in which the information contained in a set of original variables is condensed into a smaller set formed by new latent variables, which preserve the relevance of the initial data. In this way, a grouping of parameters according to their characteristics is obtained, facilitating the visualization and understanding of the relationship between the variables with the axes of the coordinates (Silva et al., 2016). The software used was R (R Project for Statistical Computing).

Results

Rainfall in the municipality of Itaporanga, Paraíba State, Brazil was unstable during 2005 and 2015, typical behavior of semiarid regions. The annual cumulative values were between 388.7 mm (2012) and 1544.9 mm (2008). Six years of the 11-year series presented an amount of annual precipitation lower than the historical mean of the municipality (838 mm).

The crop area with beans in the municipality ranged from 5,560 hectares in 2006 to 150 hectares in 2013 (Figure 1). The highest values were observed in years with precipitation near or higher than the climatological mean. Usually, the occurrence of an adequate rainfall at the beginning of the rainy season motivates the farmers to expand the productive area. Opposite behavior is observed when there is a situation of rainfall irregularities at that time. In 2012, there was a reduction of 37.9% in the crop area compared to 2011. In 1920 hectares of the crop area, only 2.6% were harvested.

It can emphasize that the year of 2012, according to the series showed in this study, presented the lowest precipitation (388.7 mm). The years of 2009 and 2013 also showed discrepancies between crop area and harvested area, with rainfall in 2009 and 2013 being superior and inferior, respectively, then the historical mean.

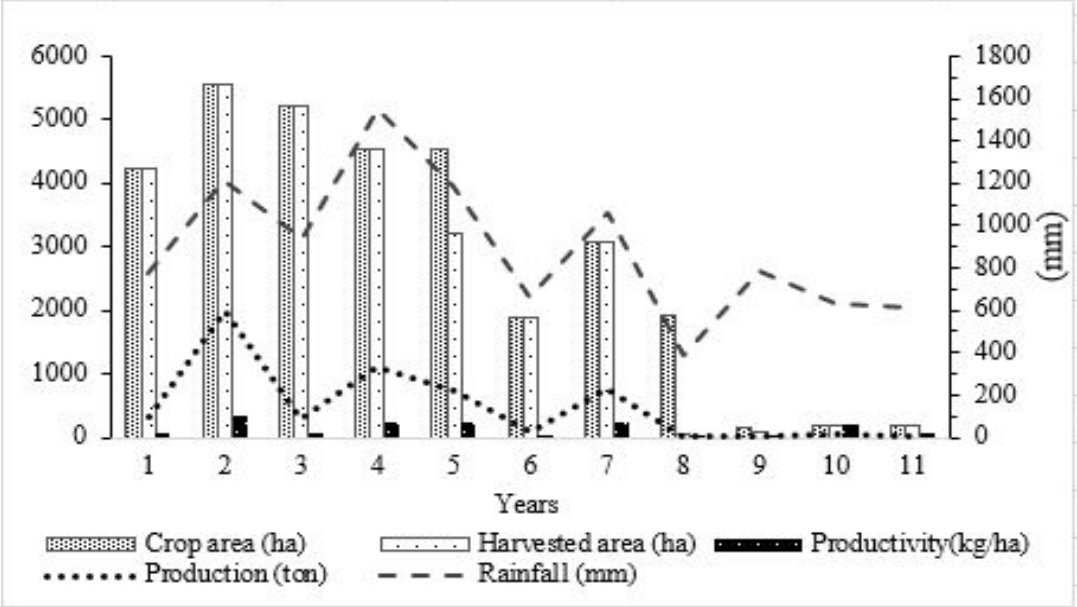

Figure 1. Variables of bean production and rainfall in the municipality of Itaporanga, Paraíba State, Brazil. The numbers 1 to 11 represent the years 2005 to 2015, respectively.

It was observed large variations in the number of beans produced, with values ranging from 2 (2012 and 2013) and 1985 tons (2006). As in crop area, the highest values of production were obtained in a year with rainfalls above the historical mean.

The highest values of crop productivity were observed in 2006, 357 kg of beans were obtained per hectare, which also had the highest crop area, harvested area, and precipitation above the mean. However, this value is well below the national mean, which is 1,020 $kg.ha^{-1}$ (CONAB, 2016). In general, the best productivity values were observed in years with precipitation above 1000 mm. Regarding the value of production, as well as for productivity, the best values were obtained in 2006, in which the bean crop generated a revenue of R$ 2,084,000. These results indicate the strong participation of the species in the municipal economy, which was drastically reduced from 2012, where this revenue fell to only R$ 60,000.

The Principal Components Analysis recorded 92.4% of explanation in the first two axes (Figure 2). For axis 1, which explains 79.5% of the original variance, the variables with the highest association were precipitation (r = -0.41), value of production (r = -0.43) and production (r = -0.43). These results confirm that for Itaporanga, Paraíba State, Brazil, the production of beans is intrinsically related to the amount of rain that occurs in the municipality.

The association between precipitation and production value confirms that, in rainy years, there is a supply of resources in the economy of this municipality, which in drought years means a strong deficit and a series of socioeconomic problems that can culminate in rural exodus and migration to other activities. Through the PCA, the years of 2006, 2008, 2009 and 2011 presented a clustering. These years are associated with the best production metrics. All these years presented precipitations above 1000 mm, demonstrating that,

despite being widely cultivated in semiarid areas, the bean needs proper pluviometric indexes on its excellent development.

In the axis 2, which explains 12.9% of the original variance, an inverse relationship is observed between productivity (r = 0.55) and crop area (r = -0.55). In the context of drought periods that hit the municipality in 2012, the crop area was reduced. However, the levels of productivity remained close to those already recorded previously. It should be considered that, regardless of the climatic conditions, the yield of the beans in this region has been well below the national average. This index under inhospitable conditions does not mean an evolution.

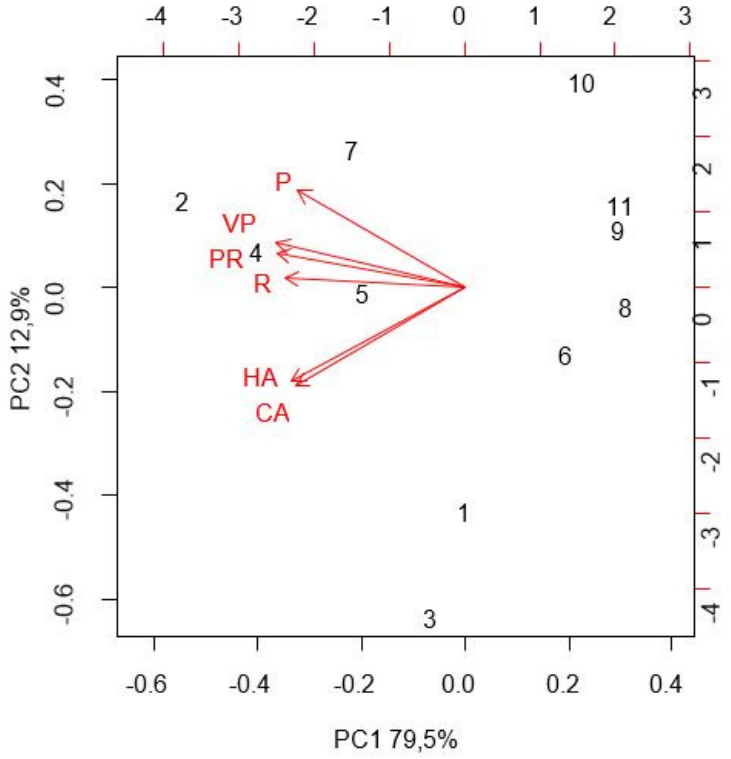

Figure 2. Principal Component Analysis. CA = Crop Area; HA = Harvested Area; R = Rainfall; VP = Value of Production; PR = Production; P = Productivity. The numbers 1 to 11 represent the years 2005 to 2015, respectively.

Discussion

In 2008, the municipality presented in this research was influenced by La Niña with strong intensity (Almeida & Medeiros, 2017). The period between 2011 and 2012 is considered as the one with the greatest rainfall deficit in Northeast region in the last 30 years, causing severe water shortage and increase in food prices (Leivas et al., 2014).

Reductions observed in the crop areas may be conditioned by the occurrence of water deficits, floods in harvest time or factors such as pests and diseases that affect these plantations (Dias & Silva, 2015; Church et al., 2017). Similar behavior of crop and harvested area reduction was observed by Farias et al. (2017) in the municipality of Boqueirão, Paraíba State, Brazil. It was observed that in the drought of 2012 and 2013, temporary crops in the municipality were severely affected. The harvested area with beans in this municipality increased from 700 ha in 2011 to 0 ha in 2012 and 40 ha in 2013. This substantial reduction caused impacts on the local economy since this is one of the plant species that guarantee the subsistence of the population in this region.

Large variations in the number of beans produced in Paraíba State were also observed by Silva et al. (2011), in the period from 1975 to 2004. In general, the curve of agricultural production of grains accompanied the values of precipitation. The authors emphasized that rainfall be crucial for grain production in Paraíba State during this period.

Silva & Silva (2016) found a strong correlation between precipitation and bean production in Aiuaba, semiarid region of Ceará State, Brazil. In this municipality, the rainfall had an influence of 80.15% on the final production of this grain. For the authors, this result was already expected due to the climatic characteristics present and the dependencies for the excellent progress of the production system.

Low productivity value, even on favorable climate conditions, can be explained by the low use of technological inputs in this region. In other regions of Brazilian Northeast, such as the region of Petrolina, Pernambuco State, the producers use modern agriculture. In the microregions of Paraíba State, the agriculture does not present so much use of technology. In this way, there is a high demand for rural labor, which is still primarily manual. Thus, winters do not only mean an increase in crop area and productivity, but they also bring a source of occupation for the population of a large number of municipalities (Aquino et al., 2014).

This strong relationship was also verified by Dias & Silva (2015), studying the municipalities of Cariri Center South of Ceará Macroregion, Brazil, where a positive correlation was observed between precipitation and maize productivity, demonstrating that the productivity of this crop is intrinsically linked to reasonable levels of precipitation.

Problems related to agricultural production in this region go beyond the volume produced and the levels of productivity. Leaning directly on the number of farmers who dedicate to this activity and make it their main source of income, Northeastern farmers in 2006, totaled 46% of the total population occupied in Brazilian agriculture and cattle raising (Araújo et al., 2014).

Silva & Almeida (2017) analyzed the production of the main crops in the semiarid region of Pernambuco State, Brazil, and the authors observed that in the interval between 2000 and 2013, the great majority of the years presented a direct relation between bean production and occurrence of rainfall in the State.

In studies conducted in the Southern of USA, Cai et al. (2013), using PCA to correlate climatic data with corn and soybean productivity in this region, between the years of 1960 and 2009, observed that the climate was a factor that negatively affected these crops in these states. Dias & Silva (2015) found out positive correlations between maize productivity and mean annual precipitation in the municipalities of Ceará State, Brazil.

Silva & Silva (2016) also observed a positive correlation between precipitation and production in Aiuaba, Ceará State, Brazil. Thus, whenever the amount of rain is high, the income of the producer also tends to increase, corroborating the results found out here.

Conclusion

Rainfall is a determinant factor in the production of beans in the municipality of Itaporanga, Paraíba State, Brazil.

This variable accounts for a large part of production losses, causing economic and social disturbances since agriculture is a pillar of the productive system in this municipality.

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