

Evaluation of climate conditions in Remanso/BA and their relations with agricultural production in the Semiarid

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Abstract— This paper aims to present the climatic conditions of the municipality of Remanso in the State of Bahia, taking into account the intrinsic relationship between climate change and agricultural production of tomato (*Solanum lycopersicum*) in the semiarid region, through data analysis of Standard Precipitation Index - SPI of about 30 years. The results showed that the tomato production system presents good prospects of obtaining positive profitability, considering the climatological indices. However, technical and managerial assistance and agricultural research actions, especially in the areas of fertilization, plant tutoring and irrigation, are necessary to promote improvement in productive efficiency.

Keywords— *Climatology, Agriculture, Oscillations, Semiarid.*

I. INTRODUCTION

Nowadays, the advance of science and technology is unquestionable, especially those dedicated to the study of food production in the world and its relations with present and future climatic conditions. However, despite all developments, climate is still the most important variable in agricultural production, affecting and determining the adequacy of food supplies through climate hazards and climate control over the type of viable agriculture in a given area.

In this sense, it can be said that climate parameters influence all stages of the agricultural production chain, including soil preparation, sowing, crop growth, harvesting, storage, transportation and marketing (AYOADE, 2004).

Tomato (*Solanum lycopersicum*) crops play an important role in the national economy, with a cultivated area of 54,931 hectares and a total production of 3,154,982 tons. It is one of the most prominent vegetables for the consumption of fruits (AGRIANUAL, 2007).

Based on these assumptions, this article aims to present the climatic conditions of the municipality of Remanso in the State of Bahia, taking into account the

relationship between climate change and agricultural production of tomato (*Solanum lycopersicum*) in the semiarid region.

The methodological basis that underpins the research is based on the Standard Precipitation Index (SPI) with data of about 30 years, emphasizing tomato cultivation, available at the Center for Weather Forecasting and Climate Studies (CPTEC). and, National Institute for Space Research (INPE).

The results showed that the tomato production system presents good prospects of obtaining positive profitability, considering the climatological indices. However, technical and managerial assistance and agricultural research actions, especially in the areas of fertilization, plant tutoring and irrigation, are necessary to promote improvement in productive efficiency.

II. THEORETICAL REFERENCE

2.1 The Influence of Climate on Agriculture

Each and every agricultural system is a man-made ecosystem that depends on the climate to function, similar to natural systems. The climatic elements that affect agricultural production are the same as those that

influence natural vegetation, including solar radiation, temperature and humidity. These climatic parameters and others that depend on them largely determine the distribution of crops and agricultural production within a climate zone, and it can be said that all crops have their climatic limits for economic production (AYOADE, 2004).

This same author argues that the ways in which the main climatic elements influence crop growth and yields occur in two ways: 1. Climate variables are interrelated in their influence on agricultural crops, and daily, seasonal or annual variations in climate element values are relevant in determining the efficiency of crop growth. 2. When considering the climatic environment in which crops grow, the microclimate around them is vitally important, as the prevailing climatic conditions within soils where seeds germinate and in the vicinity of the land where crops are grown grow, can be quite different from those that predominate in the air just above them (AYOADE, 2004, p. 262).

Thus, the influence of climate on agriculture tends to be perceived in different types of crops and by various climatic elements, such as solar radiation, temperature, humidity, wind. In addition to these can be added the climate hazards (frost, drought, hail and wind) which have a crucial influence on agricultural crops. But how do punctuated climate elements influence agriculture?

With regard to solar radiation, this is of vital importance because it is this energy that drives the agricultural system, determining the thermal characteristics of the environment, essentially air and soil temperatures during the day or photo period. In addition, the intensity of solar radiation is also an important factor since optimal light values for normal crop growth and development are generally around 8-20 kiloluxes (AYOADE, 2004).

In Ayoade conception (2004), the luminosity values (Table 1) for optimal flowering and fruiting, determined for some crops, are:

Table 1: Lightness Values

| Crops | Brightness values |
|----------------------------|------------------------|
| Pea | 850 – 1.100 luxuries |
| Corn | 1.400 – 1.800 luxuries |
| Barley and Wheat | 1.800 – 2.000 luxuries |
| Beans and Cucumbers | 2.400 luxuries |
| Tomatoes | 4.000 luxuries |

Source: Ayoade (2004)

If there is not enough radiation the root system of the plants does not fully develop, and the foliage turns yellowish, tending to stem growing at the expense of the foliage. In addition, the crops themselves can be classified

as “short day crops” and “long day crops” depending on the period in which they reach their optimum growth or maturation time.

Ayoade (2004) says that the crops that reach their optimal growth during the short days (about 10 hours of radiation) are as follows: beans, corn, cotton, cucumber, tomato and millet. These can be called “short day crops”. Already those that reach growth during the long days (about 14 hours of radiation) are mustard, clovers, oats, wheat and rye, and should be called “long day crops”.

The climate element temperature is of crucial relevance to agriculture, since air or soil temperature affects the plant's growth processes and all crops have minimum, optimal and maximum thermal limits for each of their stages of growth.

Both low and high temperatures can create serious risks to vegetables. When temperatures are below freezing point the living matter of cells can freeze and cell dehydration can occur, which can kill plants. At the same time, excess heat can destroy the plant protoplasm, where the drying effect on plants can lead to rapid rates of sweating and wilting (AYOADE, 2004).

Humidity is another very important climatic element for agriculture. Water plays an important role in plant growth and in the production of all crops, being the main constituent of plant physiological tissue and a reagent in photosynthesis. Thus, it can be stated that soil moisture is the significant source of water for the crop and the soil moisture state by the controlled by precipitation, evaporation rate and soil characteristics. In Ayoade view (2004, p. 267), “neither extremely high or low temperatures nor insufficient or excess water constitute favorable conditions for good agricultural performance”.

The role of humidity in agriculture is relevant in the tropics, mainly due to the action of high temperatures throughout the year, and also because evapotranspiration values are constantly high, however, precipitation is seasonal in large areas of the tropics (AYOADE, 2004).

The last climatic parameter is the wind that affects agriculture, being an efficient agent of plant dispersal. On the other hand, the wind can cause physical damage to the crops, favoring the high perspiration and consequent drying of the plant. In addition, erosion that the wind is capable of causing can ruin good quality agricultural land by removing the topsoil and damaging agricultural crops. In this way, extreme weather conditions are responsible for serious consequences for agriculture, as is the case with climate hazards from now on.

According to Ayoade (2004), crop development does not depend solely on weather conditions, but is also

subject to a large number of climate hazards. Among these we can highlight the following:

Frosts - These occur when the air temperature in contact with the ground is below 0°C. Surface frost is particularly important in agriculture. Such bad luck is generally not common in the tropics, except in mountainous areas, but common in temperate areas; Drought - which poses a serious risk to agriculture in both temperate and tropical regions and is typified into four types: permanent, seasonal, contingent and invisible. In arid regions [as is the case of this study] permanent drought is the most common, where rainfall is not sufficient to meet the water needs of plants; Hail - These are small ice crystals [not a solid precipitation] that cause damage to crops in the field, occurring in temperate and tropical regions; Winds - which carry moisture and heat in the atmosphere and have some effect on agricultural production, influencing evapotranspiration rates and exerting direct pressure on crops (AYOADE, 2004, p. 270-275).

Based on these assumptions, it can be said that climate is a decisive factor in the development or not of agricultural crops, and the climate elements associated with climate hazards may contribute negatively to the advancement of agricultural production in the regions.

2.2 Agricultural Production in the Semiarid and the relationship with Climate Change

The study of the impact of climate change on the functional biodiversity of plants established in different ecosystems has been the target of many researchers at the international level. Recent changes in the patterns of climate variables, especially precipitation and evapotranspiration, have been associated with global warming, resulting from the increase in carbon dioxide in the atmosphere. In addition, CO₂ in the atmosphere can directly influence the physiological, productive, water aspects and water use efficiency of agricultural production systems. However, these responses are not well defined, as they vary depending on the joint effect between: CO₂ level and environmental factors, such as type of photosynthetic plant process, changes in plant architecture and mechanisms under new cultivation conditions (AINSWORTH; ROGERS, 2007).

Unsurprisingly, climate change influences plant biodiversity, especially with regard to the range of characters involved in the vital functions of these organisms, such as photosynthesis. Regardless of the degree of climate change, it promotes a response in the vital mechanisms of plants, especially those associated with the conditions appropriate to maintaining the establishment of individuals in any ecosystem. In

contrast, the functional diversity of the plant species that make up the different vegetation types and, in most cases, is the result of the influence of the climatic factors of the environment where they are established, creating a very differentiated and specific stimulus-response system in certain biomes, as is the case of caatinga ecosystem in Bahia semiarid region (PIMENTAL, 2013).

In the conception of Silva, Souza and Azevedo (2013), the next 100 years indicate the possibility of significant climate impacts on various human activities and ecosystems, as well as natural disasters such as storms and droughts, which will be inevitable. The predicted increase in temperatures pointed by the IPCC (Intergovernmental Panel on Climate Change) will lead to changes in the behavior of world agricultural production, which may lead to the disappearance of some crops and modification of the world agricultural map.

Studies by Pereira et al., (2002) conclude that from economic activities, agriculture is undoubtedly the one with the greatest dependence on weather and climate conditions. And atmospheric conditions affect the stages of agricultural activities, from soil preparation for sowing to harvesting, transportation, preparation and storage of produce.

Researchers such as Assad et al., (2003) through the use of geoprocessing tools elaborated various climate scenarios for various crops and found that global warming will have a drastic impact on Brazilian agricultural production, and consequently will cause profound changes in Brazilian agricultural zoning.

Thus, global warming could endanger food security in Brazil in the coming years. This is the forecast of a study by researchers from Embrapa and Unicamp. In this study, it was found that rising temperatures may cause losses in grain crops in the amount of R \$ 7.4 billion already in 2020, a break that could jump to R \$ 14 billion in 2070, profoundly altering the geography of agricultural production in Brazil (SILVA; SOUZA; AZEVEDO, 2013).

2.3 Tomato Cultivation x Climate Conditions

Tomato is one of the largest market vegetables in terms of value and consumption in Brazil. However, the tomato is of Andean origin, preferring a dry climate, with high brightness and mild temperatures, and is therefore not a plant adapted to the Brazilian environment, either because of the climate, the incidence of diseases and pests (MELO, 2017).

By its origins, the tomato grows well in tropical conditions of altitude and the subtropical, fresh and dry, with plenty of light. However, the plant tolerates variations in weather factors well. With regard to

temperature, the range of 20 to 25°C favors germination, while the range of 18 to 25°C helps the vegetative development, high nocturnal temperatures also contribute to the tomato growing faster. But beyond 32 ° C the flowers fall, fruit development is inhibited and hollow tomatoes are formed (EMBRAPA/SPI, 1993).

Flowering and fruiting benefit from daytime temperatures of 18 to 25°C and nighttime temperatures of 13 to 24°C. The permanence of temperatures above 28°C impairs the firmness and color of the fruits, which tend to turn yellow due to inhibition synthesis of lycopene and other pigments that give them the typical red color (EMBRAPA/SPI, 1993).

Also according to Embrapa/SPI (1993, p. 10) “temperatures above 34°C cause respiratory disturbances and, when above 37°C, the fruits soften in the ripening phase”. On the other hand, “temperatures near 0°C cause the leaflets to burn. With intense frost the fruits are burned and the plant can die”. In addition, rainfall and high relative humidity, associated with temperature variations, favor the incidence of diseases and pests and make their control difficult, and hot and strong winds impair flowering and fruiting.

According to Geisenberg and Stewart (1986), tomatoes have critical climatic limits to their development (Table 2) and can be planted in summer or winter (Table 3).

Table 2: Temperature limits for tomato development stages

| Critical moments of development | Temperature in (° C) | | |
|---------------------------------|----------------------|----------|---------|
| | Minimum | Optimal | Maximum |
| Germination | 11 | 16 to 29 | 34 |
| Vegetative growth | 18 | 21 to 24 | 32 |
| Fruit Pickings (night) | 10 | 14 to 17 | 20 |
| Fruit Picking (day) | 18 | 19 to 24 | 30 |
| Fruit ripening | 10 | 20 to 24 | 30 |

Source: Geisenberg and Stewart (1986)

Table 3: Critical Moments of Tomato Development in Summer and Winter

| Critical moments of development | Month of occurrence | |
|---------------------------------|---------------------|------------------|
| | Summer harvest | Winter harvest |
| Germination | August | February |
| Vegetative growth | August to november | February to June |
| Fruit Pickings | October to | April to July |

| | |
|----------------------------|----------------------------------|
| (night) | January |
| Fruit Picking (day) | October to April to July January |
| Fruit ripening | November a May to July janeiro |

Source: Geisenberg and Stewart (1986)

Thus the temperature ranges for acceptability of tomato cultivation are wide, however the ranges for developing an optimal tomato are narrow and not easy to find in all regions and all seasons. According to Embrapa/SPI (1993, p. 11) the best tomato planting season is the one that offers the following conditions for the whole plant cycle: “average temperatures ranging from 18°C to 25°C, low relative humidity of the air and low rainfall for a period of 5 to 6 consecutive months”.

Moreover, some factors must also be taken into consideration when determining the best planting time, such as location of the region, topography and altitude, as these conditions influence the variation of temperatures and rainfall distribution. In adverse conditions, to reduce the risks, there is the option of installing the crop under plastic cover or in a greenhouse (EMBRAPA/SPI, 1993).

In addition to these factors, FAO also points out the water requirement, since tomatoes require 400 to 600 mm per cycle, considering cycles of only 90 to 120 days. However, in Brazil, to improve productivity, most tomato productions are irrigated (FAO, 2017).

III. MATERIAL AND METHODS

3.1 Characterization

The municipality of Remanso, is located in the state of Bahia. It has an area of 4,684 km², and according to the 2010 census, Remanso has 38,957 inhabitants, today estimated at 41,008 people, with a population density of 8.3 inhab./km², and a per capita GDP of R \$ 7,496.64 (IBGE, 2019).

According to the IBGE (2019), temporary tomato cultivation produces a quantity of 25 tons, with a production value of R \$ 27,000 per planted and harvested area of 1 hectare, with an average yield of 25,000 kg/ha.

3.2 Location

The municipality of Remanso is located at 405 meters altitude, having the following geographical coordinates: geographic coordinates: 9°36'16" south latitude and 42°6'6" west longitude, as shown in the map (figure 1).

It has a climate classified as warm semi-arid, with spring-summer rainfall regime, characterized by the scarcity and irregularity of rainfall, as well as the strong evaporation due to high temperatures. The average annual temperature is 26.3°C, with hot and humid summers and warm and dry winters. The month with the highest

average temperature of 28.2°C is November, as well as the highest average maximum temperature of 34°C, while July is the coldest with a maximum temperature around 24.1°C and a minimum of 19 0.5°C. The average sunshine time is 2,860 hours per year, with air humidity around 45%.

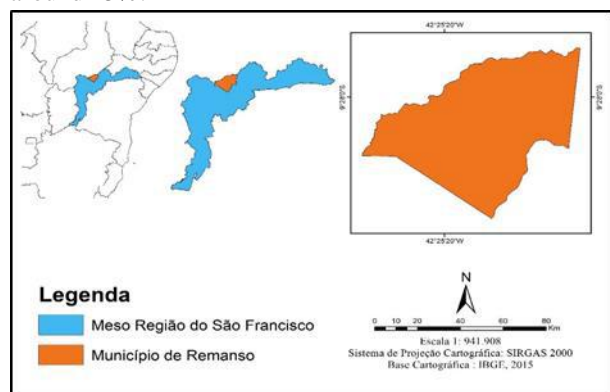


Fig.1: Location map of Remanso Municipality/BA

Source: PACHECO (2019)

3.3 Methodology

The methodology used in this study was based on the Standard Precipitation Index (SPI), often used to monitor conditions associated with drought and excessive rainfall. The RLS was developed by McKee et al. (1993), and is based only on the monthly precipitation product, in this case, produced by CPTEC/INPE, from data from various data sources in Brazil. The main feature of SPI is the ability to use monitoring of both wet and dry conditions at various time scales.

For drought monitoring from the SPI, only the negative index values are considered. Typical SPI values for characterizing a drought event are shown in the table below, based on the drought monitoring methodology used in the United States National Integrated Drought Information System, with five categories (Figure 2) that identify drought intensity.

| Category | Intensity | SPI Thresholds |
|----------|-------------|----------------|
| D0 | Weak | -0,5 a -0,7 |
| D1 | Moderate | -0,8 a -1,2 |
| D2 | Severe | -1,3 a -1,5 |
| D3 | Extreme | -1,6 a -1,9 |
| D4 | Exceptional | -2,0 or less |

Fig.2: Intensity categories of a drought event from the SPI

Source: SPI (2019)

Thus, the Standard Precipitation Index - SPI data of about 30 years will be considered for analysis, since any research using climatological data should consider a minimum analysis time of three decades.

IV. RESULTS AND DISCUSSIONS

To ensure a high-quality product, diagrams and lettering MUST be either computer-drafted or drawn using India ink.

Tomatoes, sourced from South America, are grown almost worldwide, and their global production has doubled in the last 20 years. One of the main factors for the expansion of culture is the growth of consumption. Between 1983/85 and 2003/05, world per capita tomato production grew by 36%, from 14 kg per person per year to 19 kg, according to data from the United Nations Food and Agriculture Organization (FAO/UN). Of the more than 120 million tons of tomatoes produced in the world, only 4.5 million are exported in nature.

According to FAO, the country's position has been achieved due to increased productivity. Currently, Brazil occupies the 3rd place in this ranking, behind only the United States and Spain. The spread of irrigation techniques, the intensive use of inputs and the introduction of more productive hybrids with lower postharvest losses were some of the main factors that contributed to the increase in the productivity of the national tomato. The average yield of tomatoes in Brazil is approximately 58 t/ha. However, more technical producers reach over 100 t/ha (CARVALHO; PAGLIUCA 2007).

Based on these assumptions, the data obtained through the SPI will be analyzed based on Table 1, showing periods of incipient, moderate, severe and extreme rainfall (Figure 1).

Generally, any of the rainfall patterns can significantly damage tomato or any other cultivar, since each crop has its limits to withstand incipient or extreme rainfall.

Table 1 - Patronized Precipitation Index (SPI) Values and Drought or Moisture Categories

| SPI | CATEGORIA |
|----------------|--------------------|
| 0 – 2,00 | Extremely humid |
| 1,5 to 1,99 | Severely humid |
| 1,00 to 1,49 | Moderately humid |
| 0,1 to 0,99 | Incipient Moisture |
| 0 to -0,99 | Incipient Drought |
| -1,00 to -1,49 | Moderately Dry |
| -1,50 to -1,99 | Severely Dry |
| 0 to -2,00 | Extremely Dry |

Source: MacKee at al. (1993, 1995)

An example of this is what the Embrapa/SPI (1993) document says, which points out that recently the tomato crop has been growing significantly in greenhouses or under plastic cover, in order to protect the plants from the cold and the rain. This technology has allowed farmers from Rio Grande do Sul, Santa Catarina and Paraná to

harvest tomatoes in the winter and those from São Paulo, Minas Gerais and Rio de Janeiro during the rainy season.

In this sense, the graphs below show the rainfall frequency indices in the surveyed region.

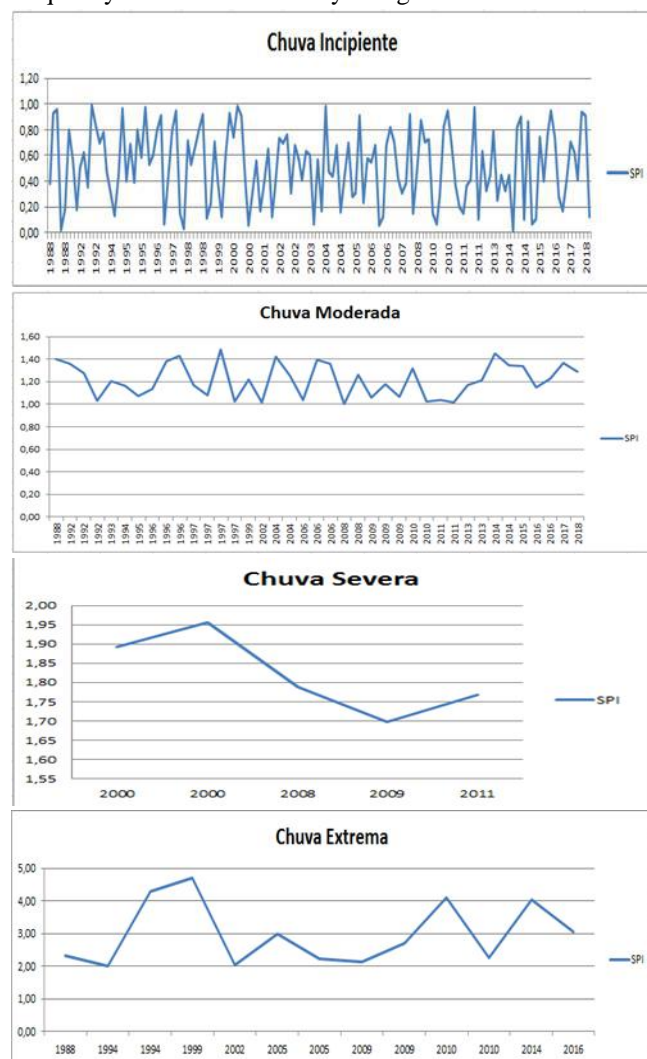


Fig.1: Rain Frequency

Source: SPI (2019)

The graphs above show the rainfall frequency distribution from 1988 to 2016, where it is possible to see extremely humid periods, even severely dry periods. In the incipient rainfall graph there is an annual variation between 0.0 and 1.0 (moderately humid), and in the moderate rainfall graph the variations range from 1.0 to 1.40 (severely humid). The severe rainfall graph for the period 2000-2011 has a frequency ranging from 1.70 to 1.96, thus representing periods ranging from severely humid to extremely humid. Finally, the extreme rainfall graph ranges from 2.0 to 4.8, indicating periods with very high humidity levels.

Taking into account the frequency distribution of rainfall found in Remanso and the favorable conditions for tomato production (10 hours of solar radiation, 20°C

to 25°C for the germination period, 18°C to 25°C for plant development, etc.), it is It can be affirmed that it is only possible to grow it during the period with incipient and moderate rainfall, since it could not withstand severe or extreme rainfall and with high humidity, because it would run several risks, because the tomato is of Andean origin, having preference for dry climate, high brightness and mild temperatures.

For drought periods, the data show incipient drought, moderate drought and severe drought (Figure 2). No extreme drought was detected during the analyzed period.

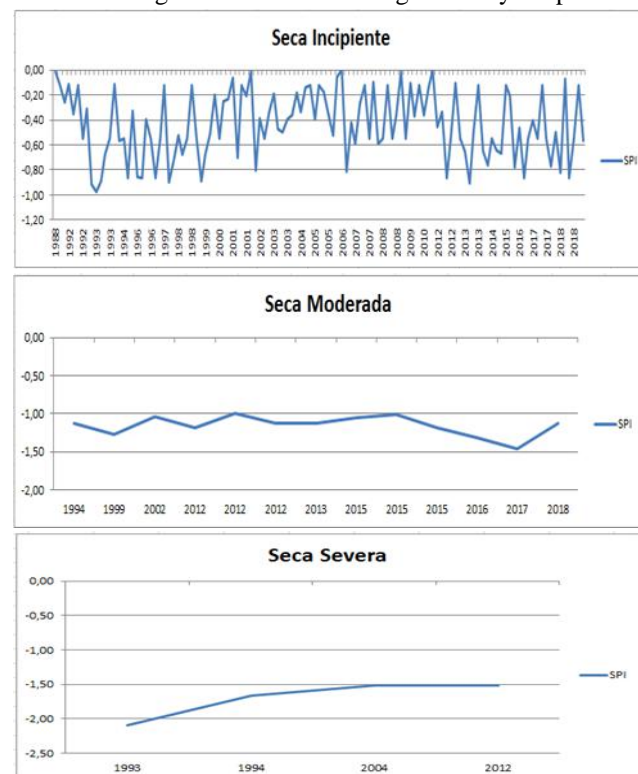


Fig.2: Drought Frequency

Source: SPI (2019)

Regarding the frequency of droughts in the surveyed period is noticeable in the first graph the annual variation between 0.0 and -1.0 (moderately dry), with incipient drought in the surveyed region. In the second graph there is a frequency between -1.0 to -1.50 (severely dry) with a so-called moderate drought. And the third graph shows a range between -1.50 to -2.20 (exceptionally dry), called severe drought.

This distribution of drought frequency in the Remanso region suggests that during these periods there was a higher rate of solar radiation, high day and night temperatures, low rainfall and low humidity, indicating a good period for tomato cultivation, although with Some observations: High solar radiation, high day and night temperatures, low rainfall and low humidity are favorable for tomato production, however, it should be noted that

temperatures above 34°C will cause respiratory disturbances greater than 37°C causes fruit softening in the ripening period.

The following graphs will be shown per quarter (2 months due to tomato flowering). Figure 3 below shows the monthly data, which will facilitate the correlation of production by period.

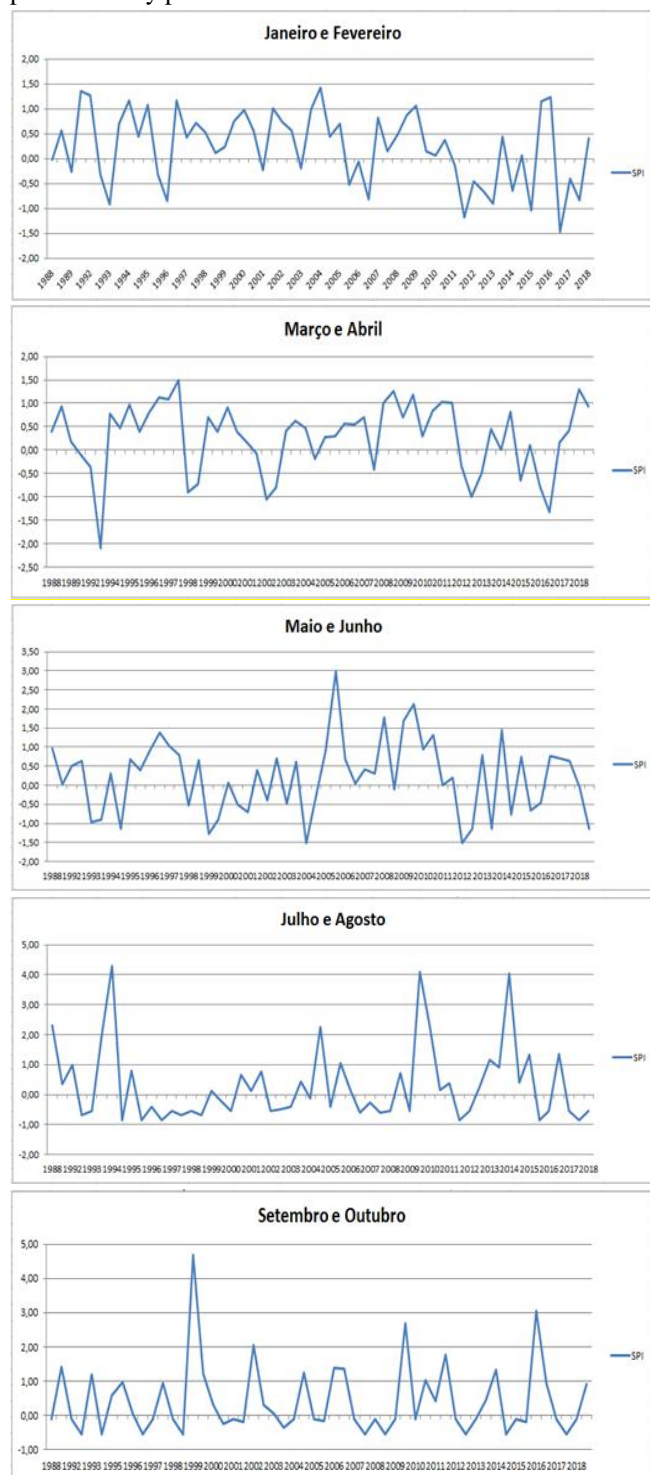


Fig.3: Annual frequency of rainfall per two months
Source: SPI (2019)

In this sense, the data indicate, by period, the following frequency of rain/ drought:

- January and February - Rates range from -2.2 (exceptionally dry) to 1.5 (severely humid).
- March and April - Rates range from -1.5 (severely dry) to 1.5 (severely wet).
- May and June - Rates range from -1.5 (severely dry) to 3.0 (extremely humid).
- July and August - Rates range from -1.0 (moderately dry) to 4.2 (extremely humid).
- September and October - Rates range from -0.8 (moderate drought) to 4.8 (extremely humid).
- November and December - Rates range from -1.7 (extreme drought) to 2.0 (severely humid).

Observing the frequencies described above, it can be stated that in January, May and November there are indices considered severely dry or extreme drought. February and April have severely humid indices, and June, August, October and December indices considered extremely humid. However, the months of July and September are classified as moderately dry or moderately dry, and March is exceptionally dry or extremely dry.

From these findings, it is possible to state that the best months for tomato cultivation in the surveyed area are the months that are severely dry, moderately dry or exceptionally dry, given that the tomato can withstand high insolation rates, low rainfall, and low humidity.

However, the month of November is severely dry, where temperatures vary from 28°C (good for tomatoes) to 34°C (bad for tomatoes, which from 32°C causes the flowers to fall and the fruits become hollow). Already in July there is a moderately dry frequency, where temperatures vary in Backwater from 24°C (great for tomato cultivation/ germination and flowering) to 19.5°C (also good for tomato), with air humidity in around 45% (which can also be considered essential for the tomato, as there is no possibility of rain here) (EMBRAPA/SPI, 1993). However, as stated by Ayoade (2004), crops are subject to climate hazards, the influence of the region's

location, topography and altitude (since Remanso has more than 400 meters of altitude), as these conditions influence the variation of temperatures and the distribution of vegetation rainfall and do not depend solely on weather conditions.

IV. CONCLUSION

Discussing the assessment of climatic conditions and the relationship with agricultural production in the Semiarid is not an easy task. For this reason, a cut was made between 1988 and 2016 and delimited a single municipality of the Semiarid to discuss such themes.

The present work aimed to present the climatic conditions of the municipality of Remanso in the State of Bahia, taking into account the intrinsic relationship between climate change and agricultural production of tomato (*Solanum lycopersicum*) in the semiarid region, through data analysis of the Standard Precipitation Index – SPI of about 30 years.

The main results indicate that the region is favorable to tomato cultivation, however in certain periods, respecting the limitations of altitude, temperatures, humidity, insolation and climatic hazards and/or climatic oscillations. In addition, the data show severely humid periods (considered inappropriate for tomato cultivation) and extremely dry periods (also harmful to cultivation). However, moderately dry and severely dry periods are possible to practice such cultivation, always observing the diurnal and nocturnal temperature indices, the humidity indices and the tolerable precipitation averages.

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