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Drought Diagnosis in the Municipality of Itaberaba-Ba and the Potential Impacts for Pineapple Growing

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***Abstract*— This work presents a diagnosis of the incidence of drought in the municipality of Itaberaba-BA, with a view to evaluating the behavior of rainfall for the last 40 years (analyzing the possible consequences for the cultivation of pineapple in the region), and for the changes that the projections future climate points. Daily historical data of precipitation (mm), maximum and minimum temperatures (ºC) were used. To characterize drought situations, the Standardized Precipitation Index (SPI) was used, which quantifies the deficiency of precipitation in different time scales, and future data came from the PROJETA Platform using the climate scenario: RCP 8.5, continental, HADGEM2-ES. The treatment of rainfall data showed that the wettest period lasted from November to March, which is the best period to plan pineapple planting. As inferences: a) There is an increase of approximately 530 ha of harvested area, when the SPI18_May transcends its classification of incipient humidity to moderately humid, in more than 95% of the years; b) At each unit increment of SPI18_May, pineapple yield tends to increase quantitatively by 6,952 kg/ha, in the rainfed system for the municipality of Itaberaba; and c) For future projections, from 2020 to 2060, it is believed that there will be no expressive change in the responses of harvested area and yield, as the climatic behaviors of drought for the present climate and future climate, when confronted, do not undergo substantial variations.*

I. INTRODUCTION

Agricultural production is heavily dependent on climatic factors such as water conditions, air and soil moisture, solar intensity, and temperature. Therefore, according to Ferreira & Silva [1], the climate, in addition to directly affecting crop productivity, influences the interaction of microorganisms with plants, interfering with the agricultural management process, need for fertilization, use of pesticides, soil conservation, etc., consequently being able to define the quality of the product.

Carlos et al. [2] cite the International Climate Change Report - IPCC, in 2014, which says that climate change must be a challenge in the 21st century, as its negative impacts can be felt on human health, ecosystems and biodiversity, water resources and, above all, in agricultural production.

Assis, Souza & Sobral [3] state that climate change has increasingly intensified the problem of water scarcity, especially in arid and semi-arid areas of the globe, highlighting the Caatinga Biome of Northeast Brazil, since it presents a great tendency to aridization, accompanied by a decrease in water supply due to the change in rainfall patterns, with a decrease in the frequency and intensity of rainfall.

Climate change can affect agricultural production in several ways: change in the severity of extreme events, in the number of degree-days of growth due to changes in air temperature, change in the occurrence and severity of pests and diseases, among others, could be a major and growing threat to global food security.

The growing attention given to climate change has not been accompanied by attempts to understand the role of knowledge on the adoption of adaptive measures, especially at the regional level. The existence of regional studies on climate change within the scope of Brazilian agriculture is reinforced based on the different realities existing in the most diverse regions of the country [2].

Global warming, with the increase in temperature and changes in rainfall, as reported in scientific publications and periodicals, could cause significant losses in grain crops, and change the geography of Brazilian agricultural production, putting food security in the country at risk.

For Marengo [4], extreme weather phenomena such as floods, prolonged droughts, heat waves, typhoons and tornadoes are called extreme events, and, according to him, nature is giving signals here and worldwide, because weather extremes are getting worse.

According to Marengo et al. [5], the Brazilian semiarid region is closely related to drought events, due to irregular rainfall and low rainfall (below 800 mm per year), which is a major obstacle to the development of agricultural and livestock activities. Therefore, it is important to understand the behavior and possible variations of these climatic events to better plan for the future.

The municipality of Itaberaba is in the central eastern region of the State of Bahia, with a relief with pediplanos and marginal mountains, and a climate characterized as semi-arid, with average annual temperatures around 24.6 °C and poorly distributed rainfall, with occurrences of relatively frequent periods. long periods of water deficit. The region became an important pineapple producer, becoming the leader in the production of the fruit in Bahia from a growth in the 1990s when production declined in the municipality of Coração de Maria-BA [6].

According to Matos & Sanches [7], pineapple has been exploited in the Itaberaba region for approximately 40 years, predominating in small properties (up to three hectares), most of the time employing family labor and own resources, with its production increasing significantly in recent years, being an important economic source for the region.

The region of Itaberaba has a favorable climate for pineapple, with temperatures and rainfall that favor planting, and soils with good permeability, allowing its cultivation in the region, which led to recognition on the national scene and in the northeast region with the importance of this activity, which involves local knowledge, as it is strongly linked to the population [8].

Due to its importance for the city's economy and in view of the global discussion on climate change and its potential impacts, research works aimed at diagnosing the behavior of the climate and its eventual changes are extremely important, because, in addition to contributing to the local planning, can warn about human actions and their direct consequences for the economy.

Therefore, the present work aims to diagnose the incidence of drought in the municipality of Itaberaba-BA, with a view to evaluating the behavior of rainfall for the last 40 years (analyzing the possible consequences for pineapple cultivation in the region), and for the changes that future climate projections point to.

II. MATERIALS AND METHODS

Study area

Itaberaba is a municipality in the state of Bahia, Northeast region of Brazil, located in the Piemonte do Paraguaçu region, close to Chapada Diamantina, as shown in Figure 1. Despite not being part of Chapada, this city works as a gateway to Chapada diamond.

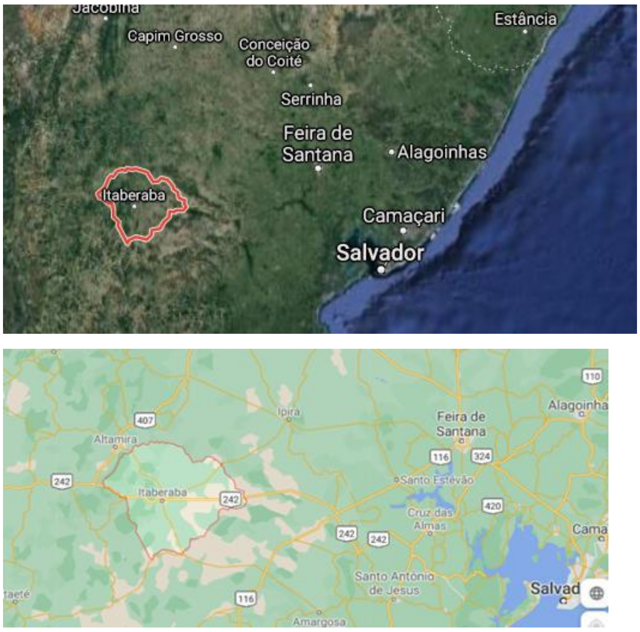

Fig.1. Location of Itaberaba in Bahia.

Source: [9].

According to an estimate by the Brazilian Institute of Geography and Statistics (IBGE), Latitude / Longitude: 12° 27' 3" S / 40° 12' 11" W, the municipality had 64,646 inhabitants in 2020. It is located on the banks of the BR-242, an important federal highway that connects Bahia to the Federal District. It has several industries and a strong trade, which makes the city one of the largest regional centers in the northeastern interior [10].

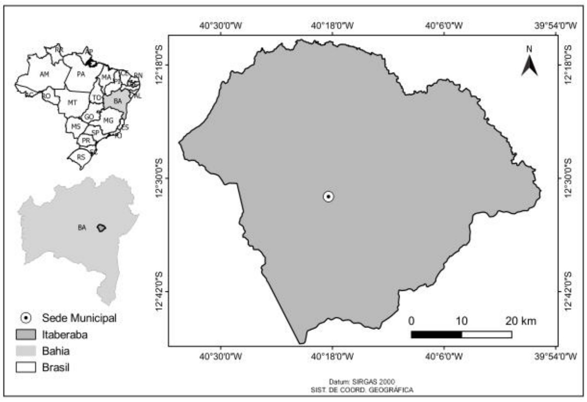

Fig.2. Maps of Itaberaba in Bahia.

Source: [9].

The municipality is one of the main pineapple producers in Brazil, reaching the second position in 2010 among Brazilian municipalities, with a production of 82.5 million fruits (average yield of 30,000 kg/ha), according to the IBGE [10;11].

Data Collection - Present Climate

To represent the present climate, historical data of daily precipitation (mm), maximum and minimum temperatures (ºC) were used, made available by the website of the National Institute of Meteorology - INMET (https://bdmep.inmet.gov.br/), between 01/01/1980 and 12/30/2018, collected at a conventional weather station located in Itaberaba (Chart 1).

Chart 1. Information about the weather station

Name:	ITABERABA
Station Code:	83244
Latitude:	-12.52416666
Longitude:	-40.29972221
Latitude:	250.11 m
Measurement Frequency:	Daily

Source: [12].

Future Projections - Future Climate

The projections of future data on climate conditions in Itaberaba were collected on the PROJETA Platform (https://projeta.cptec.inpe.br/#/dashboard), which provides climate change projections for South America using the ETA model that regionalizes the simulations of global models with a spatial resolution of 20 km.

In its fifth assessment report, in 2013, the Intergovernmental Panel on Climate Change (IPCC) presented four possible scenarios of human actions that directly affect the planet's climate, with an assessment of intensity levels of GHG emissions, aerosols and land use. Figure 2 shows these levels of the RCP's (Representative Concentration Pathways).

	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
Emissão de GEE	Muito baixa	Média - Baixa	Média	Alta
Área agrícola	Média para agricultura e pastagem	Muito baixa para ambos, agricultura e pastagem	Média para agricultura, mas muito baixa para pastagem	Média para ambos, agricultura e pastagem
Poluição do ar	Média - Baixa	Média	Média	Média - Alta

Fig.3. Characteristics of CPR's.

Source: [13].

The most pessimistic scenario is RCP 8.5, which predicts an increase in radiant energy of 8.5 W/m2 by 2100 [13], a consequence of a large increase in GHG rates in the atmosphere.

In the present study, for the future climate (2020-2060), it was decided to simulate the data using the most extreme conditions proposed by the RCP 8.5 scenario, as the prospect of no short- or medium-term mitigating actions was considered, and this work aims to draw attention to the occurrence of extreme events if there is no positive anthropic interference. Chart 2 shows the information used from the PROJETA for the period considered.

Chart 2. PROJOTA data

Climate Scenario:	20 km, RCP8.5, continental, HADGEM2-ES.
Frequency:	MONTHLY
Coordinates:	(-12,528, -40,307)
Variables:	'PREC'
Period:	1/2020 to 12/2060
Use of data:	research work

Source: [14].

To assess drought situations, the Standardized Precipitation Index (SPI) was used, a method created by Mckee et al. [15], which quantifies the deficiency of precipitation in different time scales, reflecting the impacts of water deficiency.

The SPI calculation, according to Edwards & Mckee [16] is performed from long-term rainfall data, at least 30 years, adjusted to a probability function of occurrence, which is transformed into a normal distribution. According to Mckee et al. [15], SPI values define the existence or not of drought and its degree of intensity, defining a drought event when the value becomes negative and reaches (–1), ending when it becomes positive again. Table 1 shows the categorization of drought or humidity events based on SPI values.

Table 1. Categories of drought indices.

SPI	**Categories**
≥ 2.00	Extremely humid
1.50 to 1.99	Severely wet
1.00 to 1.49	Moderately wet
0.00 to 0.99	Incipient humidity
0.00 to - 0.99	Incipient drought
- 1.00 to – 1.49	Moderately dry
- 1.50 to – 1.99	Severely dry
≤ – 2.00	Extremely dry

Source: [15].

The SPI was developed to be a drought indicator that values the importance of the time scale that affects the magnitude of rainfall [17], so the analysis based on time is essential. A period of 3 months is interesting for assessing drought conditions for agricultural activities, as it may reflect soil moisture. The analysis carried out with 12 months or more indicates water droughts, as they reflect long-term precipitation patterns and are directly associated with the lack of water, with flows and levels of water in the groundwater [17].

III. RESULTS AND DISCUSSIONS

The precipitation and temperature data from the last 40 years were treated in the Climap 3.0 program [18], generating the graphs shown in Figure 3, which translate the annual behavior of these variables, on a monthly and quarterly basis.

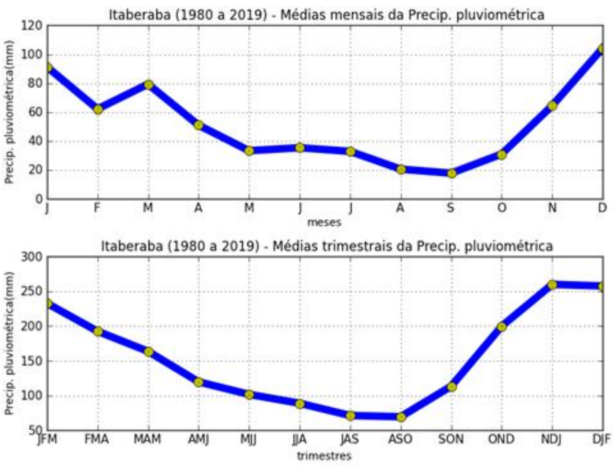

Fig.4. Average rainfall in Itaberaba (1980 to 2019).

Source: Own authorship.

Figure 4 shows that the rainiest period in the region is between the months of November and March, with the NDJ quarter (November-December-January) being the most suitable for planting, as it has the highest level of precipitation as seen in the graph. quarterly.

Despite the occurrence of relatively long periods of water deficiency throughout the pineapple cycle, the crop is not irrigated due to the very low availability of water on the properties [19].

The same authors recommend that the climatic situation of the region should be considered, as well as the reduction of the occurrence of early natural flowering, stating that pineapple should be planted from the end of the dry season and during the rainy season.

Based on the treated data, the period between March and October is the driest, in which the monthly averages do not exceed 40 mm. As, according to Reinhardt [20], in the phase of emission of the roots the water deficiency can cause deformity in the growth of the plants impairing the yield of the culture, it is indicated that its planting be carried out in the month of November or December, which have the highest rain indices.

It is observed that the temperature range, shown in Figure 4, is almost always within the ideal range for pineapple cultivation, which is, according to Reinhardt [20], between 22 and 32 °C. This is an important factor for the development of the fruit in the region.

Such thermal condition is in accordance with the adequate quality of pineapple fruits, since, according to Medeiros [21], it is reached at an optimal temperature between 23 and 25°C, tolerating a maximum temperature of 40°C and above this it can cause fruit burning, and a tolerant minimum of 5°C, below this can delay fruit ripening and prolong the crop cycle.

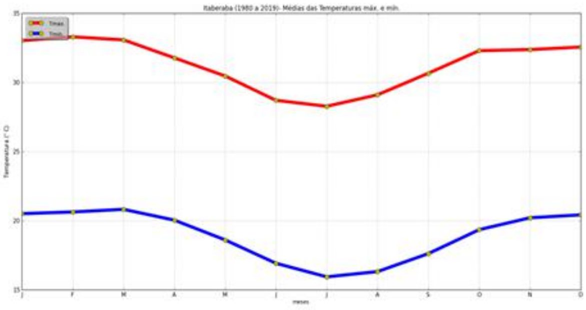

Fig.5. Average maximum and minimum temperatures in Itaberaba (1980 to 2019).

Source: Own authorship.

Table 2 shows the average monthly rainfall values with their respective standard deviations.

Table 2. Average rainfall values in Itaberaba (1980 to 2019).

Month	Precipitation (mm)	Standard Deviation (mm)	Contribution (%)
Jan	91,31	24,2 (27%)	14,64
Fev	62,20	24,8 (40%)	9,98
Mar	79,38	33,1 (42%)	12,73
Apr	51,00	27,9 (55%)	8,18
May	33,32	17,3 (52%)	5,34
Jun	35,39	8,0 (23%)	5,68
Jul	32,86	5,4 (16%)	5,27
Ago	20,56	5,9 (28%)	3,30
Set	17,77	3,3 (19%)	2,85
Out	31,00	9,0 (29%)	4,97
Nov	64,50	12,2 (19%)	10,34
Dez	104,26	9,9 (9%)	16,72
Yearly	623,55	-----	100,00

Source: Own authorship.

The average annual rainfall equals 624.84 mm, with December being the wettest month with 104.26 mm and September the driest with 17.7 mm. It is also possible to analyze the variability of these rainfall indices accumulated in the months, based on the standard deviation. It is observed that the month of December has the lowest dispersion of its values, which is an important factor for those who plan to plant in this period.

Experimentally, Gonçalves et al. [22] worked with the pineapple crop under conditions where rainfall does not exceed 50 mm per month, reaching rates around 33 mm in June. This environment is like the Itaberaba region, except for the months of August and September (Table 2). According to the authors, this water deficit can seriously compromise the development of the pineapple crop, which requires at least 60 mm of well-distributed rain throughout the month. Nevertheless, the results showed that the quality of pineapple fruits is not influenced by the planting season.

Rainfall indices from the last 40 years were used to determine drought indices (SPI). Initially, the SPI was determined using the period of 12 months to analyze the incidence of water drought, as shown in Figure 6, where it is verified the occurrence of several drought events of moderate intensity above (SPI < -1.00), as in the years 1986/1987, 1988, 1993/1994, 1999 and 2010.

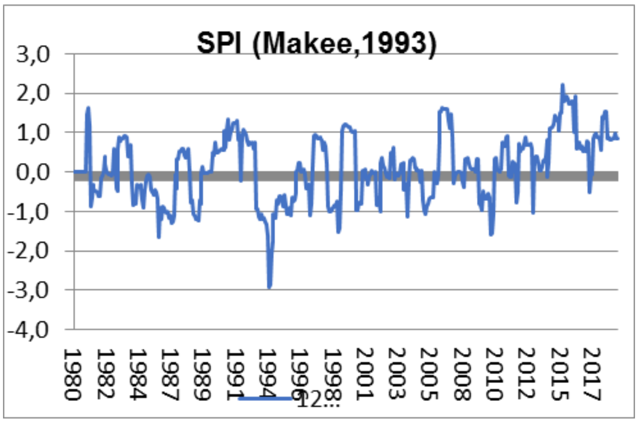

Fig.6. Drought index in Itaberaba (1980 to 2019).

Source: Own authorship.

According to Souza et al. [23], the occurrence of drought is associated with changes in the dynamics of the atmosphere, altering the surface temperature of the oceans, modifying the general circulation of air, thus displacing the precipitating systems. When there is an increase in temperature in the equatorial Pacific Ocean, there is little cloud formation in northeastern Brazil, therefore, little rainfall. This phenomenon is called El Niño.

According to CARMO and LIMA [24], there was a drought in the Brazilian Northeast in the years 1986 and 1987, between 1990 and 1995, in 1998 and another that started in 2012-2013 until 2017-2018. Therefore, this is a common event in the region and the indices calculated for Itaberaba demonstrate that the municipality does not deviate from the pattern.

It is important to emphasize the extreme drought that occurred in 1993/1994, which is highlighted in Figure 6. This event can be associated with the El Niño phenomenon that, according to Marengo et al. [5], apud [24], took place in 1993.

The SPI's of future data between the years 2020 and 2060 were also calculated, generating the graph shown in Figure 7:

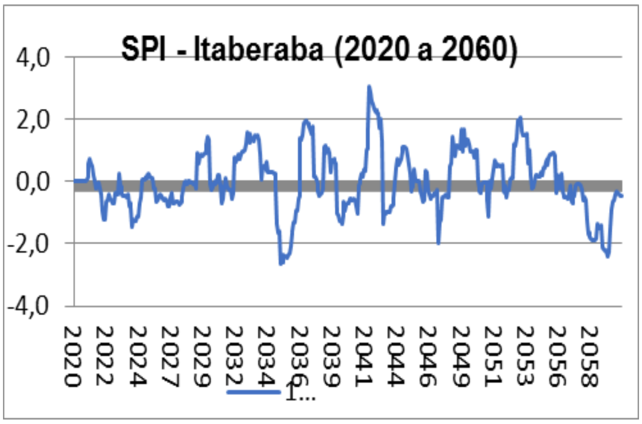

Fig.7. Forecast of drought index in Itaberaba (2020 to 2060).

Source: Own authorship.

Comparing the incidence of drought between past and future data, we observe a greater tendency of extreme droughts to occur, as shown in the graph, which predicts events of these types for the years 2034/2035, 2045 and 2059. This is an important warning for the region, as the water drought affects the water reserves with the decrease of the water level of the rivers and groundwater.

Seeking to identify the impacts of climatic variations on pineapple production, drought indices were determined on a time scale of 3 months, to analyze the hydrological drought and consequently the agricultural one. Figures 8 and 9 show the behavior of these indices in past and future time situations.

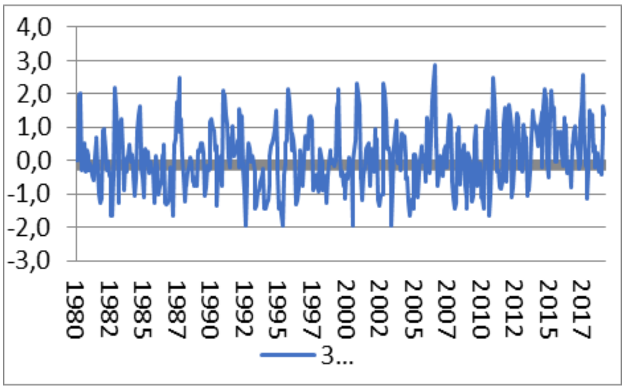

Fig.8. Drought index in Itaberaba (1980 to 2018).

Source: Own authorship.

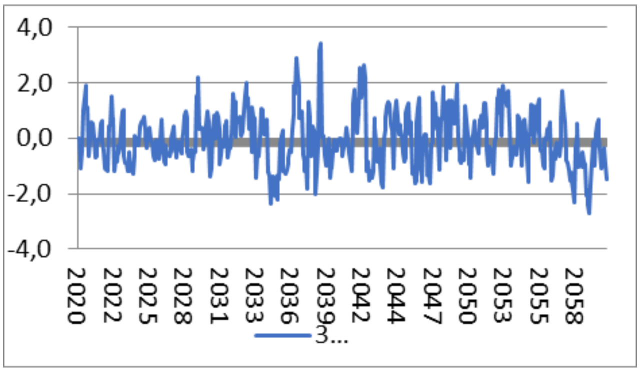

Fig.9. Forecast of drought index in Itaberaba (2020 to 2060).

Source: Own authorship.

To better systematize the results and compare them, we can analyze Tables 3 and 4 with the percentage frequencies of drought events in each period:

Table 3. Drought events in Itaberaba (1980 to 2018).

SPI	Categories	Frequency
0.00 to - 0.99	Incipient drought	35%
- 1.00 to – 1.49	Moderately dry	11%
- 1.50 to – 1.99	Severely dry	2%
≤ – 2.00	Extremely dry	0%

Source: Own authorship.

Table 4. Drought events in Itaberaba (2020 to 2060).

SPI	Categories	Frequency
0.00 to - 0.99	Incipient drought	36%
- 1.00 to – 1.49	Moderately dry	11%
- 1.50 to – 1.99	Severely dry	3%
≤ – 2.00	Extremely dry	2%

Source: Own authorship

It is noted that the occurrence of hydrological drought has a high frequency, around 50%, showing that it is an unstable region for agricultural practice. At the same time, this justifies the choice of pineapple cultivation in the region, since, according to Silva [25], the pineapple plant has physiological mechanisms such as the ability to store and low transpiration rate, which gives it high efficiency in use. water, so it is a crop that has good resistance to water deficit.

However, the incidence of severe and extreme droughts can affect agricultural production due to water limitation, causing, according to Silva [25], a drop in production, unevenness, and loss of fruit quality.

According to simulations for future data, the incidence of light and moderate droughts will not undergo significant changes. But they do show an increase in severe droughts, which is predicted to increase by 50%. On the other hand, extreme droughts that did not occur in the past appear in 2% of situations.

This can be worrying, as it is observed that the severe and extreme events of hydrological droughts shown (Figure 9) occur in some periods of hydrological droughts (Figure 7), therefore, the influence of these situations of water deficit leads to agricultural drought, which, according to Fernandes et al. [26], is associated with the availability of water in the soil to support the growth and development of plants, which can affect germination, growth and development of the plant, reducing the final yield.

In the wake of the above argumentation, regressions were set up to quantitatively evaluate the relationship between the SPI18_Maio, an independent variable, with the dependent variables harvested area (ha) and yield (kg/ha) of the pineapple crop in Itaberaba (https://sidra.ibge.gov.br/tabela/1612), respectively, Figure 9 and Figure 10.

The time scale of 18 months was chosen as a function of the total pineapple cycle, and the month of May refers to the end of the crop cycle, when planting begins during the November/December period, based on the situation climate of the region (Figure 4), considered ideal to start the cultivation, beginning of the rainy season (Table 2), with perspective of harvest at the beginning of the fifth month of the consecutive year.

In general, for both regressions, the data cloud has two points (6.4%) between moderately dry and severely dry (Figures 10 and 11). The behavior of the SPI18_May relationship with harvested area and yield showed upward trends, with indices ranging from 0.0 to 1.0 indicating the amplitude between incipient and moderately humid humidity. This indicates that there is a possibility of growing pineapple under these climatic conditions without necessarily having a significant loss with the reduction of harvested area or yield.

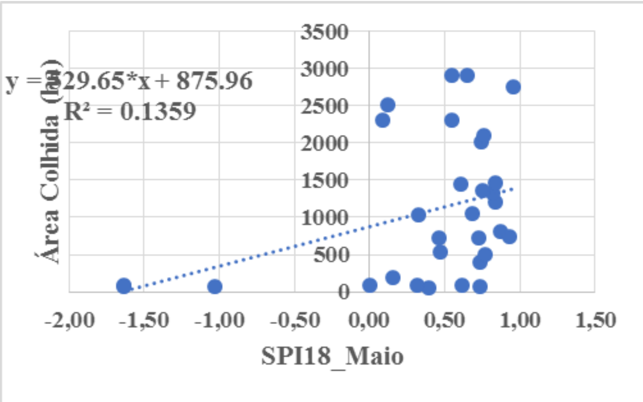

Fig.10. Relationship between SPI18_May and the area harvested for the period from 1988 to 2018.

Source: Own authorship.

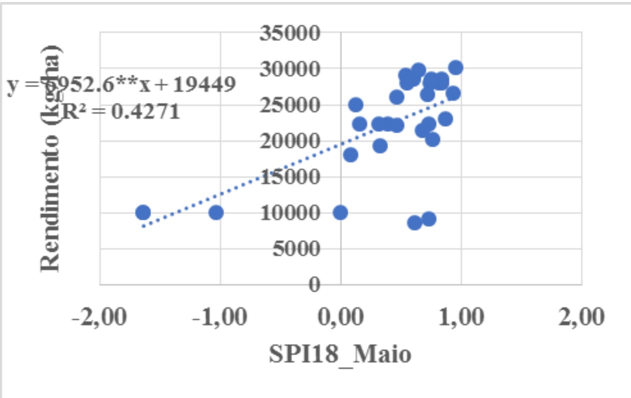

Fig.11. Relationship between SPI18_May and yield (kg/ha) from 1988 to 2018.

Source: Own authorship.

Table 5 summarizes the linear regression tests used to assess the significance of these trends. For the harvested area despite the measurement of the total size of the variation, which is shown by the regression equation of the model, explaining only 13.6%, it is observed that the DV coefficient is significant at 5% (P-value).

Thus, it can be inferred that, for an 18-month scale, there is an increase of approximately 530 ha, when the SPI18_May transcends its classification of incipient humidity to moderately humid, in more than 95% of the years. In terms of yield, there was a better fit in terms of coefficient of determination (0.427) with the highly significant p-value (1%) indicating that for each unit increment of SPI18_May, pineapple yield tends to increase quantitatively by 6,952 kg /ha, in the rainfed system for the municipality of Itaberaba.

For future projections, from 2020 to 2060, it is believed that there will be no expressive change in the responses of harvested area and yield, since the climatic behaviors of drought for the present climate and future climate, when confronted, did not undergo substantial variations in the SPI3 reading, namely agricultural drought, which could affect the beginning of planting (Tables 3 and 4).

Table 5. Linear Regression Analysis of the Dependent Variables Harvested Area (ha) and Yield (kg/ha).

Dependent Variable (DV)	DV coefficient	R Square	P-value
Harvested Area (ha)	529,65*	0,136	0,0412
Yield (kg/ha)	6952,57**	0,427	6,7E-05

*Significant at 5% and **Significant at 1%.

Source: Own authorship.

As for pineapple yield, a descriptive statistical analysis was performed using the data series between 1988 and 2020, revealing standard deviation at the level of 7,070 kg/ha. This value is like the slope coefficient of the regression line between SPI18_May and income. This analysis also resulted in a coefficient of variation of around 32%. With this information, how to explain a relatively high deviation in productivity, with the production environment showing substantial incipient and moderate moisture in the Itaberaba region? To answer this question, the average annual income of Itaberaba was divided by the average annual income of Brazil, generating the "Rend IT/BR" index. The evolution of this index is shown in Figure 12.

The evolution of this index is shown in Figure 5. In an interpretative way, when the IT/BR income tends to below the unit, it is understood that the pineapple production system in the municipality of Itaberaba is below the national average. The variation of the index over the period studied shows three phases: F1) 88-95, at the beginning, there was no technology for cultivation, which was incorporated into the production system and became a reference in Bahia; F2) 1996-2008: Maintenance of the index above 1, it became a reference crop in Bahia and the main agricultural activity in the [27] and F3) 2009-2020: Decrease of the index with emphasis in the years of 2013 and 2019, in which the values resembled the F1 phase.

Figure 13 shows the regression of the cut that revealed a highly significant adjustment (p-value: 0.0059) with an annual drop of 1/3 of the Rend_IT/BR index, in the same period in which the SPI18_May values were uninterrupted between 0.0 and 1.0, that is, no indication of drought within the period from planting to harvest. Thus, it appears that the downward trend in the Rend_IT/BR index may have been caused by weaknesses in other factors linked to the production system and not to climatic conditions related to the incidence of severe drought or thermal stress.

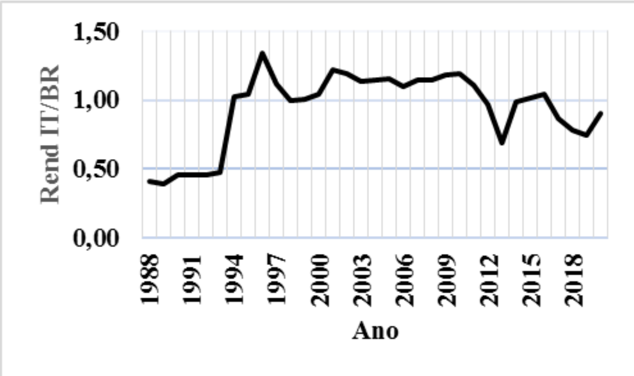

Fig.12. Evolution of the Rend_IT/BR index between 1988 and 2020.

Source: Own authorship.

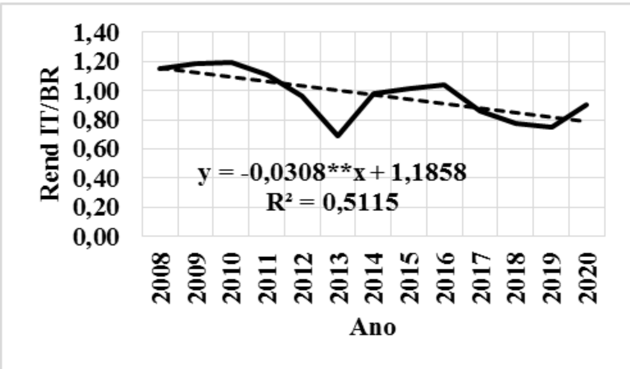

Fig.13. Linear Regression between the Rend_IT/BR index and the recount of the last 13 years.

Source: Own authorship.

IV. CONCLUSION

In the last 40 years, the Itaberaba region has an average annual rainfall of 623.55 mm, with the rainy semester from November to April, contributing 73% of the average annual total, with December being the best time of the year for pineapple planting. with higher rainfall and lower dispersion of values. There is an increase of approximately 530 ha of harvested area, when the SPI18_May transcends its classification from incipient to moderately humid humidity, in more than 95% of the years.

At each unit increment of SPI18_May, pineapple yield tends to increase quantitatively by 6,952 kg/ha, in the rainfed system for the municipality of Itaberaba. For future projections, from 2020 to 2060, it is believed that there will be no expressive change in the responses of harvested area and yield, since the climatic behaviors of drought for the present climate and future climate, when confronted, do not undergo substantial variations.

In the present study, it cannot be considered that the absence of the thermo-hydric contribution must have interfered negatively in the production process, and therefore causing the drop in the annual yield rate of the pineapple crop. It is believed that the lack or misuse of other vectors linked to production technology, such as: fertilization management, genetic improvement, phytosanitary management, post-harvest, among others, may have a decisive effect on this slowdown in productivity. However, these vectors were not objects of analysis in this research.

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