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Artículo

Analysis of extreme climate indicators and local percepti on in two communities of the Lacandon Rainforest

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Abstract

In the present study, the climate change indices of the Lacantún climate station, Mexico, and their influence on the agricultural field (milpa system) in two communities of the Lacandon Rainforest region were analyzed. The detection of changes and identification of temperature and precipitation trends in the study area was carried out by calculating the indices proposed by the expert team on climate change detection and indices through the RClimdex program. In addition, through interviews with the local population, the perception of climate changes and their impact on agriculture was known. The results indicate that, from 1980 to 2016, there was an increase of 1.5 °C in the maximum temperature, an increase of 0.5 °C in the minimum temperature, precipitation decreased by 500 mm, dry days increased, and wet days did not vary. According to the perception of the population, there is a delay and a decrease in rains, delaying sowings for up to 20-30 days, the dog days have extended 10 or 15 more days, there is a greater presence of pests and diseases (fall armyworm and bean rust); these changes have caused yield reductions of 20-25% in corn and 20-30% in beans.

Keywords:

climate change, precipitation, RClimdex, temperature.

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Introduction

Throughout history, the planet has experienced changes in climatic elements (radiation, temperature, precipitation, cloudiness, among others), these have been attributed to various factors such as changes in solar activity, ocean circulation, plate tectonics, volcanic activity, and changes in atmospheric composition, these variations occurred through geological times, however, in recent decades, human actions have greatly affected the climate rapidly (Haj-Amor and Bouri, 2020; Casana and Olivares, 2020).

The Intergovernmental Panel on Climate Change (IPCC, 2007) reported that in the last 100 years, the global temperature increased by approximately 0.74 °C, information that was recently ratified (IPCC, 2019). Studies carried out at the regional level detected that in the last 30 years, the periods of heat have been higher than averages, others report that thermal conditions presented increasing trends and suggest that the frequency and intensity of extreme temperatures will increase (Yu and Li *et al*., 2015; Bocalandro *et al*., 2021).

Therefore, the elements of climate (temperature and precipitation) have presented important variations in time and space, either recurrently or cyclically, which impact in different ways and degrees the different regions of the planet, society, and its economy (IDEAM AND UNAL, 2018). According to the IFRC (2022), the extreme events that this warming is already producing are increasing, and a high percentage of global natural disasters is related to the rapid increase in the frequency, severity, duration, and extension of extreme events.

From the perspective of the social sciences, numerous studies establish that climate is, first and foremost, the result of the way in which individuals perceive, appropriate, and interpret the meteorological and climatic events that occur around them (Olivares, 2014a). Therefore, the concept of climate is a cultural construction that is created from material and symbolic processes and that denotes cultural, spatial, and historical aspects (Pinilla *et al*., 2012).

Studies conducted around climate change (CC) models and projections at the local scale are limited, so research on observations and perceptions in traditional peasant populations in Latin America is of utmost importance and relevance (Olivares, 2014b), as they provide climate data at the local level and can help characterize local systems (Fernández *et al*., 2014); Cortez *et al*., 2016; Olivares *et al*., 2016).

The studies by Jori (2009); Olivares *et al*. (2012) emphasize that knowledge of social attitudes towards climate change has an extraordinary value; therefore, it is convenient to know the attitudes and opinions of individuals based, fundamentally, on the experiences lived, it can be very useful when defining effective policies against global warming (GC).

The expert team on climate change detection, monitoring, and indices (ETCCDMI) developed a methodology to calculate 27 basic climate indicators for use in climate change monitoring and detection studies (Zhang and Yang, 2004).

The analysis of extreme events has been used in various investigations (Aguilar and Pedraza, 2016; Pinilla and Pinzón 2012; Serrano *et al*., 2012) performed analyses of maximum, minimum temperatures, and precipitation with RClimdex and obtained important increases that can be considered consequences of climate variability and change.

Particularly in the Lacandon Rainforest, climate extremes and atypical meteorological phenomena, such as increase in temperature, delays and advances in the seasonality of rains, droughts, and floods, have had a significant impact on crop production (Carabias *et al*., 2015). Nevertheless, the perception of the climate can vary according to the culture and traditions of the community. Therefore, the objective of this research was to analyze extreme climate events and local climate perception in two communities of the Lacandon Rainforest, Mexico.

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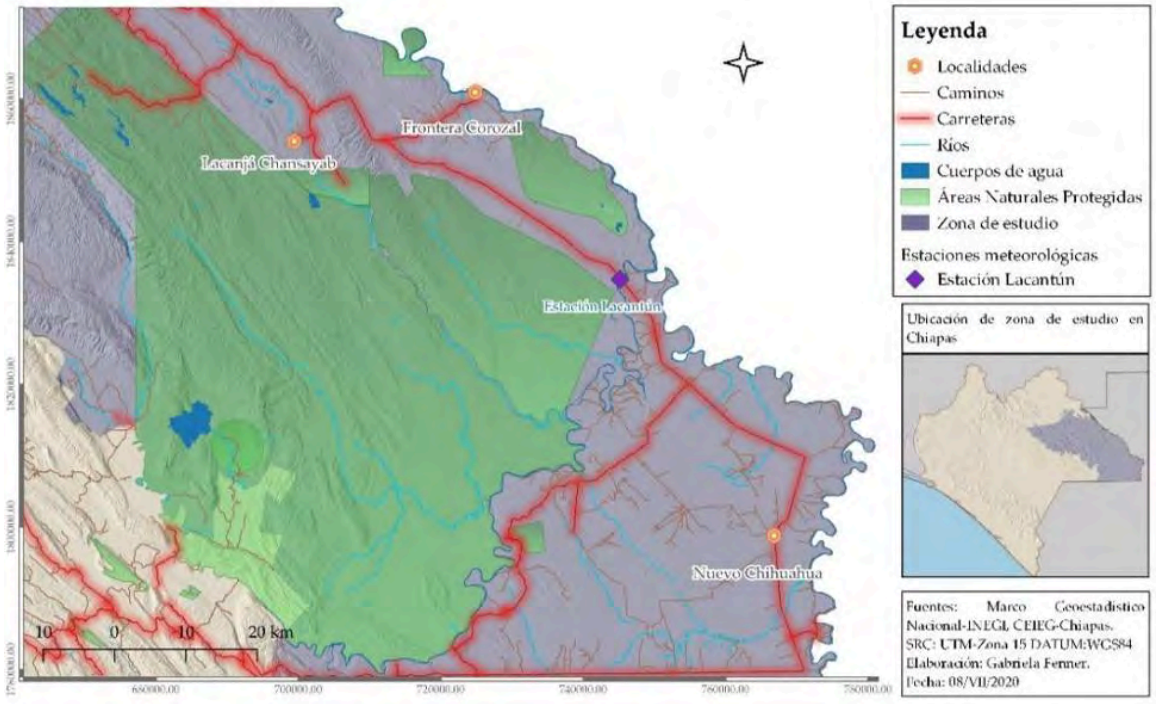
Materials and methods

Area under study

The localities studied are located in the Lacandon Rainforest of Mexico: the first locality is Frontera Corozal, whose coordinates are 16° 47′ 31.27″ north latitude and 90° 52′ 22.31" west longitude in the municipality of Ocosingo, the second corresponds to the Nuevo Chihuahua ejido N 16° 15′ 17.59" north latitude and 90° 29′ 59.82" west longitude, in the municipality of Benemérito de las Américas (Figure 1).

The average annual temperature ranges from 22-35 °C, and the total annual rainfall varies from 2 500-4 000 mm per year; rainfall is abundant in summer > 200 mm from May to October. The climate is warm humid, according to (García, 2004).

Figure 1. Location of the area under study.



The population of the locality of Frontera Corozal is constituted by the Chol ethnic group and the Nuevo Chihuahua ejido by mestizos from central and northern Mexico and by a small group of the Tzeltal ethnic group, the type of land tenure is communal. In both communities, the predominant agricultural production system is the milpa.

The milpa is a unique agricultural technology that combines polycultures such as beans, tomatoes, chili, quelites, squashes, and corn (*Phaseolus vulgaris*, *Solanum lycopersicum*, *Capsicum annuum*, *Amaranthus* spp., and *Cucurbita* and *Zea mays*). The productive cycle of the milpa depends to a large extent on temperature and precipitation; so, a variation in these elements can change the entire cycle of this type of agriculture, so diverse and, at the same time, so fragile.

The methodology included both qualitative methods (interviews) and quantitative methods (calculation of indicators). The sampling method used was snowball, where key actors were identified, who provided names of a third party, and so on according to Atkinson and Flint (2001), a total of 20 interviews were conducted in the two localities. Climate data for the analysis of

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indicators of climate extremes, such as maximum and minimum air temperature and precipitation, were downloaded from the official website of the National Meteorological Service (SMN, 2019). Table 1 breaks down the information from the climate station used.

Table 1. Climate station information.

State	Municipality	Name	Code	Location	Years with data
Chiapas	Ocosingo	Lacantún	07337	16.581 NL -90.702 WL	38 years (1980-2016)

SMN (2019).

Subsequently, the RClimDex method was used for the analysis of climate extremes indicators developed by Byron Gleason of the National Climatic Data Center (NCDC) and has been used in workshops of the International Commission for Climatology (CCl) and by the climate and ocean group: variability, predictability, and change (CLIVAR).

Finally, in this study, only six indicators were used, which are: wet days, dry days, total precipitation, number of days with rainfall less than 20 mm, night temperature, and minimum daily temperature (Table 2).

Table 2. Indices calculated by RClimdex.

Code	Index (unit)	Details	Grouping
01	CDD (days)	Highest number of consecutive dry days in a year	Associated with the behavior of precipitation and extreme rainfall events
02	CWD (days)	Highest number of consecutive wet days in a year	
07	PRCTOT (mm)	Total precipitation in a year	
09	R20mm (days)	Number of days in a year with rainfall greater than 20 mm	
20	TNn (°C)	Minimum night temperature	Associated with the behavior of the minimum temperature (temperature at night)
27	TXx (°C)	Maximum daily temperature: maximum monthly value of the maximum daily temperature	Associated with the behavior of the maximum temperature (temperature during the day)

Zhang and Yang (2004).

Finally, the fieldwork consisted of the application of interviews in the localities: Frontera Corozal and Nuevo Chihuahua. The questions used to collect the information were the following: describe the environmental characteristics of about 30-35 years ago in the locality, as well as the characteristics of production in the milpa, what are the main changes you have noticed in recent years? Has it affected sowing and harvesting periods, yield, and income? What actions are you taking or are taken within the community to adapt to these changes?

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Results and discussion

Analysis of climate extremes indices

Table 3 breaks down the values calculated with the RClimdex program: maximum temperature (TXX), minimum temperature (TNN), total precipitation (PRCTOT), precipitation of 20 mm (R20 mm), dry days (CDD) and wet days (CWD).

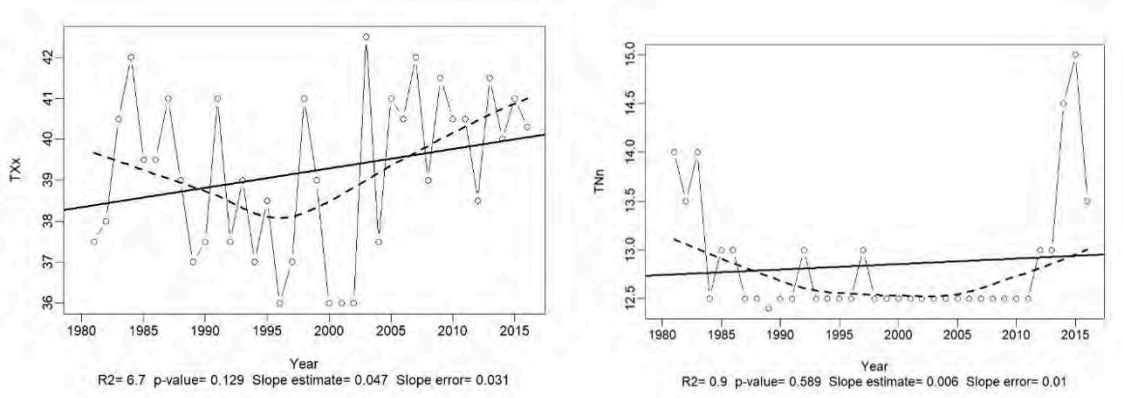
Table 3. Indices of climate extremes.

Station	PRCTOT	R20mm	TXX	TNN	CDD	CWD
Lacantún	0.122*	0.187*	0.129	0.589	0.766	0.749

*= Negative trend.

The extreme index of maximum temperature indicates that as the value is close to one (1), the changes are minimal, otherwise, if the value is closer to 0, the changes are palpable and visible. The maximum temperature in the station indicated that from 1980 to the present, they have increased, with the calculated index value being 0.129, so it can be said that in a period of 38 years, the temperature increased by approximately 1.5 °C, it went from 38.5 to 40 °C (Figure 2a).

Figure 2. Behavior of maximum temperature(a) and minimum temperature (b).



The TNN, Figure 2b, has the same behavior as the maximum temperature, the trends indicate that there is an increase, the calculated index value was 0.589, which means that the changes in temperature are minor; in 1980, the minimum was 12.5 °C, and for 2016 it was 13 °C, the difference was 0.5 °C.

These data coincide with what was reported by Ruiz *et al*. (2016), who analyzed 16 meteorological stations in the state of Chiapas and observed that 63% of them presented significant positive trends for extreme temperatures and 31% presented higher minimum temperatures.

As for the total annual precipitation, a decrease was observed, the index value is *p*= 0.122, with a negative trend. In Figure 3a, it was observed that, in 1980, the total rainfall was 3 100 mm and 2 600 mm for 2016, there was a decrease of 500 mm, a highly significant amount.

Precipitations of 20 mm, considered heavy rains, were frequent in previous years, the analysis showed a tendency to decrease, the value of the index is 0.187 with a negative trend (Figure 3b). In 1980, a total of 52 days with rainfall of 20 mm were reported, and for 2016, only 43 days, there was a decrease of 9 days.

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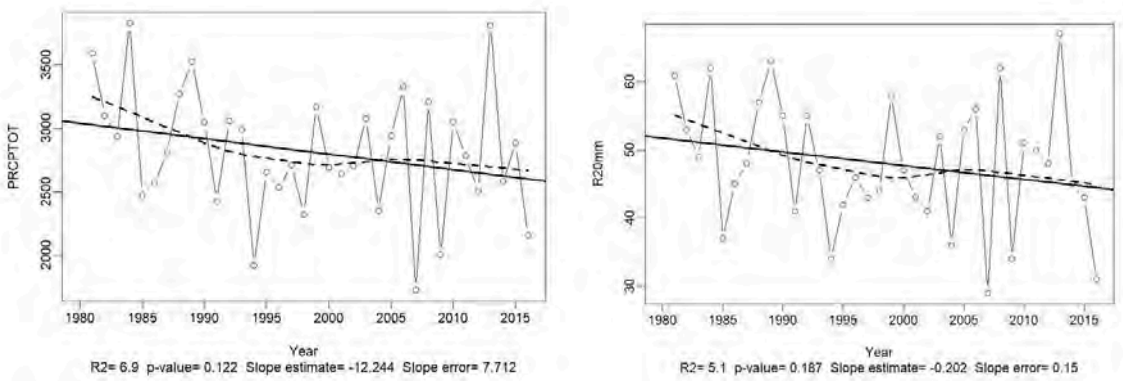
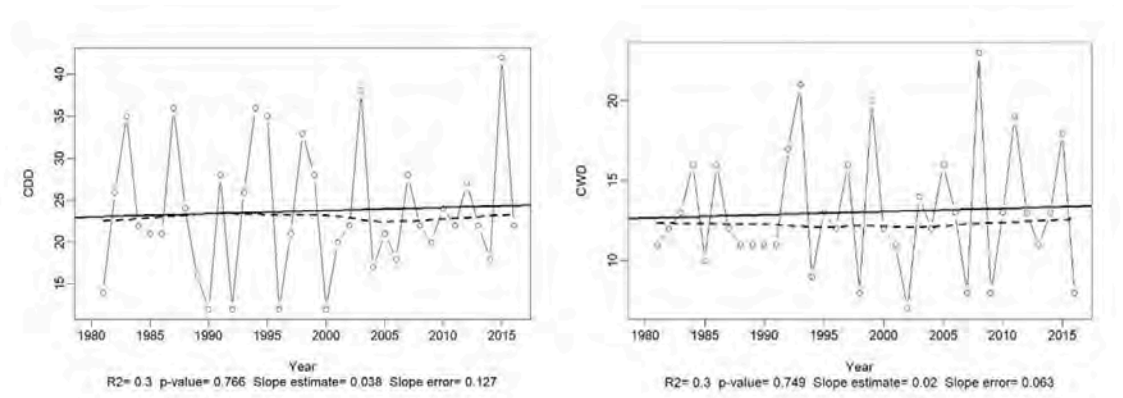
Figure 3. a) behavior of total precipitation; and b) behavior of the precipitation of 20 mm.



When analyzing Figure 4a, the dry and wet days showed minor variations in the number of dry days, the index value was 0.766, for 1985, the number of dry days was 23 days, and for 2016, it went to 25 days, a difference of 2 days in a period of 38 years.

Figure 4. a) behavior of dry days; and b) behavior of wet days.



Regarding wet days, no significant changes were observed (Figure 4b), in 1985 a total of 13 days were reported, and for 2016, a total of 14 days. Reports by Ruiz *et al*. (2016) mention that in Chiapas, only one station presented a positive trend. Regarding deforestation, this is not a direct effect of climate change but plays an important role in the variation of the local climate.

The inhabitants mentioned that, when they began to populate the region, the vegetation was virgin, a resident of the Nuevo Chihuahua ejido mentions *'*we were afraid to enter the mountain, here on the edges of the locality, we could see huge trees, and at night you could hear the tiger and many other animals, now we only see paddocks (cultivated pastures) and palm plantations*'*. Decades later, with the arrival of new settlers and population growth, the rainforest gave way to livestock and agricultural activities.

Local perception of climate

The people interviewed mention that, currently, the heat has intensified, every year it is stronger, the periods of drought are longer, the rains have been delayed for up to a month, the milpa no longer produces as in previous years, the streams have dried up, the dog days have extended for more days, and it affects the filling of the corn grain, they also mention that the pests and diseases of the milpa are getting stronger, causing losses in production.

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The heat is getting stronger, Don Javier from the locality of Nuevo Chihuahua says 'I remember that when I arrived, more or less in the 70s, it rained a lot, there was water everywhere, many streams, on days when it rained hard it was cold, the days were much cooler; now all that has changed, there is no more water in the streams, the rains are late (late May and early June), and the heat is much stronger'.

The availability of water is another problem that is occurring recurrently in the region, a young man called Gerardo from the community of Frontera Corozal says 'during the last five years, we have seen how the different streams have begun to dry up, the delay of the rains and the intense heat causes the streams to dry up, in 2019 the Usumacinta River lowered the water level a lot, we even thought it was going to dry up'.

The drought problem has intensified in various regions; in 2016, Bolivia witnessed one of the largest droughts in its history (López, 2016a), in that same year, Peru also witnessed an intense drought, the towns did not have access to water resources (López, 2016b). We can certainly affirm that the problems faced by the Lacandon Rainforest region are not isolated from the global environment and climate, so actions to mitigate the impacts must be at global, regional, and local scales.

Agricultural production in the Lacandon region is characterized by the extensive practice of the slash-burn system, extensive livestock, the extraction of non-timber species (camedor palm, edible and medicinal species), African palm plantations, rubber plantations, logging, cultivation of corn, beans, chili, among others.

According to the perception and feeling of the local population, in the last ten years, all these activities have been affected due to changes in climate (temperature and precipitation). One of the systems that have been most affected is the milpa, from which corn, bananas, cassava, beans, quelites, and other products that the family consumes are obtained. Figure 5 and 6 show the productive calendar of the 70's and another of 2019.

Figure 5. Production cycle of the milpa in the 70's in the Lacandon Rainforest.

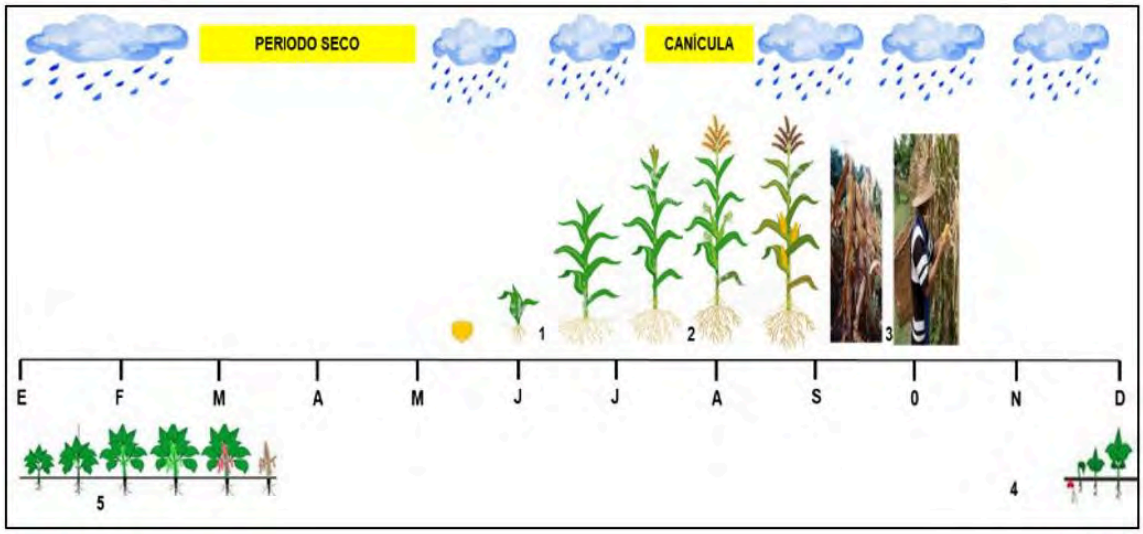

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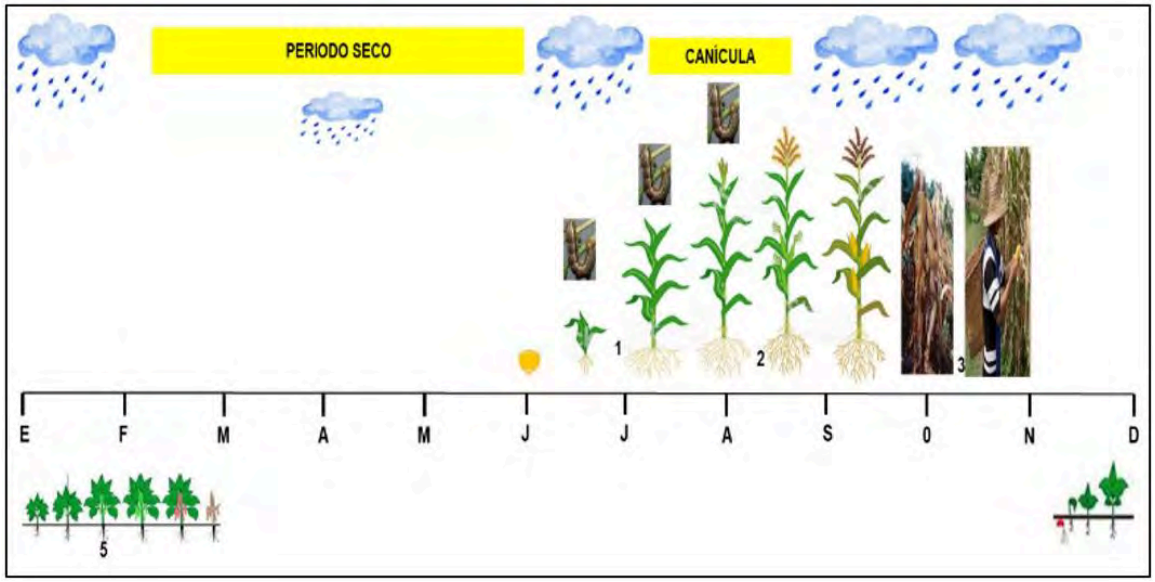
Figure 6. Production cycle of the milpa of the year 2018-2019 in the Lacandon Rainforest.



Based on the testimonies of the inhabitants, it can be concluded that there are changes in the periods of the productive cycle of the milpa, in the 70's, the weather was more stable, and in recent years, the situation has changed, they are attributed to local deforestation, divine mandate, others to global climate change.

The rainy season began at the beginning of May, there is currently a delay of up to 30 days (end of May or beginning of June), the dog days, which usually occurred from mid-July to August, have now extended 10 or 15 more days, causing problems in the filling of corn grain. The dry period occurred in March and April, recently, it occurs until the end of May.

Another unusual aspect was that the first rains are intense, and even river and stream floods occur. A 28-year-old man called Andrés from the locality of Frontera Corozal mentioned that in 2019 'when people saw that the rains were already heavy, some began to plant, they thought that the rainy season had already begun, but it was not the case, there was a fairly strong drought, and practically the milpa died'. Stories like this show that the population is confused by perceived changes in temperature and precipitation.

In the state of Tlaxcala, Mexico, the relationship of climatic variables with the production of basic crops has also been worked, Bernal-Morales *et al*. (2020) they found that, when relating the climate with the production of corn under rainfed conditions, in some areas the production had decreased, in others it was similar, and in a few, it increased.

Another problem that has arisen with changes in climate is the proliferation of pests and diseases. The fall armyworm (*Spodoptera frugiperda*) has increased its presence in the last two years. Producers mentioned that, due to this problem, they have harvested 20-25% less, the average yield per hectare went from 1.5 to 1.2 t. Rust (*Uromyces phaseoli*) is another disease that is affecting beans more intensely, causing losses of up to 30% or sometimes 100%.

Don Jesus, 65 years old from the locality of Frontera Corozal, mentioned 'I remember that until 2005-2006 on Mother's Day, it always rained, sometimes it was the first rain or one of the first, now that day it does not rain, not even a sign of rain, it is only quite hot', with these stories it can be affirmed with certainty that, in the last two decades, the rainy season has changed. The situation that the population of these localities is facing forces them to look for production alternatives or actions to adapt to these changes, these actions are based on ancestral knowledge or day-to-day experiences.

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Authors such as Altieri and Nicholls (2013) emphasize that peasant and indigenous agriculture are alternatives in the fight against CC. On the other hand, the more biodiverse agroecosystems are, the more stable and resilient they tend to be, a clear example of them is traditional agriculture in countries in Africa, Asia, and Latin America, which have developed and inherited complex agricultural systems in hostile environments (Altieri and Nicholls, 2008). Likewise Altieri and Nicholls (2009) affirm that indigenous and traditional technologies are an invaluable source of information on adaptive capacity in the face of CC.

In the agricultural field, actions have also been carried out to adapt to changes, approximately 25 years ago, it was common to use a variety of corn of long cycle (six months to harvest), changes in precipitation patterns have motivated to sow varieties of corn of short to intermediate cycle (4-5 months to harvest), these, in addition to being adapted to soil conditions, resist more to low rainfall and are yielding (2-3 t in soils of medium fertility).

The diversification of the milpa is gaining importance again, within this space, we can find bananas, squashes, quelites, sweet potatoes, cassava, taro, chilies, yams, and other species that are consumed or used locally. The previous problem has been taken up by FAO (2022), which states that climate and its influence on agricultural production is a priority and indicates that climate change threatens food production, food security and can bring famine problems, so action must be taken at the global, national, regional, and local level, as is done in the present research.

Conclusions

The analysis of climate extremes is of utmost importance to evaluate changes in climate elements, which will serve to make short, medium, and long-term planning. The results calculated by RClimdex indicate increased temperature and variations in precipitation, information that was supported by the observations and perceptions of the inhabitants of the area.

In the last 20 years, temperatures have increased significantly, and this is reflected in more forest fires, disappearance of water sources, delayed rainfall, downpour-type rainfall, resulting in variations in agricultural cycles and losses in corn, beans, bananas, cassava, chilies, and other plant species for local consumption.

Studies of this nature should not be limited to the analysis of climate data but investigate or make use of other alternative methodologies, such as ancestral knowledge, which provides invaluable knowledge. Studies on climate change are generally done at a macro level and not at a regional level, much less locally, so it is very important that studies to understand the impact should be at the regional level since, as research points out, the effects or impacts vary from one region to another.

The future of the Lacandon Rainforest is uncertain, slash-burn agriculture, livestock farming, and commercial plantations continue to expand their frontiers year after year, adding to this forest fires, which become more intense every year. The importance of doing local research in a regional context since only specific studies can contribute to the best use of the soil and the relationship with crops, adapting the sowing of new varieties of corn or changing crops.

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