Article

Citrus farmers' perception of the effect of climate change in Campeche

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Abstract

In Mexico, citrus cultivation has a food, social and cultural importance that comes to govern family life and community dynamics in the regions where it occurs and that are being affected by climate change. The objective of this research was to measure the perception of citrus growers, faced with the effect of climate change. A participatory survey was applied to 65 citrus producers in Campeche. Variables on the occurrence of events associated with climate change, direct damage to plants, perception of the increase in meteorological phenomena, technological and socioeconomic change were measured. The surveyed are men (86.3%), of older age and basic education. 55% of the participants own common land and 44% have private property. The average yield of citrus fruits is low due to the lack of technical irrigation systems and the effects of climate change, particularly the increase in temperature and the decrease in precipitation. Producers have a total of seven types of crops on their plots, without correlation with the size of the property (r= 0.032), nor with the area destined for cultivation (r= 0.33). The 66.6% of the participants have heard about climate change being the source of information television. The 69.6% have perceived greater changes in the climate, which has motivated them to make changes in the type of tillage (McNemar.test χ^2= 10.56, p< 0.01**). Thus, the effects of climate change are influencing the citrus management practices of the producers of Campeche; however, they are reactive actions, so research is required to quantify and assess the damages caused by this phenomenon and strategies are designed to counteract its effects in the medium and long term.

Keywords: changes, citriculture, climate, producers, vulnerability.

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Introduction

Citrus farming is an activity that takes place in tropical and subtropical climates. At the national level, Michoacán ranked first in lemon production, with 711 181 t and a yield of 16 047 t ha^{-1}, followed by Veracruz with 661 733 t. The citrus producing areas in Mexico are well delimited, on the coast of the Gulf of Mexico, they are cultivated in states such as Tamaulipas, Veracruz, Tabasco and Yucatan, and of less relevance in Nuevo Leon and Puebla. Another area is that of the Pacific coast in states such as Sonora, Colima, Michoacán and Oaxaca.

Orange is the citrus with the largest number of hectares planted and harvested in Mexico (58.9%) (60.5%), followed by lemon (34%) (32.2%); mandarin (3.8%) (4%) and grapefruit (3.4%) (3.3%) (SIAP, 2019). This contributes to Mexico being in an important position worldwide with respect to citrus production: 5 place as producer of orange, 2 place as producer of lemon, 4 place as producer of grapefruit and 13th place as producer of mandarin (SAGARPA, 2018).

The Mexican lemon (*Citrus aurantifolia*) has found its main buyer in the Japanese market, annually exporting around two thousand tons (Maya, 2017). For its part, the state of Campeche reported a surface planted with lemon of 2 018 ha, considering the total cultivation, with a production of 13 453 t and a yield of 7 539 t ha^{-1} (SIAP, 2017). However, tropical conditions and rainfall are the main climatic factors that influence the growth, development and productivity of citrus plants (Orduz-Rodríguez *et al*., 2017; Agovino *et al*., 2018).

The permanence of climatic difficulties in the citrus sector has the main negative effect on the low productivity of the orchards and therefore on the gradual abandonment of the plantations. This phenomenon of changes in the magnitudes and meteorological distributions of the classic climatic variables that include temperature, precipitation, humidity, wind speed and evaporation, will cause changes in the physiological behavior of plants and in turn will impact agricultural productivity at global scale (Orduz-Rodríguez *et al*., 2017; Zhang *et al*., 2017; Agovino *et al.*, 2018).

In this way, climate change poses serious challenges for agriculture and adaptation to its impacts (Klocker *et al*., 2018), making producers and their production systems increasingly vulnerable to its effects. The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability to climate change as the ‘degree of susceptibility or inability of a system to cope with the adverse effects of climate change and, in particular, climate variability and extreme events. Vulnerability will depend on the nature, magnitude and speed of climate change to which a system is exposed, and on its sensitivity and adaptability’ (Ibarrarán *et al*., 2014).

In the current debate on climate change, the issues of social vulnerability and perceptions of the population regarding this phenomenon occupy a prominent place, mainly because it nurtures knowledge about the interests, demands and needs of different social sectors and allows laying the foundations to build social participation processes aimed at reducing the risks of disasters caused by the increase in hydrometeorological phenomena (Sandoval *et al*., 2014).

The agricultural sector is sensitive to climate change and the capacity of small farmers to develop (Makuvaro *et al*., 2018). Therefore, it is necessary to adapt current practices and develop new strategies for climate resistance in crop systems (Makate *et al*., 2019). Another important challenge of studies related to vulnerability and adaptation to climate change is that despite the existence of physical and geographic studies on the impacts of this phenomenon, and which to date have allowed establishing scenarios of impacts at the territorial level.

At this time there is not enough information on a reduced scale about the perception of their vulnerability, or the impacts of the phenomenon on the economic and social well-being of the population (Sandoval *et al*., 2014), this can reduce the efficiency and effectiveness of the implementation of agricultural conservation practices, alter hydrology, alter ecosystems, cause erosion and affect the ability of farmers to develop (Wagena and Easton, 2018) decreasing profits from agriculture (Dussel-Peters, 2002; Pérez *et al*., 2006).

Increasing the volatility of food prices (López-Feldman and Hernández-Cortés, 2016) and becoming a potential threat to food security and sovereignty of developing countries, in complex ways (Kusangaya *et al.*, 2014; Golcher *et al.*, 2017). In adaptation to climate change, government efforts have been distinguished by the search to improve agricultural productivity and the development of irrigation based on current technology (Islam and Nursey-Bray, 2017; Karimi *et al*., 2018).

Some strategies implemented to reorient agricultural development under the reality of climate change is climate-smart agriculture, conservation agriculture, improved species varieties among many others (Islam and Nursey-Bray, 2017; Thornton *et al*., 2018). Consequently, this manuscript aims to show the perceptions of producers in the state of Campeche, Mexico.

Given the impact of climate change on citrus cultivation and adaptation agro-ecological strategies in the face of this phenomenon. Therefore, the hypothesis derived from this work is that citrus growers perceive the damage that CC can cause, but have not yet established adequate agroecological strategies to counteract these effects.

Materials and methods

Study area

The research was carried out in two municipalities in the state of Campeche: Champoton and Campeche, because these municipalities are considered among the seven that concentrate the majority of citrus producers, along with Escarcega, Hopelchen, Tenabo, Hecelchakan and Calkini (Tribuna, 2020), Campeche is located in the southeast of the Mexican Republic and limits to the north with the state of Yucatan, to the south with Guatemala and Tabasco, to the east with the state of Quintana Roo and to the west with the Gulf of Mexico (INEGI, 2012).

It is one of the states of the Mexican Republic with the greatest vulnerability to the effects of climate change. The elevation of the mean sea level represents for its coastal strip one of the most pressing challenges due to the impact and acceleration of the erosion processes on its beaches. Situation that puts billions of pesos at risk in vital communications and transport infrastructure, in addition to affecting landways, of great importance as it is the entrance to the Yucatan Peninsula (Ecosur, 2012).

Campeche is highly vulnerable to the effects of climate change due to its geographical location and its coastal condition, as well as the levels of marginalization and poverty of its population and the concentration of more than half of its inhabitants in its coastal area (Márquez, 2016). In this state, the sub-humid warm climate predominates, which occurs in 92% of its territory, 7.75% has a humid warm climate located in the eastern part of the State, and in the northern part, a small percentage of 0.05% with a semi-dry climate.

The average annual temperature ranges between 26 and 27 °C. The maximum temperature exceeds 30 °C and the minimum is 18 °C. The rains are abundant to very abundant during the summer and the total annual precipitation varies between 1 200 and 2 000 mm, although in the northern region, with a semi-dry climate, it is less, around 800 mm annually. However, the predictions point to an upward evolution of the average annual temperature, with an increase of between 2.5 °C and 4 °C between 1961 and 2099, due to the expected increase in minimum and maximum temperatures (Gobierno del Estado de Campeche, 2015).

Determination of sample size

The sample size was calculated using the formula (1) Sierra (1995) proposed for finite populations, taking N from a list of producers provided by the Plant Health Committee of the municipalities of Champoton and Campeche corresponding to 605 producers in total. This equation yielded 65.21 producers, so a total of 66 citrus producers were surveyed.

$$n= \frac{N\times Z_a^2\times p\times q}{d^2(N-1)+Z_a^2\times p\times q} \qquad 1)$$

Where: N= population size= 604 producers; $Z_α$= confidence level= 1 96^2 (if the security is 95%); p= expected proportion= 5%= 0.05; q= probability of failure= 1-p (in this case 1-0.05)= 0.95; d= precision= 5%= 0.05.

Data collection and survey

The participatory survey was used as a diagnostic instrument to measure perception; applying questionnaires to 66 citrus producers under the precept of collaboration, the only condition to apply the questionnaire was that they had citrus cultivation regardless of the type of cultivation or the species of them within their production units. The applied questionnaire consisted of open and closed questions where qualitative and quantitative variables were evaluated.

The 'snowball' non-probability sampling was implemented (Hernández-Sampieri *et al*., 1991). Five indicators were used, which were: phenomena caused by CC (Climate Change) that affect citriculture, effects of CC on citriculture, cultural management in the face of the effect of CC, perception of the level of increase in climatic situations and agro-ecological strategies before the effect of the CC. Variables on the occurrence of events were obtained from these indicators; variables on direct damage to parts of the plant.

Such as loss of branches, leaves, flowers and fruits, erosion and loss of nutrients from the soil, as well as a decrease in production and productivity; all these variables were measured through a YES, NO. Before starting the survey, we talked with the producers in order to assess the degree of knowledge they had about CC, although with their answers they did not clearly define the word CC, it was perceived that they did have knowledge about what CC phenomenon involved, so the questionnaire was applied.

In addition, other variables such as perception of the increase in prolonged droughts, heavy rains, hurricanes, storms, floods and strong winds were evaluated. Likewise variables, to measure the change in cultural practices in the face of the effects of climate change previously described, such as cutting, fallow, tracking, weed control, fertilization and fertilization, pest and disease control, irrigation and pruning, these variables are also measured with a yes or no.

To complement this information and establish relationships between variables, five variables were measured to reflect socioeconomic characteristics, such as the age of the producer, the area destined for citrus cultivation, schooling and gender. Likewise, exploratory tours and in-depth interviews were conducted with some citrus producers to learn more about citrus production and vulnerability to the effects of climate change.

Analysis of the information

The data thrown by the diagnostic instrument were analyzed with the R statistical package (3.4.2, 2017). Descriptive analyzes were performed for most of the variables. Variables for principal component analysis were converted to binary values. Linear correlations were made, looking for relevant factors. The McNemar non-parametric test was also used to detect changes in the use of technologies in the face of environmental changes.

Results and discussions

Socioeconomic and productive characteristics of citrus growers

In the long term, there may be profound effects on ecosystems and society, and part of the effects that affect the population will depend on the intensity and frequency of climate events, as well as on the way in which a given community is ready to face them. Therefore, in the face of similar disasters, it is expected that the less prepared the population is, the greater the negative effects.

This inability to respond or vulnerability is intimately linked with some of the community's intrinsic socioeconomic characteristics, which reflect the level of development and well-being in which its population lives (IPCC, 2007). Therefore, in this research, the socioeconomic characteristic ‘average age’ of the people who dedicate themselves to citrus cultivation in the state of Campeche is 56.5 years (sd= 14.6, n= 65).

This means that they are producers of advanced age, similar data to that reported for the majority of people engaged in agricultural activities in Mexico (Bahena-Delgado and Tornero-Campante, 2009), where the youngest prefer to engage in other activities and have abandoned agricultural activities in their communities, migrating to other parts of the country or to the United States of America (Rosales *et al*., 2015). On the other hand, in the distribution of citrus growers with respect to gender, the results indicate that 86.3% of the producers are male.

This trend is similar not only for farmers and peasants engaged in citrus farming but also in general for people engaged in some field activity, and has to do with the idiosyncrasy and culture of the Mexican peasantry (Camargo-López and Espericueta-Reyna, 2006), because by tradition, it has been the family man who has dedicated himself to the tasks of agriculture and the woman has been relegated to the tasks of the home (Rosales-Martínez and Leyva-Trinidad, 2019).

The level of studies predominantly reached among the citrus population is basic education, 50% primary education and 22% secondary, and in contrast, only 4.2% have undergraduate studies (Figure 1). This data is similar to that reported by Galindo *et al*. (2000) for 11 regions established in different development districts in rural areas in Zacatecas Mexico and those reported by Bahena-Delgado and Tornero-Campante (2009).

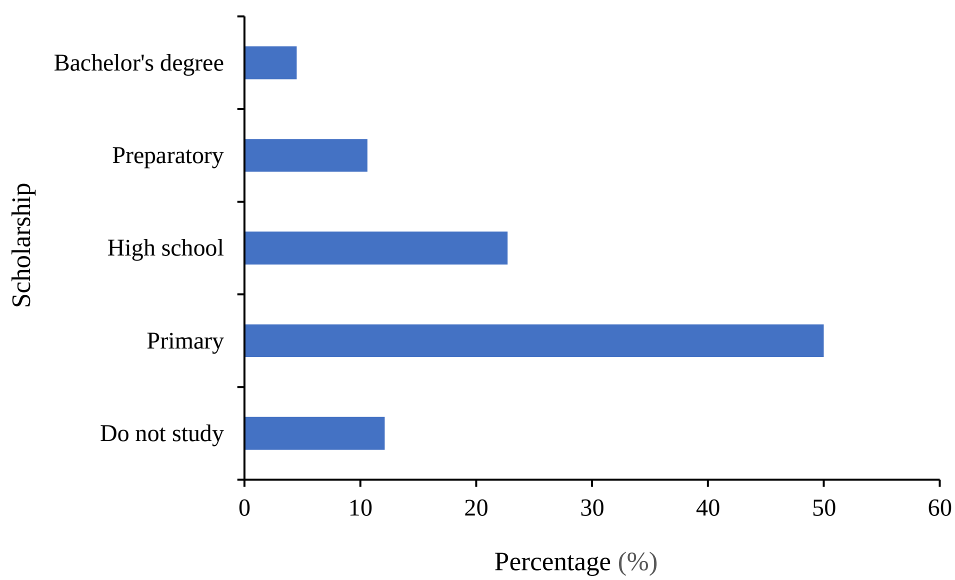

Figure 1. Distribution by schooling of citrus producers in the state of Campeche.

For small production units, where the majority of the bulk of the population has only basic education. Corona (2018) mentions that, under this cultural context, educational level, as well as gender and occupation, make up individual and group perception of climate change. According to land tenure, 55.3% are common parcels and the remaining 44.6% are privately owned.

The trend of land tenure is an approximate of the national average that in past times was dominated by common lands (Morett-Sánchez and Cosio-Ruiz, 2017), which saw its extent decrease due to the country's agrarian reforms, being more evident during the time in the 2007 Agricultural, Livestock and Forest Census. The yield per hectare of the lemon crop, with varieties of sweet and sour lemon, according to the volume of production in the municipalities of Champoton and Campeche (3.03 t producer^{-1}, sd= 3.54, n= 36), of sweet orange (2.5 t producer^{-1}, sd= 5.06, n = 36) and tangerine (2.34 t producer^{-1}, sd= 10.03, n= 36) (Figure 2).

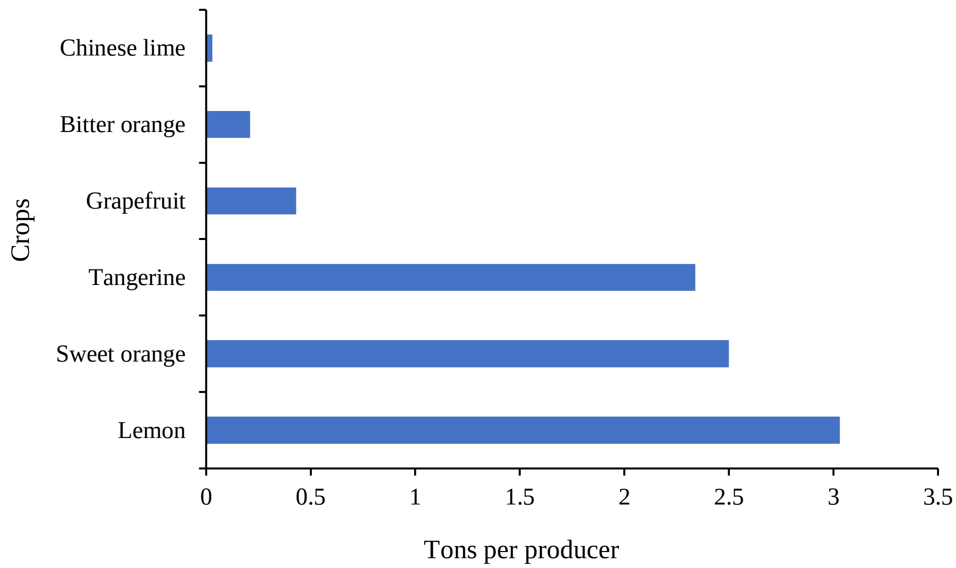

Figure 2. Yield of citrus production in the State of Campeche.

It is below that reported for the state of Campeche. With a production of 7 539 t ha^{-1} (SIAP, 2017) and it is very far from reaching the production levels of large producing states such as Michoacán, who ranked first in lemon production with a yield of 16 047 t ha^{-1} (Maya, 2017; Orduz-Rodríguez *et al*., 2017); this low yield can be explained by the fact that the surveyed population is engaged in citrus farming without technification, in addition to the contrasting climatic conditions currently present in these regions.

Thus, the vulnerability to flooding due to storm surges, the increase in rainfall in some areas and the decrease in them, as well as the increase in temperature generates loss and/or modification of biodiversity in municipalities of Carmen, Champotón, Campeche, Tenabo, Hecelchakan and Calkini. The human settlements and strategic infrastructures located in the coastal area are the most exposed and sensitive to climatic events such as cyclones, cold fronts and northern fronts.

The consequences of these events grow with rising sea levels and storm surges resulting in coastal flooding and penetration of seawater (Gobierno del Estado de Campeche, 2015). On the other hand, there is no correlation between the total size of the common or property with the area intended for cultivation, according to the Pearson correlation (r= 0.32). A total of seven types of cultivated citrus are reported, a single owner can have up to five citrus crops.

However, crop diversification is also not correlated with the size of the property (r= 0.032), nor with the area devoted to citrus cultivation (r= 0.33). Likewise, no correlation was found with the total production and the size of the citrus growing area (r= 0.47).

Therefore, it is perceived that the decisions of the producer, on what type of crops to establish and the tendency of the use of the land for citrus farming, depend solely on the personal decision of the producer, who does not have access to extension services and technical advice specialized. As well as the ease you have to market your products. In this sense, Almaguer-Vargas and Ayala-Garay (2014) mention that in Mexico, the increase in lemon production has been based on an increase in the surface and not on innovations that improve yield, because the transfer and the adoption of innovations has had multiple limitations. As well as the reduced coverage of public technical assistance of less than 1% of the productive units in the country and the use of inefficient methodologies for this (Almaguer-Vargas and Ayala-Garay, 2014; Lucatello, 2014). Where adequate perception is a prerequisite to the successful adaptation of agricultural strategies (Makuvaro *et al*., 2018).

Knowledge about climate change

The results in this study reflect that 66.6% of the interviewed people declare having heard about the CC, of which 4.5% are not really informed on the subject, 86.3% are poorly informed and 9.0% consider themselves quite informed about the CC theme. Guerrero-Carrera *et al*. (2015) reported in sugarcane agroecosystems of Veracruz, Mexico, that approximately 81% of farmers had heard of CC, 97% perceived changes in the climate, of them, 73.5% perceived changes in temperature, 87.8 % perceived changes in precipitation, 49% in wind, and 69% claimed damage to their agroecosystems by the CC.

This means that many of the producers have information regarding this topic and have perceived its effects. Evans and Durant (1995) mention that the level of knowledge determines the quality of perception; in this sense, it does not seem that the level of knowledge determines individual perception, although, on the contrary, it stabilizes and consolidates it, either positively or negatively. Furthermore, the most relevant sources where citrus producers have obtained information on CC are television, followed by technicians and by the newspaper, the other sources included in this study are not relevant due to their low impact (Figure 3).

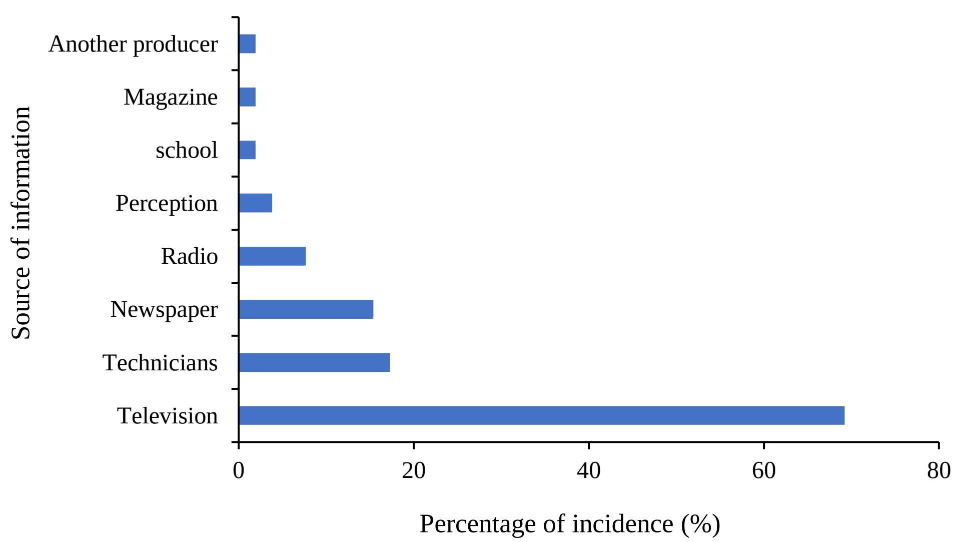

Figure 3. Information and broadcast media on climate change.

Perception of the effect of climate change on agriculture

When asked about the perception of climate change, 1.5% consider not perceiving a change, 28.8% have perceived a little change and 69.6% perceive a greater change. 43.0% believe that climate is modified by human causes, 27.6% attribute it to natural causes, however, 24.6% consider that these two factors influence CC. So this indicates that CC is perceived by most citrus growers; also Zhang *et al*. (2017); Karimi *et al*. (2018) they coincide with these opinions on the perception of CC and the factors that accelerate global warming; In addition to this, Márquez (2016) mentions that although the CC, although it is perceived, its appreciation is not so clear, as demonstrated by municipal officials in Campeche, Mexico, where their perception and knowledge were based on television and the internet. On the other hand, the principal component analysis shows a variance of 63.5% in the first two components obtained for this variable (Table 1).

Table 1. Principal component analysis for the perception of environmental factors in Campeche.

Weather events	Component 1	Component 2
Prolonged droughts		0.695**
Strong rains	-0.49	-0.343
Hurricanes	-0.533*	0.223
Floods	-0.597*	-0.223
Strong winds	-0.345	0.548**

*= there is no change; **= if there is change.

The first component is related to water phenomena (hurricanes and floods) and has the greatest relevance in the perception of CC, and the second component is associated with droughts and winds. A group of people belonging to the first component believe that hurricanes and floods do not have a significant impact on citrus cultivation. A second group of people believes that they are affected by droughts and winds (Figure 4).

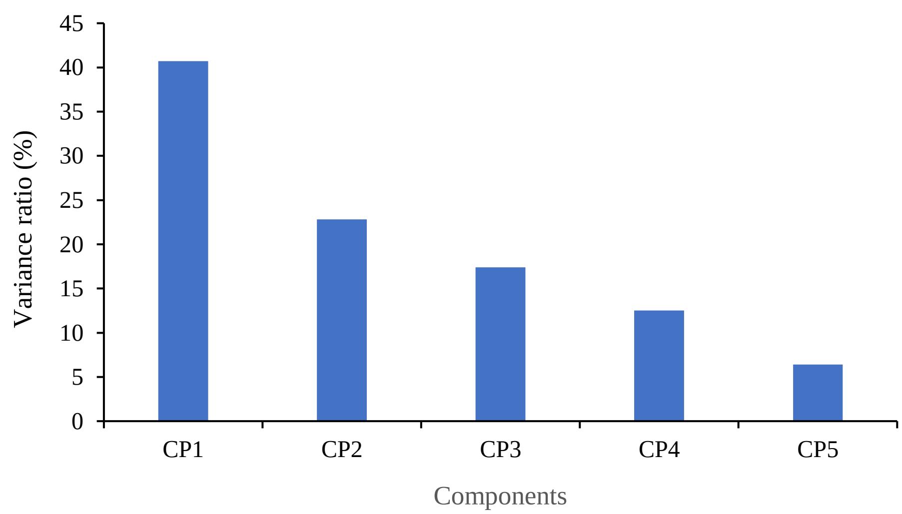

Figure 4. Principal component analysis on the perception of climate change in citrus growers in Campeche.

Effects of climate change on citrus cultivation

Hurricanes cause total loss of trees, in addition to the presence of diseases and pests due to excess humidity due to heavy rains. The degree of affectation that the producers of the state of Campeche reported due to natural disasters in their citrus production system was as follows: 18.5% had a great impact, 70.3% had little and 11.1%, nothing.

In addition, the producers mention that not only is it a disaster that affects their citrus, but they detect various phenomena that occurred during the different seasons of the year, reporting prolonged droughts as the most frequent. Likewise, 54.5% have detected a decrease in their production after a disaster, although they do not have exact reports of such losses.

Campeche, as well as the Federal District, Baja California, Baja California Sur and Durango are twice less vulnerable than floods and related events than Chiapas, Veracruz, Tamaulipas, Oaxaca and Sinaloa, among the determining factors is the use of soil that integrates indicators of anthropogenic activities and their effect on the reduction of natural areas, so that the vulnerability of Campeche is due to its type of relief (karst). Soil degradation is another important element, according to an analysis carried out, due to floods, droughts and hail (Ibarraran *et al*., 2014).

Although lags in economic and social capacity can also affect vulnerability to disasters and resilience to them (Ibarraran *et al*., 2014). In this way, the effects of prolonged droughts, heavy rains, hurricanes and strong winds are related to the loss of branches, leaves, flowers and fruits in citrus trees. Likewise, in the Yucatan Peninsula, drought produces losses and low yields of crops, cattle and hives, a decrease in the quality of products, as well as an increase in production costs, which produces a reduction in income of the producers (Estrada-Medina *et al*., 2016).

Similarly, Mora-Aguilera *et al*. (2016) they found that the increase in the frequency of rainfall has affected biological events of the pests, so the relationship between exotic pests historically detected and the number of hurricanes that occurred in Mexico is highly significant (r^2= 0.98); among these specific pests, related to hurricanes can mention the *Trips Palmi* and pink mealybug.

Technological practices in the face of the effect of climate change

In this investigation, there was no significant change in the use of technological practices after a natural disaster with the exception of tillage, which increased its practice (McNemar.test χ^2 = 10.56, p< 0.01**) (Table 2).

However, citrus growers do carry out other agroecological practices to reduce vulnerability to floods such as: making drains and making channels; before drought: have an irrigation system, wells, take care of the water and leave stubble on the ground to maintain humidity, in the face of winds: plant trees that serve as curtains, break winds and place supports on the plants.

Table 2. McNemar test to detect changes in the use of technologies after a climatic event.

Technology	Chi-square	*p*
Tillage	10.56	< 0.01**
Weed control	2.25	0.133 ns
Fertilization	0.25	0.617 ns
Pests	0.57	0.449 ns
Irrigation	0	1 ns
Pruning	1.45	0.227 ns

**= change in the use of technology due to climate event.

The effects of CC can reduce efficiency and effectiveness by implementing agricultural conservation technology practices and affect the ability of farmers to develop (Wagena and Easton, 2018), in addition to increasing the volatility of food prices (López-Feldman and Hernández-Cortés, 2016), becoming a potential threat to food security and sovereignty of developing countries in complex ways (Kusangaya *et al*., 2014; Golcher *et al*., 2017).

On the other hand, it is necessary to design strategies for greater dissemination and promote practices once the citrus farmer has evidence of affectations by this phenomenon and even before them. Given this scenario, Nuñez *et al*. (2017) propose some strategies such as: the selection of rootstock as a key element and the inoculation with suitable strains of arbuscular mycorrhizal fungi, to contribute to tolerance to both water and salt stress, and to the application of some chemical agents.

Similarly, some agroecological practices to combat erosion reported by Debray *et al*. (2019) are the holes of zai (wells dug in the preseason to catch water), half moons, stone bales and terraces to rehabilitate farmland, avoid soil loss due to water erosion, and reduce wind erosion.

Conclusions

The main effect of CC in citrus agroecosystems based on the perception of its managers is that its yields are decreasing. A fact that will worsen in the medium and long term based on the proposed scenarios that indicate an increase in temperature and a reduction in precipitation. Given this situation, it is essential that the producer design and implement strategies aimed at better management of soil fertility and humidity, and the conservation of the diversity and agrobiodiversity associated with this agroecosystem.

Failure to do so would generate conditions of possibility for this type of agroecosystem to gradually disappear and with it, its role as a supplier of an important fruit for the population's food. It is essential to point out that, although citrus producers perceive the effects of CC on their citrus agroecosystems and most of them indicate that they have heard about this phenomenon, they still do not have the necessary knowledge to design strategies on how to face their effects.

This is mainly due to the complexity of the phenomenon and the way in which it has been reported, as well as its relationship with increasingly recurring and severe phenomena such as torrential rains, hurricanes and strong winds, agroclimatic elements related to the loss of branches, leaves, flowers and fruits that cause loss in the quantity and quality of the product, which limits their trade in national or international markets to obtain fair prices that allow them to cover the basic needs of themselves and their families.

These and other actions should be promoted and strengthened by public policies as potential strategies to combat and counteract the effects of CC. This will support the citrus sector and with it, families whose economy is based on income generated by citrus, in addition to contributing to the food security and sovereignty of the region and the country.

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