Journal of Agricultural Science; Vol. 7, No. 10; 2015
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

Climate Change Impact on Sugarcane Crop in the Gulf of Mexico: A Farmers Perception and Adaptation Measures

Jesús Guerrero-Carrera[1], Cesáreo Landeros-Sánchez[1], Juan Pablo Martínez-Dávila[1], Gustavo López-Romero[1], Iourii Nikolskii-Gavrilov[2], Juan Manuel Hernández-Pérez[1] & Alejandra Soto-Estrada[1]

[1] Colegio de Postgraduados, Campus Veracruz, México

[2] Colegio de Postgraduados, Campus Montecillo, México

Correspondence: Cesáreo Landeros-Sánchez, Colegio de Postgraduados Campus Veracruz, Km 88.5 Carretera Federal Xalapa-Veracruz, vía Paso de Ovejas, entre Puente Jula y Paso San Juan, Tepetates, Manlio F. Altamirano, Veracruz C.P. 91690, México. E-mail: clandero@colpos.mx

Received: July 12, 2015 Accepted: August 12, 2015 Online Published: September 15, 2015

doi:10.5539/jas.v7n10p140 URL: http://dx.doi.org/10.5539/jas.v7n10p140

Abstract

Climate change is one of the main threats to agriculture, including sugarcane agro-ecosystems, affecting the productivity of growers, and forcing them to implement adaptation measures. The study objective was to understand grower perceptions of climate change impact on sugarcane crop and the adaptation actions they are implementing in managing their crop in relation to socioeconomic and technological factors. This work was carried out in Irrigation Module II-1 Actopan, Veracruz, which serves part of sugarcane areas of the sugar factories La Gloria and El Modelo, Veracruz, Mexico. The Irrigation Module is located in the central region of the Gulf of Mexico. Information was attained by interviewing 90 sugarcane growers. Approximately 81% of growers had heard of climate change, 97% perceived changes in climate, 73.5% perceived changes in temperature, 87.8% perceived changes in precipitation, 49% in wind and 69% claimed damages to their agroecosystems from climate change. Using nonparametric statistics (Spearman ranks) ($p < 0.05$), there was a high perception by growers of climate change and sufficiently related to the adaptation actions they had implemented ($r_s = 0.3225$, $p = 0.0002$). Given that the socioeconomic level of a producer influences perception level ($r_s = 0.561195$, $p = 0.0000001$) and the development of actions for adapting to climate change ($r_s = 0.4436907$, $p = 0.000012$), the results for the technological level of the grower were not related to adaptation measures. The latter can be explained in terms of the non-availability of financial resources for sugarcane growers, which prevents them from buying, for instance, a modern irrigation system or new agricultural machinery and equipment.

Keywords: climate change impacts, adaptation actions, sugarcane growers and climate change, sugarcane agroecosystem

1. Introduction

Agroecosystem (AES) studies are based on the concept of applied agricultural systems, in their broadest expression. According to Hart (1979), agroecosystems are those that have at least one agricultural community, a biotic community, and a physical environment with which these communities interact, and which man regulates using a programmed interaction. Yet, Gliessman (2002) conceptualized agroecosystems as frameworks used to analyze agricultural production systems in their entirety, including the complex set of inputs and outputs, and interactions among its parts. Martínez et al. (2011), considering a conceptual model of farming at its minimum level of human cybernetic control, projected the optimal unit for the study of agriculture for its own transformation. The unit is integrated into a regional agricultural and rural system through production-consumption chains, with political and cultural interference from public and private institutions; the sugarcane agroecosystem as delimited in this study within the state of Veracruz.

Sugarcane agroecosystems in Mexico are one of the most important agricultural activities, due to their rural economic and social relevance, generating more than two million jobs directly and indirectly employing more than 12 million people (SE, 2012; Aguilar-Rivera, 2012). Production of this crop covers 664,000 hectares, producing 5 million tons of sugar worth nearly 27 billion pesos, thus contributing 11.6% to the primary sector GDP and 2.5% of GDP manufacturing nationwide. According to PRONAC (2009), the state of Veracruz produces the most with regard to harvested area, contributing 36% of total domestic production.

The adaptation is an important component of climate change impact and vulnerability assessment, and is one of the policy options in response to climate change impacts (Fankhauser, 1996; Smith & Lenhart, 1996; Smit et al., 1999). Also, agricultural systems in general are highly vulnerable to climate change (Parry & Carter, 1989; Reilly, 1995) and sugarcane agroecosystems are no different in suffering from the adverse effects of this phenomenon (Ojeda 2010; ISO, 2013). Kuhnel (1993), Deressa et al. (2005), Gawander (2007) and ISO (2013) indicate that sugarcane production is highly sensitive to effects from climate change, affecting productivity and crop yield, mainly due to variations in temperature and precipitation. In Veracruz, Mexico, Conde and Palma (2005) reported damage to thousands of hectares planted with sugarcane, mainly from extreme effects of climate change.

Such damages reflect adverse events that climate change is inducing on the management of sugarcane production. The Intergovernmental Panel on Climate Change (IPCC, 2007) and Altieri and Nicholls (2009) have suggested that prepared growers, and those moving to this end, can through a series of measures and actions implemented in their agroecosystems, reduce the effects of this phenomenon. Rodríguez (2007) and UE (2008) reported that among such measures are the adoption of new varieties or the combination of different crop types; adoption of technologies such as irrigation; adjusting planting and harvesting dates to changes in temperature and rainfall; and use of varieties that are better suited to new weather conditions (i.e. more resistant to heat and drought). Although relatively inexpensive changes, such as shifting planting dates or switching to an existing crop variety, may moderate negative impacts, the biggest benefits will likely result from more costly measures including the development of new crop varieties and expansion of irrigation (Rosenzweig & Parry, 1994). Fischer et al. (2002), IPCC (2007) and Sobrino (2008) suggested that grower adaptation to this phenomenon is related to socioeconomic and technological level, with those most vulnerable to climate change having the least access to resources. Therefore, Adger et al. (2007) indicated that the ability to adapt to climate change is uneven within and among societies. As well, human and social capital are known to be determinants of adaptive capacity at all levels, and are as important as income levels and technological capabilities.

Thus, Zaluaga et al. (2012) highlighted the importance of inquiring about the general perception that growers have of climate change and, therefore, the adaptations they have developed and implemented in their agroecosystems, since this depends on the adoption of technical recommendations that have been issued regarding this phenomenon in the central region of the Gulf of Mexico.

Thus, the present research was focused on understanding the perceptions of sugarcane growers to climate change and the adaptive measures implemented in managing their agroecosystems in relation to their socioeconomic conditions in the central zone of Veracruz state, which is located in the central Region of the Gulf of Mexico.

2. Materials and methods

This research was conducted within Irrigation Module II-1 Actopan, in the central zone of Veracruz state, located in the central region of the Gulf of Mexico and is part of Irrigation District 035, La Antigua, Veracruz, capturing surface waters from Rio Actopan. This Module covers the municipalities of Úrsulo Galván and Actopan (Figure 1).

Figure 1. Location of Irrigation Module II-1 Actopan and sugar factories La Gloria and El Modelo, Veracruz, Mexico

2.1 Sample Size

Irrigation Module II-1 Actopan, has 2 287 sugarcane growers, and this information was used to determine the sample size, using the stratified random sampling technique described by Schaeffer et al. (1987). To generate different socioeconomic strata, we used the variable size (ha) of grower areas (Table 1). The selection of sample size was made based on sample representativeness, as defined by financial viability. Ultimately, 90 interviews were selected as part of a Bmax (maximum error disposition) indicating that between a minimum of 40 and an optimum of 1000 (B) growers were needed (Figure 2).

Table 1. Categorization of sugarcane growers in Irrigation Module II-1, Actopan

Economic levels	Irrigation area	Number of growers	Standard deviation	Variance	wi*	Sample size by strata
Field workers (0-5 ha)	2.49869	1,780	1.347143	1.81480	0.34	30.8
Transitional (5-20 ha)	8.23499	471	2.92797	8.57301	0.43	38.5
Business owners (20-50 ha)	27.005	36	7.742141	59.94075	0.23	20.6
	4.065815†	2287‡	4.227643§	17.87297§§	1.00 ‡	90 ‡

Note. * $wi = \frac{N\left(\delta i^2\right)}{\sum Ni\delta i^2}$, where wi is the distribution weight of the total sample size per stratum; N is the number of growers for each stratum; and δi^2 is the standard deviation for each stratum.

†: Mean value; ‡: Total sums; §: Standard deviation; §§: Variance.

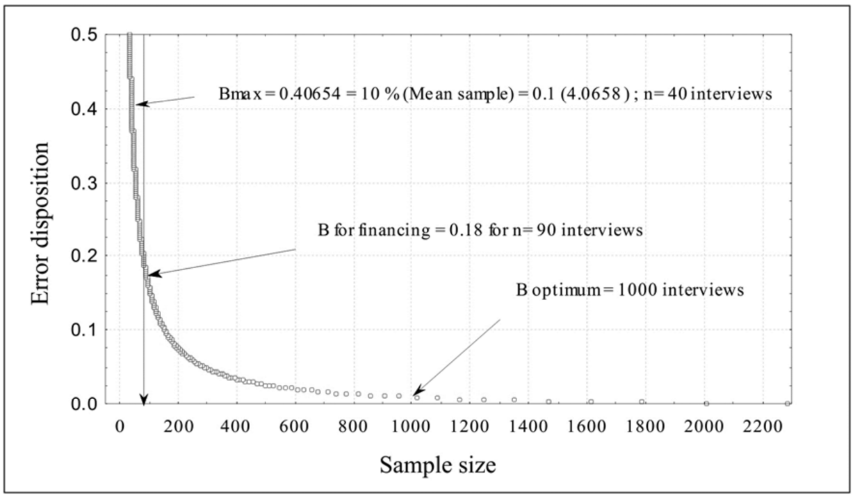

Figure 2. Sample size (n) selection following Scheaffer et al. (1987), with an error disposition of B = 0.18

2.2 Questionnaire

A survey was conducted and a questionnaire was distributed to collect information. The questionnaire was developed based on the variables in the objective and applied as an interview to growers who formed the selected sample size.

2.3 Analysis of Results

Data on the opinions and perceptions of growers were standardized, from which values and frequencies were used in the discrimination of socioeconomic and technological levels, perception and adaptation.

2.4 Principal Components

Principal Components Analysis (PCA) was used to synthesize information collected in the field, with the aim of reducing the number of explanatory variables to the fewest number possible. Major components, or factors, are linear combinations of the original variables and mutually independent. For perception indices, adaptation and socioeconomic and technological levels extracted from the principal components were used nonparametrically to obtain correlations with new factors contrasting with the objective.

3. Results and Discussion

Approximately 6.6% of the interviewed growers had no education level, 34.4% had incomplete primary education, 20% had completed primary school, 14.4% completed middle school, 10% completed high school, 3.3% had incomplete university education, and 11.1% had completed a bachelor's degree. The principal means of information transfer were radio and television, and to a lesser extent newspapers, magazines and internet. All growers had access to IMSS (Instituto Mexicano del Seguro Social) services and 10% attended private health consulting. Nearly 44.4% had large dwellings, 43.3% average sized, and 12.2% small. Approximately 62.2% had homes with tile floors, 36.6% with rustic cement floors, and 1.1% with soil-based floors. Nearly 70% of homes were based on concrete blocks, 24.4% on bricks, and the rest on other material. Approximately 84.4% of the roofs were concrete and the remainder of metal or other forms of lamina.

Nearly 45% of growers were devoted exclusively to the production of sugarcane, while the remaining 55% also had other agricultural activities such as corn, beans, mango, taro, papaya, banana and livestock production; 40% of growers were engaged in non-farm activities. Growers indicated that their average income per hectare of sugarcane was $17,000.00 pesos annually, and earnings varied depending on prices managed by the sugar industry, annual and input values with good rainfall or, at least, regular rainfall.

3.1 Principal Components of Socioeconomic Status

To create a general index of socioeconomic level for growers, an index of access to media and an abstract standard of living index were formed. The level of access to media was assessed as the amount growers have available to them and the importance they place on issues related to environmental degradation.

Later, through "loadings", each component and its correlation with levels of information was verified. Component 1 explained 66.68% of the variation for level of access to media, and was significantly and directly proportional to the variables surrounding media access (i.e. newspapers, magazines and internet). Component 2 linearly explained internet access; to newspapers the correlation was negative, while for access to journals there was no explanation. Therefore, component 1 explained most of the variability regarding an index of media access (Table 2).

Table 2. Principal components correlations for access to information and its variables

Variables	Component 1	Component 2
Newspapers	0.837476	-0.402640
Scientific journals	0.882238	-0.177570
Internet	0.721767	0.684238
% Variance explained	66.6886%	22.0611%

For standard of living (lifestyle), component 1 linearly explained better conditions in housing and characteristics that provide better access to health, such as floors and ceilings. Component 2 only explained health by taking into account the first component to represent a standard of living (Table 3).

Table 3. Principal components correlations for lifestyle and its variables

Variables	Component 1	Component 2
Life style	0.726196	-0.202380
Floor type	0.765580	-0.033699
Roof type	0.805935	-0.162510
Health service	0.322781	0.941009
% Variance explained	46.6798%	23.8500%

3.2 Socioeconomic Status

Component 1 was directly related with its variables, explaining 43.18% of the variability. Component 2 was inversely proportional to the level of education and access to media information, but was directly proportional to the standard of living and the surface area managed by growers (Table 4).

Table 4. Principal components correlations for socioeconomic status and its variables

Variables	Component 1	Component 2
Education level	0.807173	-0.339259
Ínformation access level index	0.780595	-0.373069
Lifestyle index	0.597984	0.507933
Grower area (ha)	0.329932	0.792044
% Variance explained	43.1824%	28.4902%

For the representativeness index, component 1 was considered as an index of socioeconomic level. As such, five distinct groups could be identified from the characteristics included in the socioeconomic classification of sugarcane growers (Figure 3).

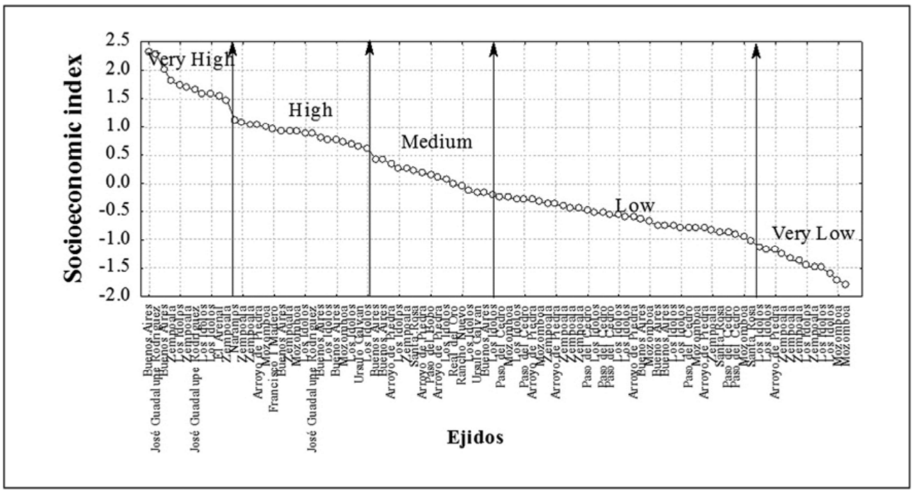

Figure 3. Index and socioeconomic classification (the name of the grower is substituted for the location)

In the discriminant analysis, the *ejidos* containing growers with higher socioeconomic status were José Guadalupe Rodríguez and El Arenal. *Ejidos* containing growers having low socioeconomic status were Zempoala, Los Ídolos, Arroyo de Piedra, Mozomboa, Paso del Bobo, Real del Oro, Rancho Nuevo and Paso del Cedro (Figure 4).

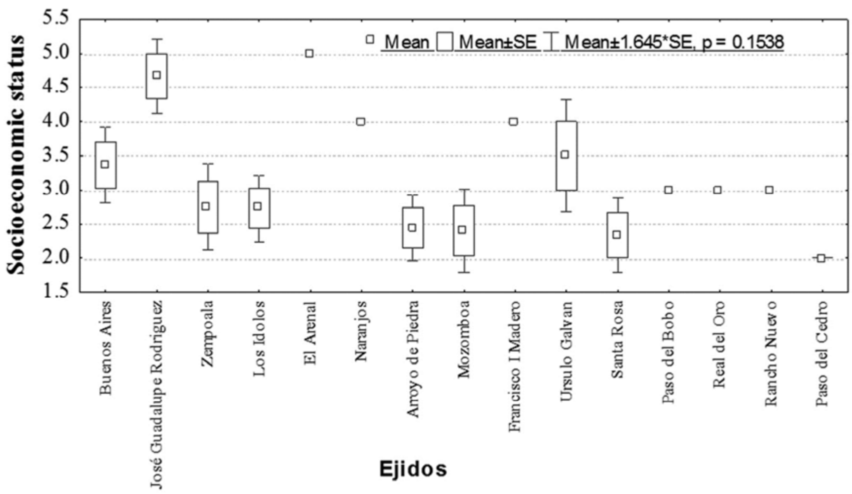

Figure 4. Socioeconomic levels by locality (SE: standard error)

3.3 Technological Aspects

Technological aspects were considered if growers were implementing (or not) agricultural practices shown in Figure 5, pertaining to a basic technology package for sugarcane agroecosystem management.

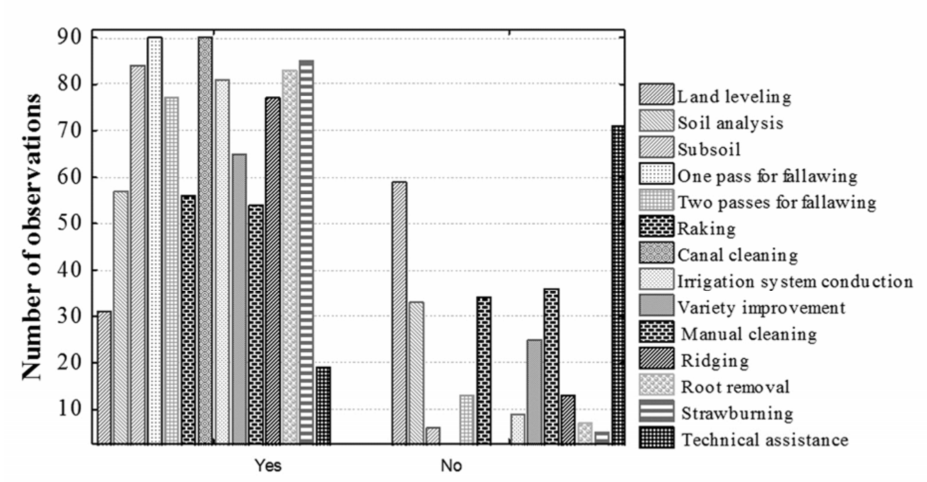

Figure 5. Technological practices in sugarcane production

Other practices that were evaluated for technological level were manual weed removal, trenching, leveling of inter-trench hillocks, herbicide application, pest and disease control, type of fertilizer (chemical/organic) and number of fertilizations. However, most of the technological variables showed insufficient statistical variance, and thus were not meaningful for integration into the components for the index of technological level. Thus, six variables were chosen for integration into the index (Table 5).

Table 5. Principal components correlations for technology level and its variables

Variables	Component 1	Component 2
Irrigation construction	0.728316	-0.525578
Furrowing	0.734896	-0.453789
Fertilization type (organic, chemical)	0.495557	0.703243
Frequency of fertilizer applications	0.441808	0.673189
Manual plant removal	0.313879	0.027284
Technical assistance	0.494097	0.125064
% Variance explained	30.8990%	24.1046%

The technological level components accounted for 30.89% of the explanatory power. According to component 1, the relationship between the index of technological level and the other variables was directly proportional. Component 2 did not provide a sufficient explanatory percentage to explain the technological variables (Table 5).

The final index allowed for the classification of 5 technological levels of growers. Those at a high level produced a greater proportion due to their technological practices (Figure 6). On average, there were no technological differences among *ejidos* or localities (Figure 7).

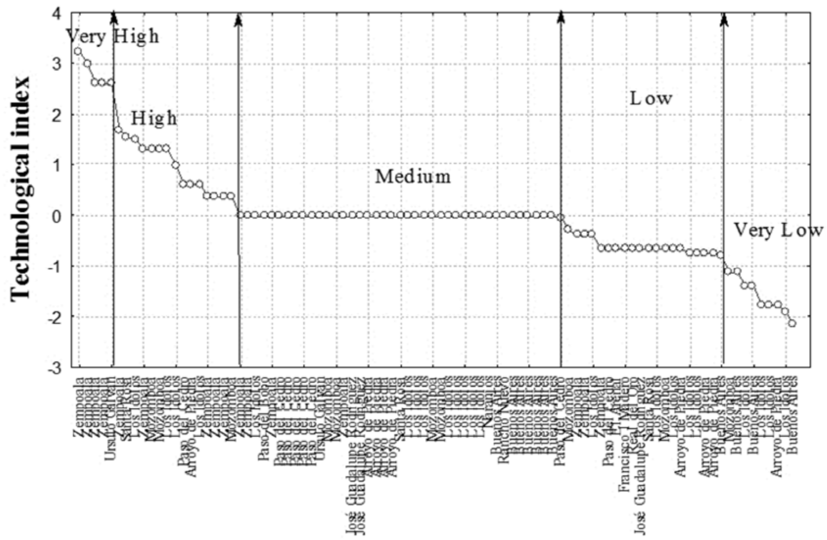

Figure 6. Index and classification of technological level (grower name is substituted with locality)

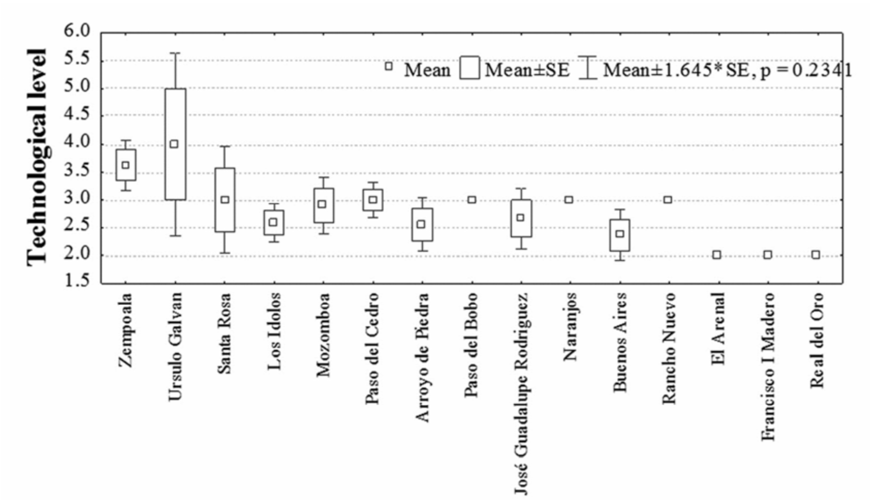

Figure 7. Technological level and location

3.4 Perceptions of Growers to Climate Change

Climate change for sugarcane growers in the region has not been an unnoticeable factor in their lives, as a significant number have indicated variations in temperature, rain and wind. As well, the perception of existing climate change differs over time, indicating that for growers climate has not been equal to earlier times, and a significant number admit to knowing of the phenomenon (Figure 8). The perceptions and knowledge that growers have of weather patterns in recent years are discussed below, and their prospects for future events.

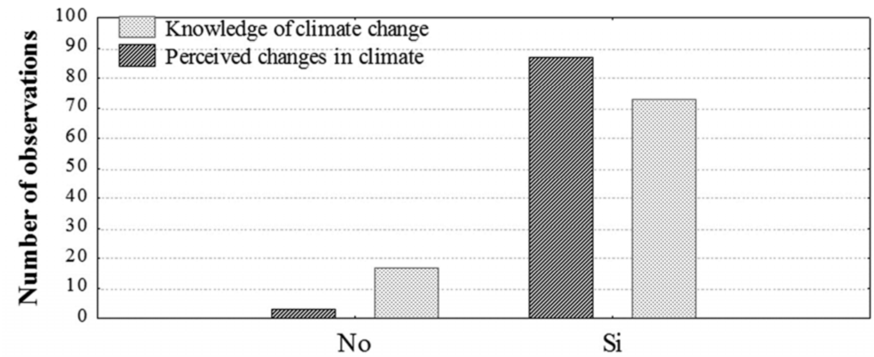

Figure 8. Grower responses to perception and knowledge of climate change

3.5 Perceptions of Temperature Changes

Certainly, for most growers, temperatures have increased in recent years. Nearly 73.4% perceived differences in temperature; most frequently mentioned is that it is recently warmer than in previous periods (Table 6).

Table 6. Perceptions of sugarcane growers on temperature changes

Temperature	**Frequency**	**%**
Now it is warmer	30	33.33
Now it is warmer and the temperatures are more extreme	7	7.78
Now it is warmer and it burns more	4	4.44
Now it is extremely hot	3	3.33
Now it is less hot tan before	2	2.22
Now the temperatures are extreme	2	2.22
Other perceptions (changes in temperature and evaporation, presence of droughts and reduction of yields)	18	20.01
Temperatures have not changed	24	26.67
Total	90	100

Other growers commented on wider perceptions, how they have seen the change in temperatures today. For example, "Now it's warmer; the weather has become more unstable and is hurting us; for example, before you could work longer in the field, from sunrise to sunset, but now the high temperatures no longer allow this."

"The weather has already changed very much from 20 years ago; for example, extreme temperatures now feel warmer and colder than before."

"Now it's warmer, the sun burns more than before, it burns more and causes more droughts."

"In the last seven years there has been more heat; we are not as strong as before with less heat, it is more intense and burns more than before."

Therefore, growers perceive that in recent years and decades, temperatures have changed enough to say that they are no longer equal to today. This is evidenced as an increase in temperature manifested by climate change.

Meanwhile, climate variability is leaving growers uncertain about the future. Approximately 27.8% have negative perceptions about temperature trends, which will continue to rise and be more extreme and hot, including increased deforestation. Approximately 16.65 % believe that temperatures will not change and 55.55% of growers did not respond.

3.6 Perceptions of Changes in Rainfall

As for precipitation, 87.78% of growers said that the rains have changed, relating most often to the erratic and decreased rainfall, affecting the provision of water for irrigation, which has been perceived differently by sugarcane growers (Table 7).

Table 7. Perceptions of sugarcane growers on changes in precipitation

Precipitation	Frequency	%
Now it rains less	18	20.00
Now it rains less and the rains are irregular	8	8.89
Now the rains are delayed	6	6.67
Now the rains are extreme	4	4.44
Now the rains are irregular and extreme	4	4.44
Now it rains less, rivers have less water	3	3.33
Now it rains less, water is scarce	2	2.22
Now the rains are delayed, water is less available	2	2.22
Now it rains less, there are more dry periods	2	2.22
Other perceptions (changes in temperature and evaporation, presence of droughts and reduction of yields)	30	33.37
The rains have not changed	11	12.22
Total	90	100

Among comments from growers there was: "Before, the normal rains were in May, and are now delayed until June; earlier rain-fed areas produced well and rains were not a problem, but now it rains more, and we have more than available water."

"Nearly 20 years ago, the rains were on time and frequent; in rain-fed areas corn could be planted because it was raining on time; now it cannot produce well."

Comments were very common on gaps in dates for rain, mainly about delays, which reduced the production of sugarcane.

Regarding extraordinary rainfall, "Now it rains soon, before it rains in a year", indicating that the rainy season has been shortened, but the rains have intensified. Therefore, growers commented that the current rains have generated more negative impacts on their lives, causing occasional flooding of their crops.

Thus, rainfall has changed much as perceived by growers and these changes are more significant than temperature and wind, providing the greatest impact on crops and daily lives.

For future precipitation, 29% said that there will be low rainfall and water, as will most extraordinary rain events; those with positive attitudes commented: "if it is reforested, we will improve the situation and it will rain better." Almost 10% felt that the rains would continue as present and 61% did not respond.

3.7 Perceptions of Changes in Wind

Wind is a climatic element that can lead to the loss of productive yield of sugarcane, but has been difficult to describe and differentiate regarding changes. However, for at least 48.89% of growers, winds have changed in frequency and intensity, becoming sufficiently violent in recent years to affect production (Table 8).

Table 8. Perceptions of sugarcane growers on changes in wind

Winds	Frequency	%
Now the winds are stronger	13	14.44
Now the winds are more frequent	8	8.89
Now the winds are less frequent	3	3.33
This year the winds were more frequent	2	2.22
Now the winds are more intense	2	2.22
Now the winds are more violent	2	2.22
Other perceptions (changes in temperature and evaporation, presence of droughts and reduction of yields)	14	15.57
The winds have not changed	46	51.11
Total	90	100

In addition, they mentioned that there are now winds previously unexperienced and with stronger intensities. As well, winds today are more extreme and the north-winds are more constant, resulting in a flattening of the sugarcane stalks. According to growers, winds have not changed as much compared to temperatures and rainfall.

In the future, 14.4% of growers expect winds to continue behaving as they are currently, 10% considered them to be more intense, strong and violent, while the remainder did not respond.

3.8 Repercussions of Climate Change on Sugarcane AES

According to growers, it is important to understand the negative impacts that climate change has generated on production (Table 9).

Table 9. Climate change effects on sugarcane agroecosystems

Effects on sugarcane AES	Frequency	%
Winds cause the sugarcane to fall, reducing production	5	5.56
Scarce rains reduce the availability of water for irrigation	5	5.56
Cyclones reduce sugarcane production	4	4.44
Scarce rains delay the production process	4	4.44
Temperate zone sugarcane production is more affected by scarce rains	3	3.33
Scarce rains and water reduce sugarcane production	5	5.56
Other perceptions (changes in temperature and evaporation, presence of droughts and reduction of yields)	36	40.01
Climate change has benefited sugarcane production	1	1.11
Do not know how climate change has affected sugarcane production	9	10.00
Climate change has not affected sugarcane production	18	20.00
Total	90	100

Some growers further described the impacts that climate change has on sugarcane production: "Now the heat dehydrates the sugarcane and evaporates the water for the crop, so there will need to be more irrigation, and this may not be enough. Also, the strong winds break the sugarcane stalks which reduce crop performance, just as with high temperatures and water scarcity, which increases pest abundance and distribution, such as spotted spittlebug (*Aeneolamia* spp.) and screw-worms."

Growers also have realized that pests and diseases have been more noticeable in recent years, mostly during years having lower rainfall and higher temperatures. This impacts the provision of water for irrigation, which directly affects crop production and yield.

Another problem which growers face is that some have land where there is no irrigation service. Thus, rain-fed areas have been most affected by erratic rainfall, because they depend directly on rainfall which has been very unstable, or at a deficit, in recent years. Also, they have faced extreme events such as hurricanes, a situation that is stressful, especially in rain-fed areas. Magaña (2006) mentioned that the lack of irrigation in much of Mexico has made agriculture in rain-fed areas even more vulnerable to water deficits. However, irrigated areas of the country are often faced with shortages and uncertainty about water availability and increased competition from non-agricultural water users. Growers repeatedly emphasized that rainwater and irrigation have declined in recent years, representing a major threat to sugarcane agroecosystems.

Therefore, sugarcane agroecosystems are being affected by changes in temperature and wind, but mainly by shortages and delays in rainfall, coupled with the presence of heavy rains.

3.9 Grower Concerns about Climate Change

Most growers were aware of climate variability and the impacts it has generated on sugarcane production. Thus, climate change at present leaves some uncertainty for the future, leaving many producers concerned (Table 10).

Table 10. Grower concerns regarding climate change

Concerns about climate change	**Frequency**	**%**
Concerned about wáter scarcity	5	5.56
Concerned about the scarcity of rain	3	3.33
Concerned about increased diseases	3	3.33
Increased temperatura from deteriorating ozone layer	2	2.22
Concerned about high temperatures	2	2.22
Concerned about periods of extreme climate	2	2.22
Melting polar icecaps	2	2.22
Rise in sealevels	2	2.22
Concerned about the rise in sea-level	2	2.22
Other concerns	35	38.9
Not worried	24	26.67
Do not know	8	8.89
Total	90	100

Water shortages related to deforestation were widely discussed by growers and considered it their greatest concern. Another concern for growers was that there was little information for communities to use when addressing environmental issues and to reduce pollution, reaffirming that there is insufficient information for effective initiatives to address the issue of climate change.

In addition, growers were concerned about the frequent occurrence of hurricanes impacting the region, reducing crop production and impacting the stability of their lives.

According to Ojeda-Bustamante et al. (2012), the real concern is that climate change will add more stress to agricultural production systems, so that crop productivity would decrease to critical levels, testing the sustainability of agriculture in several regions.

3.10 Grower Awareness of Climate Change

Although growers were concerned about climate change, the available knowledge and their awareness makes it possible for them to speculate about possible causes of this phenomenon (Table 11).

Table 11. Causes of climate change from the perception of growers

Causes of climate change	Frequency	%
Contamination	6	6.67
Deforestation and contamination	5	5.56
Deforestation and industry	3	3.33
Industry	2	2.22
Industry and burning of sugarcane	2	2.22
Little conscience and contamination	2	2.22
Other	34	37.78
Do not know	25	27.78
Deforestation	11	12.22
Total	90	100

Most growers mentioned concerns about pollution from industrial activities as the main cause of climate change, and also referred to deforestation as a vital part in the problem of global warming. Still others felt that more natural causes were responsible for climate change, mainly by changes in solar activity.

Some sugarcane growers were aware of the problems and said part of the changes were due to agricultural practices that took place while managing their agroecosystems. For example, some commented: "How are we not going to contribute to climate change with the great amount of pollution we generate during harvesting, when we burn thousands of hectares of sugarcane; as well, many chemicals are used during production (of course we are altering the climate, the problem is we cannot do anything, it is the only way to harvest sugarcane)."

Other growers generally considered the lack of education and culture as root problems causing climate change. Some erroneously attributed global warming as the cause of holes in the ozone layer, which in reality are brought about by the use of aerosols and other chemicals. According to Oltra et al. (2009), confusion with the phenomenon of the destruction of the ozone layer is common in different groups of growers, because it usually occurs in individuals with low levels of education and even in growers with sufficient education.

3.11 Principal Components of Perception

The perception index was developed based on grower perception variables; how they perceived climate change before as compared to today, what was their outlook on the future, what were their concerns about climate change and their awareness of the causes of this phenomenon.

Component 1 linearly explained 55.55% of the variability related to grower perceptions of climate changes seen earlier, at present, and for the future, knowledge of impacts from climate change on their AES, their concerns about this phenomenon and knowledge of its causes. Component 2 did not explain previous perception or that presently existing, but instead best explained perspectives on future climate, with positive perceptions of growers about the impacts of climate change on their AES. Component 2 also explained grower concerns about this phenomenon and knowledge of its causes (Table 12).

Table 12. Correlations among perception indices and principal components

Variable	Component 1	Component 2
Index (Previous perception)	0.843489	-0.175555
Index (Current perception)	0.829549	0.022908
Index (Future perception)	0.695851	-0.452098
Index (Other perceptions)	0.581646	0.762781
% Variance explained	55.5537%	20.4393%

Component 1 represents an index of perception (categorized into five groups); the perception level that growers possessed according to their respective *ejido* or locality. Growers located at a high level in the graph expressed a better perspective on observed changes in temperature, precipitation and wind, plus they had better awareness of issues related to this phenomenon (Figure 9).

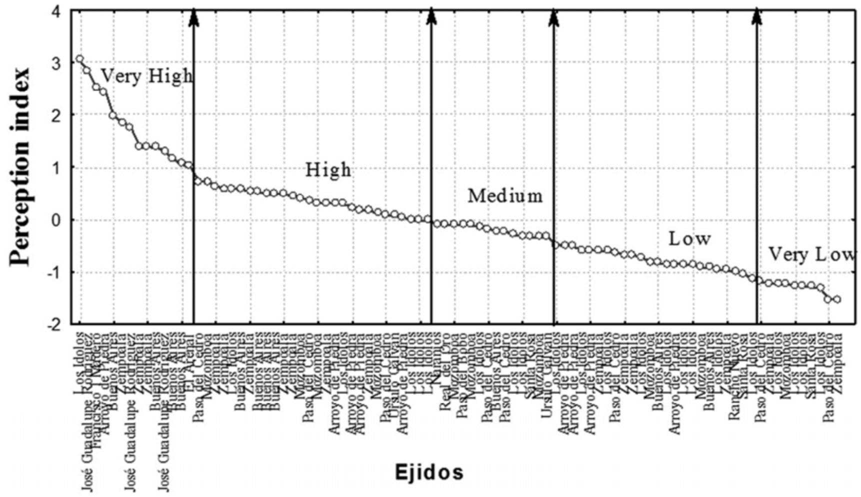

Figure 9. Perception level classification index

Here, the growers having better insight and knowledge about climate change were from the *ejidos* José Guadalupe Rodríguez, Francisco y Madero, and El Arenal. Growers in Arroyo de Piedra, Buenos Aires, Zempoala, Paso del Cedro, Mozomboa and Úrsulo Galván had an intermediate level in terms of their perceptions, while growers in Ídolos, Santa Rosa and Rancho Nuevo were not as aware of issues regarding climate change (Figure 10).

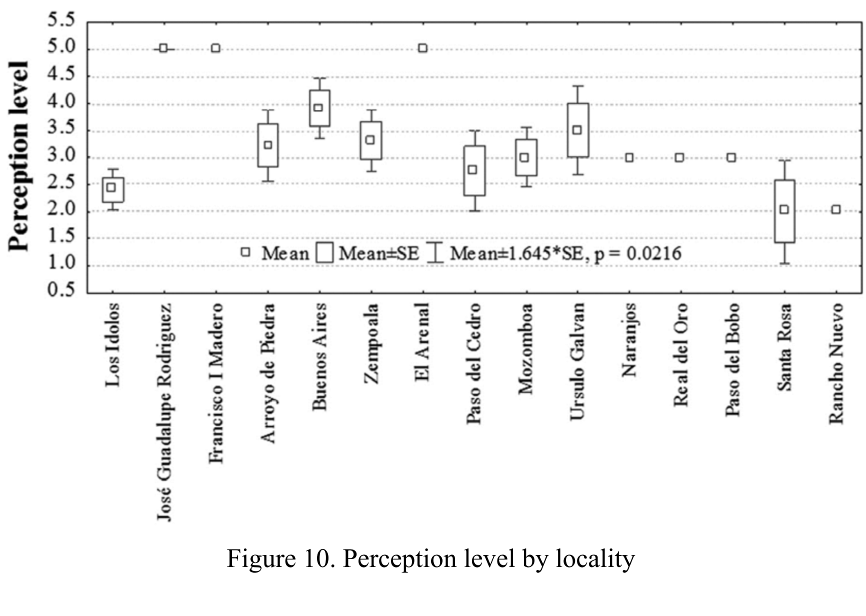

Figure 10. Perception level by locality

3.12 Adaptation Measures of Sugarcane Growers

Altieri & Nicholls (2009) and IPCC (2007) suggested that many growers adapt to climate change through a series of actions and techniques implemented in the management of their crops.

In the Central Gulf region of Veracruz, 67.78% of growers were not conducting any form of adaptive activities. However, 32.2% were taking some adaptive action regarding climate change (Table 13).

Table 13. Adaptive measures that growers implement in managing their AES

Adaptive methods used in managing sugarcane AES	**Frequency**	**%**
Apply risk assessment before constructing an irrigation system	4	4.44
Wait for seasonal rains for production	2	2.22
Use seasonal rains for irrigation	2	2.22
In more seasonal zones, use spray irrigation	2	2.22
Do nothing but accept the dry periods	1	1.11
In seasonal zones, adapt to the times of rain	1	1.11
Do not plant before, but after it begins to rain	1	1.11
Use pumps to access irrigation water	1	1.11
Technical improvement with spray irrigation (irrigation cannon)	1	1.11
Modify planting dates to periods of greater water availability	1	1.11
Increase chemical pesticide use to combat pests favored by climate change	1	1.11
Change planting dates to August and September	1	1.11
Construct a well when water is scarce to store water for irrigation	1	1.11
Use an irrigation pump to store water in the fields	1	1.11
Use an irrigation pump to store water in the fields and think about taking other actions	1	1.11
During periods of scarce rain in seasonal zones, join with other growers for a low pressure system	1	1.11
Use an irrigation pump to store water in the fields, modify planting dates	1	1.11
Sell land in seasonal zones as it is not viable, and buy land in irrigation zones	1	1.11
Use a 2-inch sprayer for irrigation, and explore for well-water	1	1.11
Nothing	**61**	**67.78**
For sugarcane do nothing, as in other AES	4	4.44
Total	90	100

Relatively few growers were performing adaptive actions in response to climate change, even though they themselves had witnessed significant changes in climate and were suffering their affects. Adger et al. (2007) mention that adaptive actions that have taken place in agriculture have been scarce or limited, although there is awareness of the problems caused by climate change.

On the other hand, most of the adaptations that growers are making relate better to the use of water by using automated irrigation systems. Rodríguez (2007) mentioned that adaptation to climate change in agriculture essentially means being able to adapt at different points in time to the excess or lack of water.

In Australia, for example, there has been research on the development of strategic options to help sugarcane growers adapt to climate change. These include the use of new varieties of sugarcane, different landscape arrangements, different tillage practices, choice of equipment and technology for irrigation, and use of fertilizers and herbicides (ISO, 2013).

In Guatemala, the Instituto de Investigación sobre Cambio Climático (Research Institute on Climate Change) has created an early warning system for floods to prepare growers. They also have a management program for groundwater and aquifer retention. In addition, there is work on minimizing environmental impact from burning sugarcane (ISO, 2013). An important aspect mentioned previously, is the impact that sugarcane management practices have generated on the environment through gases emitted during burning of the harvest, which is important when considering all actions engendered to counter climate change.

Growers mentioned that not only has sugarcane production suffered, other agricultural production systems have been affected and even appear to be more vulnerable to gradual climate changes and its impacts, so they have been taking some adaptation actions (Table 14).

Table 14. Measures of adaptation in other ecosystems

Adaptive actions in other agroecosystems	Frequency
For rice, change the planting date from May to July	1
For bananas, irrigate manually with containers	1
For papaya, provide manual watering using containers, and support this effort with pumped water	1
Have cattle use grasses more resistant to dry periods	1
Construct a well for cattle for periods of scarce water	1
Change papaya planting dates and reduce cattle production in temperate zones	1
Abandon corn production due to insufficient water	1

Adaptation actions appear to be serving agriculture in unexpected ways. Rodríguez (2007) cited a recent World Bank study on climate change and rural poverty where the results differentiated impacts causing climate change among small and large growers. Both have weather sensitivities in their agroecosystems, but which outweigh the negative effects on the incomes of small-scale growers, a situation evident in the results of the present study.

3.13 Principal Components of Adaption Level

The variables included in the adaptation level component were adaptations in AES and in other agroecosystems. Therefore Component 1 explained 70.64% of the variation (Table 15).

Table 15. Correlations among indices of adaptation and principal components

Variable	Component 1
Adaptations in sugarcane AES	0.840535
Adaptations in other AES	0.840535
% Variance explained	70.6499%

Three categories of grower capacity to perform actions to mitigate the effects from climate change were classified as those taking more specialized action and modernization of irrigation, those whose actions were less specialized regarding precipitation dates, and growers who simply could not make changes (Figure 11).

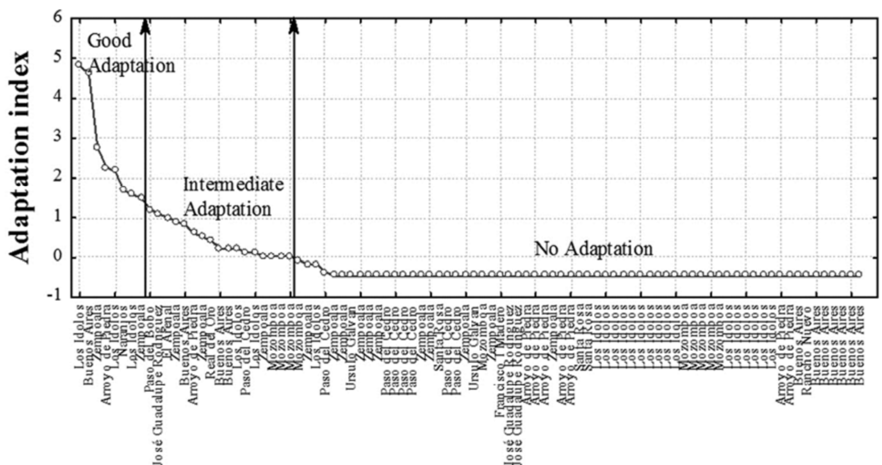

Figure 11. Classification and index of adaptation level by location

Therefore, those who have taken the greatest actions against climate change are growers in the *ejido* Naranjos. Among those making fewer changes were Santa Rosa, Francisco I, Madero and Rancho Nuevo. Growers from *ejidos* who have taken the least action were Úrsulo Galván and José Guadalupe Rodríguez (Figure 12).

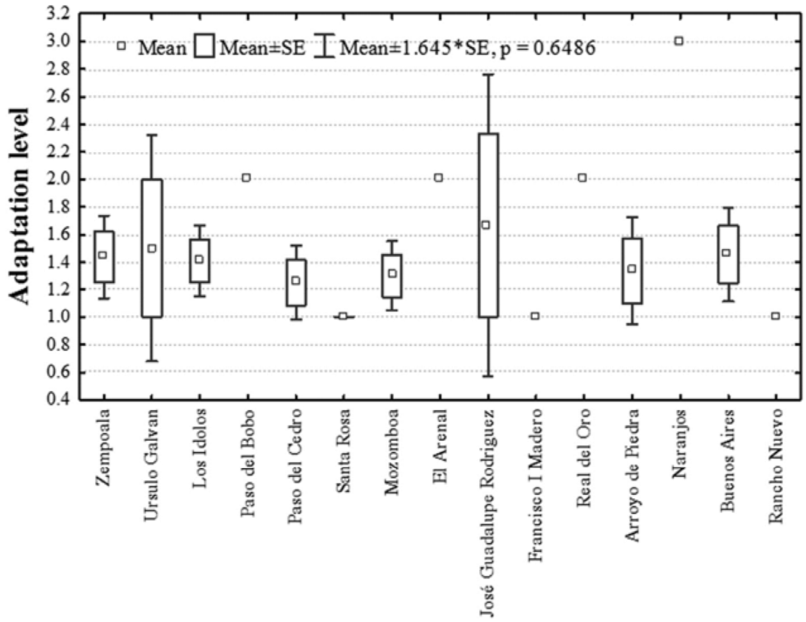

Figure 12. Adaptation level by location

Finally, through non-parametric statistics, a significant ($p < 0.05$) effect was found showing that producer perception of climate change was related to adaptation actions recently taken ($r_s = 0.322470$, $p = 0.0001937$). As well, grower socioeconomic level influenced their level of perception ($r_s = 0.561195$, $p = 0.00000001$), and in the development of actions to adapt to climate change ($r_s = 0.4436907$, $p = 0.000012$). In the present research, the technological level of growers was not related to adaptive actions.

4. Discussion

Sugarcane growers have perceived climate change through progressive changes in temperature, precipitation and wind, changes which have directly and indirectly affected the management of sugarcane production. However, despite the effects climate change has caused on agroecosystems, adaptive measures by growers are still scarce. Certainly, growers who have taken action to help mitigate the impacts from climate change are those with better economic standing that is reflected in their quality of life.

In addition to influencing adaptive actions, socioeconomic status affected grower perceptions, where those with higher socioeconomic status had better knowledge and perspectives on climate change. At the same time, grower perspective influenced the implementation of actions to help mitigate the effects from climate change. Technological factors were not issues, because the technologies implemented by growers in their AES were focused on addressing problems other than climate change.

Finally, the cognitive aspect of grower consciousness in recognizing and interpreting the significance of what is happening to the environment significantly influences the process of making judgments about the phenomenon under study, as with the adaptive processes in the AES being studied with regard to the effects from climate change.

Therefore, changes and modifications made by growers to adapt to the increasingly negative influences from climate change need an education program, knowledge of the most suitable adaptation measures and financial resources to convert perceptions of influence into AES management actions to mitigate climate change.

Acknowledgements

To CONACyT for the grant awarded to carry out my Master of Science Program and to Colegio de Postgraduados (LPI-8 Impacto y Mitigación del Cambio Climático) for financial support.

References

Adger, W. N., Agrawala, S., Mirza, M. M. Q., Conde, C., O’Brien, K., Pulhin, J., ... Takahashi, K. (2007).

Assessment of adaptation practices, options, constraints and capacity. In M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden & C. E. Hanson (Eds.), *Climate Change 2007: Impacts, Adaptation and Vulnerability* (pp. 717-743). Contribution from Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK.

Aguilar-Rivera, N., Rodríguez, L, D. A., Enríquez, R. V., Castillo, M. A., & Herrera, S. A. (2012). The Mexican Sugarcane Industry: Overview, Constraints, Current Status and Long-Term Trends. *Sugar Tech., 14*(3), 207-222. http://dx.doi.org/10.1007/s12355-012-0151-3

Altieri, M., & Nicholls, C. (2009). Cambio climático y agricultura campesina: impactos y respuestas adaptativas. *Revista de Agroecología LEISA, 24*(4), 5-8.

Conde, Á. C., & Palma, G. B. (2006). Escenarios de riesgo para el territorio Veracruzano ante un posible cambio climático (pp. 285-299). Tejeda Martínez Adalberto y Welsh Rodríguez Carlos, 2006. Inundaciones 2005 en el Estado de Veracruz. *Edición preliminary* (p. 432). Universidad Veracruzana y Consejo Veracruzano de Ciencia y Tecnología. Xalapa, Veracruz, Mexice.

Deressa, T., Hassan, R., & Poonyth, D. (2005). La medición del impacto del cambio climático en la agricultura en África del Sur: el caso de las regiones de cultivo de caña de azúcar. *Revista Agrekon, 44*, 524-539. http://dx.doi.org/10.1080/03031853.2005.9523726

Fankhauser, S. (1996). The potential costs of climate change adaptation. In J. B. Smith, N. Bhatti, G. Menzhulin, R. Bennioff, M. Budyko, M. Campos, B. Jallow & F. Rijsberman (Eds.), *Adapting to Climate Change: An International Perspective* (pp. 80-96). Springer, New York. http://dx.doi.org/10.1007/978-1-4613-8471-7_8

Fischer, G., Shah, M., & Velthuizen, H. (2002). *Climate Change and Agricultural Vulnerability* (No. 1113, p 117). International Institute for Applied Systems Analysis, United Nations Institutional Contract Agreement, Johannesburg.

Gawander J. (2007). Consecuencias del cambio climático sobre los cultivos de caña de azúcar en el Fiji. *Boletín de la Organización Meteorológica Mundial (OMM), 56*, 34-39.

Gliessman, S. (2002). Agroecología. *Procesos Ecológicos en Agricultura Sostenible* (p. 328). Turrialba, Costa Rica.

Hart, R. (1979). *Conceptos Básicos Sobre Agroecosistemas* (p. 159). Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), Turrialba, Costa Rica.

IPCC (Intergovernmental Panel on Climate Change). (2007). *Cambio climatic* (p. 73). Informe de síntesis. Contribución de los Grupos de Trabajo I, II y III al Cuarto Informe de evaluación del Grupo Intergubernamental de Expertos sobre el Cambio Climático. Geneva, Switzerland.

ISO (International Sugar Organization). (2013). *Cambio climático y cultivos azucareros* (MECAS 07, p. 30). Comité de Evaluación del Mercado, Consumo y Estadística, Organización Internacional del Azúcar.

Kuhnel, I. (1993). Impactos de las condiciones climáticas extremas en la producción de caña de azúcar en el noreste de Australia. *Extreme Hydrological Events: Precipitation, Floods and Droughts* (Vol. 213, pp. 157-163). The International Association of Hydrological Sciences (IAHS) Publ.

Magaña, R. V. (2006). Cambio climático global. Qué significa? In S. J. Urbina & F. J. Martínez (Eds.), *Más Allá del Cambio Climático* (pp. 79-94). Secretaria de Medio Ambiente y Recursos Naturales, Instituto Nacional de Ecología, Universidad Nacional Autónoma de México.

Martínez, D. J. P., Gallardo, L. F., Bustillo, G. L. F., & Pérez, V. A. (2011). El agroecosistema, unidad de estudio y transformación de la diversidad agrícola. *Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (Conabio)* (pp. 453-461). La Biodiversidad en Veracruz: Estudio de Estado. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Gobierno del Estado de Veracruz, Universidad Veracruzana, Instituto de Ecología, México.

Ojeda, B. W. (2010). *El papel del agrónomo ante el mito y realidad del cambio climatic* (pp. 1-17). Segundo Congreso Nacional de Egresados de Chapingo, Coordinación de Tecnología de Riego y Drenaje, Instituto Mexicano de Tecnología del Agua (IMTA), México.

Ojeda-Bustamante, W., Sifuentes-Ibarra, E., Rojano-Aguilar, A., & Iñiguez-Covarrubias, M. (2012). Adaptación de la agricultura de riego ante el cambio climático. *Adaptación al cambio climático: efectos del cambio climático en los recursos hídricos de México* (pp. 71-119). Volumen IV/editado por Polioptro F. Martínez Austria y Carlos Patiño. Gómez. Instituto Mexicano de Tecnología del Agua. Jiutepec, Morelos, México.

Oltra, C., Solá, R., Sala, R., Prades, A., & Ganemero, N. (2009). Cambio climático. Percepciones y discursos públicos. *Prismasocial Revista de Ciencias Sociales 2* (pp. 1-23).

Parry, M. L., & Carter, T. R. (1989). An assessment of the effects of climatic change on agriculture. *Climatic Change, 15*, 95-116. http://dx.doi.org/10.1007/BF00138848

PRONAC (Programa Nacional de la Agroindustria de la Caña de Azúcar). (2009). *Estudio de gran visión para la identificación de necesidades de riego y drenaje en las zonas de abasto cañeras y propuestas de tecnificación en zonas potenciales como base para el desarrollo de proyectos de inversion* (p. 79). Secretaria de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (SAGARPA), México.

Reilly, J. (1995). Climate change and global agriculture: Recent findings and issues. *American Journal of Agricultural Economics, 77*, 727-733. http://dx.doi.org/10.2307/1243242

Rodríguez, V. A. (2007). Cambio climático, agua y agricultura. Dirección de Desarrollo Sostenible–IICA. *Revista COMUNIICA 1* (pp. 13-23).

Rosenzweig, C., & Parry, M. L. (1994). Potential impact of climate change on world food supply. *Nature, 367*(6459), 133-138. http://dx.doi.org/10.1038/367133a0

Scheaffer, R. L., Mendenhall, W., & Ott, L. (1987). *Elementos de Muestreo* (3rd ed., p. 321). Iberoamericana, Distrito Federal, México.

SE (Secretaría de Economía). (2012). *Análisis de la Situación Económica, Tecnológica y de Política Comercial del Sector Edulcorantes en México* (p. 94). Dirección General de Industrias Básicas, Secretaría de Economía, México.

Smit, B., Burton, I., Klein, R. J. T., & Street, R. (1999). The science of adaptation: A framework for assessment. *Mitigation & Adaptation Strategies for Global Change, 4*, 199-213. http://dx.doi.org/10.1023/A:1009652531101

Smith, J. B., & Lenhart, S. S. (1996). Climate change adaptation policy options. *Climate Research, 6*, 193-201. http://dx.doi.org/10.3354/cr006193

Sobrino, H. J. M. (2008). Desarrollo Sostenible, Calentamiento Global y Recursos Vitales Para la Humanidad. *Anuario da Facultade de Dereito da Universidade da Coruña (AFDUC), 12*, 883-904.

UE (Unión Europea). (2008). La agricultura en la UE – Aceptar el Reto del Cambio Climático. *Comisión Europea* (p. 15). Dirección General de Agricultura y Desarrollo Rural. Retrieved from http://ec.europa.eu/agriculture/index_es.htm

Zaluaga, S. G., Ruiz, A. A., & Martínez, C. E. (2012). *Percepciones sobre el Cambio Climático y Estrategias Adaptativas de Agricultores Agroecológicos del Municipio de Marinilla, Colombia* (p. 21). Sociedad Científica Latinoamericana de Agroecología (SOCLA), Universidad Nacional de Colombia.

Copyrights