Sociedad y Ambiente

Less Rain and More Heat":
Smallholders' Perception and Climate Change Adaptation Strategies in Tropical Environments

"Menos lluvia y más calor":
Percepción y estrategias de adaptación de pequeños productores hacia el cambio climático en ambientes tropicales

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Abstract

The main objective of this study was to analyze local perceptions of climate variability and the different adaptation strategies of four communities in the southern Yucatán Peninsula, using the Social-Ecological System (SES) approach. Four SESs were considered: two in the coastal zone and two in the tropical forest zone. Data were collected using different qualitative methodological tools (interviews, participant observation, and focal groups) and the information collected from each site was triangulated. In all four sites, changes in climate variability were perceived as "less rain and more heat". In the tropical forest (or Maya) zone, an ancestral indigenous weather forecasting system, known as "*Xook k'íin*" (or "las cabañuelas"), was recorded and the main activity affected by climate variability was found to be slash-and burn farming or the milpa. In the coastal zone, the main activities affected are fishing and tourism. In all the cases analyzed, local climate change adaptation strategies include undertaking alternative work, and changing the calendar of daily, seasonal and annual labor and seasonal migration. The population of all four SESs displayed concern and uncertainty as regards dealing with these changes and possible changes in the future.

Keywords: adaptive strategies; climate change; environmental perception; marginalized communities; Social-Ecological System;

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Resumen

El objetivo principal de esta investigación fue analizar la percepción local de la variabilidad climática y las diferentes estrategias de adaptación en cuatro comunidades del sur de la península de Yucatán, utilizando el enfoque del Sistema Social Ecológico (SSE). Se analizaron cuatro SSE: dos en la zona costera y dos en la zona de selva (zona Maya). Los datos fueron colectados utilizando diferentes herramientas de metodologías cualitativas (entrevistas, observación participante, grupos focales) y la triangulación de datos para cada uno de los sitios del estudio. En los cuatro sitios se percibieron cambios en la variabilidad climática descritos como "menos lluvia y más calor". En la zona de selva se registró un sistema ancestral utilizado en la predicción del clima conocido como "*Xook kíin*" (o las "cabañuelas") y la principal actividad afectada por la variabilidad climática es la producción de roza-tumba-quema o milpa. En la zona costera, las principales actividades afectadas son la pesca y el turismo. En los casos analizados, las estrategias de adaptación locales hacia los efectos de la variabilidad climática incluyen la realización de otros trabajos remunerados, cambios en el calendario agrícola, la migración estacional, entre otros. En los cuatro SSE se expresó preocupación e incertidumbre para enfrentar estos cambios y los posibles cambios a futuro.

Palabras clave: comunidades marginadas; estrategias de adaptación; percepción ambiental; Sistema Social Ecológico; variabilidad climática;

Introduction

A great deal of uncertainty exists regarding how climate change and variability may impact the rural sector at global level, particularly how rural and indigenous producers (farmers and fishermen) will be able to respond to those changes. In the recent literature on climate change, local inequality, vulnerability and poverty have become the main concerns of the scientific community because they influence adaptation processes in local rural communities, in addition to the implementation of public policies targeting adaptation (Sánchez-Cortés and Chavero, 2011; Mosberg and Eriksen, 2015; Burnham *et al.*, 2016). The climate change policy of Mexico endorses that of the United Nations and related international agreements (DOF, 2015). It includes the creation and updating of both the General Law on Climate Change (Spanish acronym LGCC) and similar laws at state and provincial levels. A National Climate Change Strategy has also been published (ENCC, 2013), which states that, in devising transversal and inclusive policy strategies, gender as well as ethnicity, disability, health condition and inequality of access to public services must be considered (ENCC, 2013: p. 27). Finally, a more strategic document on climate change, the Special Climate Change Program (Spanish acronym PECC; SEMARNAT, 2015), is also in place.

Climate variability comprises the fluctuations that occur in the climate system, whereas climate change constitutes statistically significant variations in the mean state of the climate or its variability (long term variations). Despite this difference, since global climate change is also the cause of changes in climate variability, it is impossible to treat the two concepts separately (Hageback *et al.*, 2005). In Latin America, wide variation has been forecasted for temperature and precipitation ranges (IPCC, 2007; Altieri and Koohafkan, 2008; Orellana *et al.*, 2009). The Peninsula of Yucatán is located in the transition zone between dry and humid climates, making it subject to a clash of meteorological phenomena (such as tropical waves, hurricanes and the passage of cold weather fronts), which can intensify in frequency and magnitude as a result of ocean surface warming (Orellana *et al.*, 2009; Carrillo, 2013).

Climate patterns are important for rural productive activities in the Yucatán Peninsula since they can negatively or positively influence the livelihoods of the population (Berkes and Jolly, 2001; Sandoval *et al.*, 2004). Accordingly, the study of local perception of climate variability and the analysis of adaptation responses are increasingly important, especially given the existing prognoses indicating drastic climate change trends. There is therefore a need to conduct research into how producers could respond to these changes. Primary sector activities, such as agriculture and fisheries, are considered extremely vulnerable in less industrialized countries since they are doubly exposed; first, to the major social and economic changes that form part of economic globalization and second, through their inherently high sensitivity to climate variation (O'Brien and Leichenko, 2000). Perception of climate variability is complex, and involves the opinions, beliefs, values and rules people have regarding climate change, which determine the orientation of their actions, in other words, whether they are positive or negative as regards adaptation. The purpose of this research is therefore to analyze smallholders' perception of climate variability and the different local adaptation strategies of four SESs in the southern Yucatán Peninsula, and to show that when certain natural features differ from the norm, they are objective determinants of human behavior and have a proven importance in terms of controlling and shaping local social reality.

Approach

In epistemological terms, this study used various qualitative methodological tools to create new knowledge. To this end, the Social-Ecological System (SES) approach (Berkes and Folke, 1998) was chosen to elucidate the two-way relationships that exist between human (societal, economic) and natural (ecosystem) systems. The links or interactions among SES subsystems can take place through ecosystem dynamics such as climate variability, seasonal changes and transformations that produce effects on social systems. In response to these interactions, the systems continually readjust and self-organize with no requirement for centralized control (Holling, 2001). SESs are complex, adaptive and uncertain. Social systems have faced climate impacts and, depending on their reductive capacity, including their set of measures and strategies, can act to reduce their vulnerability to these impacts. It is this capacity for adaptation that makes it possible to strengthen the resilience of a system (Berkes *et al.*, 2003 Anderies *et al.*, 2004; Folke, 2006, Berkes and Folke, 2008).

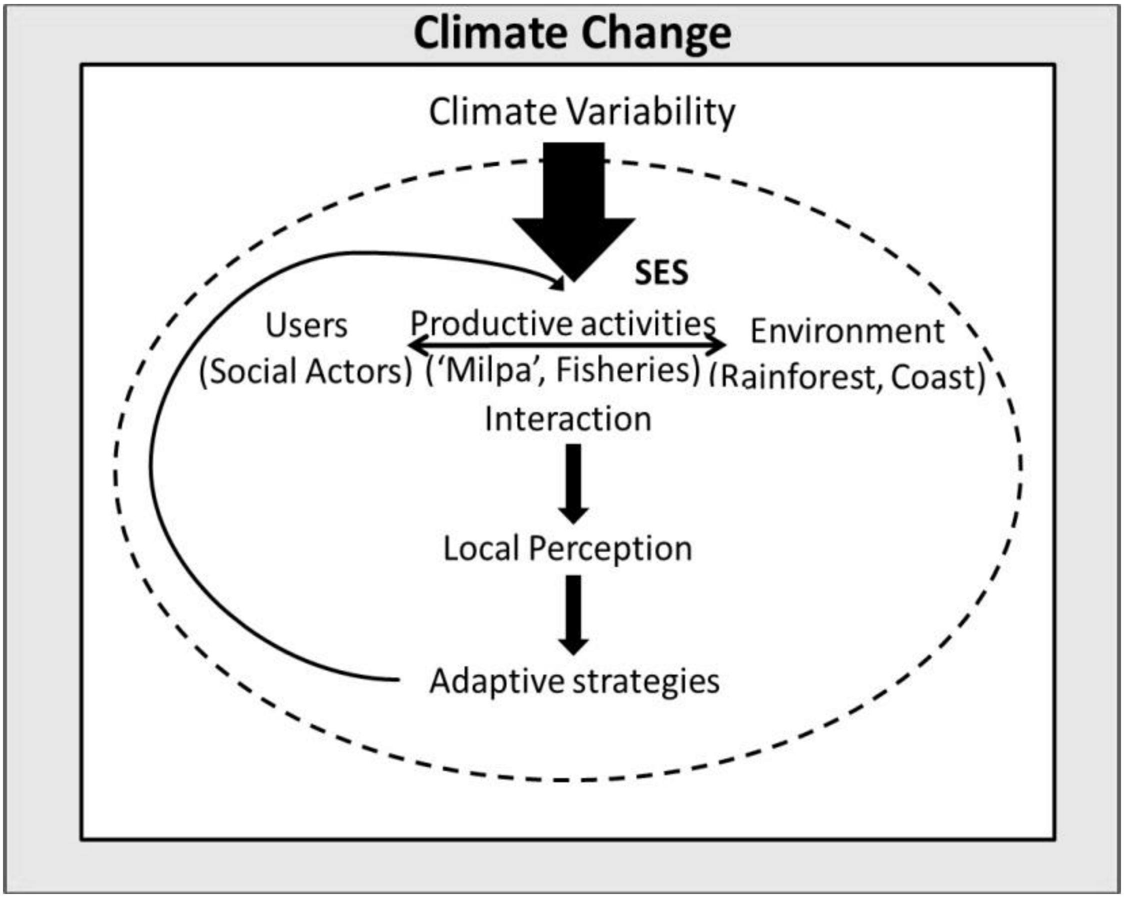
The term “adaptation” in the ecological sense refers to any response that increases the likelihood of population survival. In anthropology and development studies (Berkes and Jolly, 2001), adaptation is analyzed through resistance and adaptive strategy mechanisms, which are distinguished by time and are multiscale in nature. Resistance mechanisms are defined as the set of responses to short-term situations that increase the risk to livelihood systems. They take the form of an emergency response during anomalies in average weather and can overlap temporally. Over time, resistance mechanisms can develop and turn into adaptive strategies. Thus, resistance mechanisms arise at the individual or familial level whereas adaptive strategies, which are related to cultural values, arise from a larger spatial scale (Berkes and Jolly, 2001; Mosberg and Eriksen, 2015).

According to recent studies, adaptive strategies are centered on the development or improvement of technology that includes, for example, drip irrigation in areas with high drought risk; pest and disease control and the adoption of new crops to adapt to future conditions (Baca *et al.*, 2014; Altieri and Koohafkan, 2008). Migration has also been considered within the strategies that adopt individual responses to the effects of climate variability (Ramos, 2011; Márdero *et al.*, 2014; Burnham *et al.*, 2016; Chale-Silveira, 2016). In the human dimension of SES (Berkes and Folke, 1998), perceptions of climate variability allow us to identify, construct or reinforce resistance and adaptive strategy mechanisms. The state of Quintana Roo is vulnerable to the effects of climate variability due to its geographic location and the degree of marginalization of human settlements in rural zones (Walther *et al.*, 2002; Torrescano, 2007; Orellana *et al.*, 2011; Carrillo, 2013). It is the state with the highest population growth (4.1 %) nationwide. The main zones for tourist activity (Cancún and the surrounding areas) have received priority attention from the state, as well as multinational capital, leaving the indigenous Maya zone with high to very high degrees of marginalization. In the context of climate change, it is crucial to study in detail the extent to which human systems have adapted to climate variability.

In this study we argue that, within a SES, since rural community populations are active agents of change in climate variability, a variety of mechanisms and strategies are employed to enable the population to ensure its subsistence and wellbeing. Figure 1 shows a cycle in the relationship between climate variability and the social actors in a SES. Through their perception of environmental change, it can be observed that social actors respond through resistance and adaptive strategies to maintain their livelihoods.

In our study, interactions between climate variability and productive activities were made explicit in the four SESs (four communities) of the southern Yucatan Peninsula, specifically in the state of Quintana Roo. These interactions between users and the environment are manifested in productive activities, for example, the rainforest milpa (slash and burn agriculture) and coastal fishing, which are affected by climate variability (Figure 1).

Figure 1. Continuous Interactions between the Social (Users) and the Ecological Systems (environment: rainforest, coast)



Source: compiled by the authors, based on Berkes and Jolly (2001) and Holling (2001).

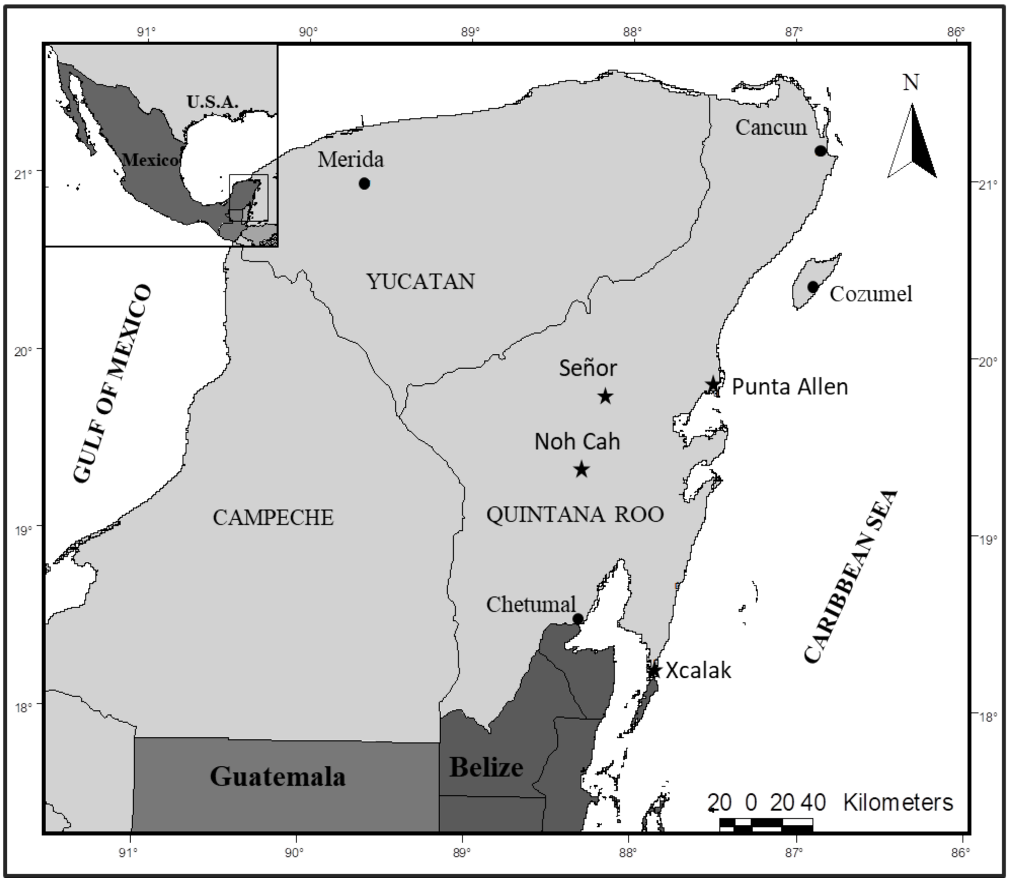
SESs are complex, adaptive and uncertain. Furthermore, social systems have faced climate impacts and, depending on their adaptive capacity, which includes the set of measurements and strategies (whether actual or potential), they are able to reduce their vulnerability to those impacts. This capacity for adaptation makes it possible to strengthen the resilience of the system (Holling, 2001; Berkes *et al.*, 2003).

Methodology

Area of Study

The four SESs are in the southeast of the Yucatán Peninsula, specifically in the state of Quintana Roo (Figure 2) and form part of the Mesoamerican Biological Corridor. They are located in a region with a warm, sub-humid tropical climate (Aw) and an average temperature of 26°C. Three seasons are recorded: dry (February to April) and rainy (June to October), with bimodal behavior, and a period of decreased precipitation within the rainy season (mid-July through mid-August, known as the "canícula" or dog days), and a series of cold weather fronts, mainly featuring northerly winds and reduced temperatures (November to February). These seasons can overlap throughout the year (Arce-Ibarra and Charles, 2008; Carrillo *et al.*, 2009). During the rainy season, there is a high likelihood of tropical storms and hurricanes (Carrillo *et al.*, 2009).

Figure 2. Geographical location of the four SESs under study (Señor, Noh Cah, Xcalak and Punta Allen)



Source: compiled by the authors.

Table 1 provides a summary of the participants in the study in each community and Table 2 displays the degree of marginalization of the communities studied, comprising mid to very high values (CONAPO, 2010), particularly since they have a limited presence of health services and educational attainment.

Table 1. Demographic characteristics of participants

Community	Group	Average age (Years)	Interval (Years)	N
Noh Cah (MZ)	Men	55	84-41	15
	Women	43	27-77	8
Señor (MZ)	Men	54	30-94	46
	Women	50	36-60	9
Xcalak (CZ)	Men	39	22-78	44
	Women	36	30-40	4
Punta Allen (CZ)	Men	46	17-68	21
	Women	32	53-25	5
Total				152

N= number of people that participated in the study; MZ= Maya Zone; CZ= Coastal Zone.
Source: compiled by the authors with data obtained during field and documentary research.

Table 2. Available services in participating communities

In situ observation	Noh Cah (MZ)	Señor (MZ)	Xcalak (CZ)	Punta Allen (CZ)
Running Water	Yes	Yes	Yes	Yes
Electricity	Yes	Yes	Yes	Electric generator
Medical Service	No	SSA, IMSS	IMSS	IMSS
Anticyclone Center	Yes	Yes	No[a]	No[a]
Internet	No	Yes	Yes	Yes
Meeting Centers	Yes	Yes	Yes	Yes
Civil Protection	No	No	No	No
ONG/Cooperatives	No	4	6	7
Highest education level	Elementary School	High School	Tele Middle School [b]	Tele Middle School[b]

In situ observation	Noh Cah (MZ)	Señor (MZ)	Xcalak (CZ)	Punta Allen (CZ)
Government support (Programs)	4	4	4	4
Access	Highway	Highway	Highway/Sea	Secondary Road/Sea
Marginalization level	Very High	High	High	Medium

MZ= Maya Zone; CZ= Coastal Zone.
[a] In the event of a contingency, the entire community is evacuated.
[b] Tele Middle School is a Mexican education model, instituted in 1968 by Álvaro Gálvez and Fuentes with the aim of providing secondary education through television broadcasts to rural or inaccessible areas in Mexico and to reduce the illiteracy prevailing in the 1960s, which continues to exist to this day (Cortés, 2004).
Source: compiled by the authors with data obtained during field and documentary research.

The rainforest zone geographically coincides with the area known as the Maya zone. Most of the Maya population in the Quintana Roo region are descendants of the Maya rebels that initiated the Caste War in the 19th century and call themselves 'macewales'.[1] The communities of the Maya zone included in this study are in the X-Maben and Noh Cah ejidos,[2] in the municipality of Felipe Carrillo Puerto.

The X-Maben ejido, founded in 1937, has an area of 73 400 ha managed by 482 ejido members (*ejidatarios*). It comprises seven communities, the main one being "Señor", which is the focus of this study. By 2010, the total population of Señor was 3,095 inhabitants; 1,583 men and 1,512 women, distributed among 658 households (INEGI, 2010). The Noh Cah ejido was founded in 1968 with 2 166 hectares for 27 *ejidatarios* (RAN, 1995). In 2010, a total of 75 inhabitants were registered (INEGI, 2010).

In the coastal zone, the communities in the study were Punta Allen and Xcalak, both located in region 7 of the Marine Priority regions of Mexico (Arriaga Cabrera *et al.*, 1998). Punta Allen lies within the Sian Ka'an Biosphere Reserve, founded in 1986, whilst Xcalak is in the 'Xcalak National Reef Park' Marine Protected Area. This area was founded by a community initiative between 1995 and 1997. Various ecosystems coexist in this area, including mangroves, seagrass, coastal dune vegetation, rainforest, coastal lagoons and coral reefs. According to the National Institute for Statistics and Geography (INEGI), Xcalak was founded in 1900 and, by the year 2010, had a population of 375 distributed among 100 households (INEGI, 2010). The main economic acti-

[1] Macewal: Nahua word meaning "common person" that entered the Mayan language during the Mexican conquest. By 1847, when the Caste War broke out, the word had lost its original pejorative meaning and the Maya used it to refer to themselves. This attitude persists in Quintana Roo, but the Yucatecan Maya now use it to designate a social inferior (Bello and Estrada, 2011).

[2] Ejido: a form of land tenure that emerged at the beginning of the 20th century in Mexico, whereby the land is the property of the state, but the people are the beneficiaries. In the Maya zone, the ejido operates as communal property, where the ejido assembly is the highest authority in the decision-making process as regards land access.

vity promoted by the government is tourism. The community contains a lobster fishing cooperative (founded in 1954), one of its main economic activities.

The community of Punta Allen, officially known as "Javier Rojo Gómez", was founded in 1968 and belongs to the municipality of Tulum. The first settlers exploited the coconut (copra). Subsequently, 49 fishermen from the Cozumel Island cooperative migrated to the mainland and established settled in Punta Allen, where they set up their own lobster fishery cooperative, known as "Vigía Chico" (Sosa-Cordero *et al.*, 2008). The population has gradually increased and, due to the natural beauty of the island, tourism is now one of the principal economic activities. In 2010, the population of Punta Allen comprised 375 inhabitants; 243 women and 226 men, distributed among 128 households (INEGI, 2010).

Field and desktop work

Fieldwork was conducted in 2014 (December), 2015 (January-June and August-October) and 2016 (September). Information was obtained using qualitative methodology which included various methods. This was performed to triangulate data from various sources, allowing a better approach to reality (Valencia, 2000; Cantor, 2002). These methods included participant observation, interviews (open and semi-structured) with family leaders, informal conversations with key informants and community workshops with focus groups (Herrera *et al.*, 2005; Bernard, 2006). Information was also drawn from secondary sources, such as archival research on related issues present in the zone to complement the contextual information. A total of 152 interviews were conducted in the households, covering different aspects of the interaction between climate variability and the communities under study. A 74 % response level was obtained (204 were invited, of which 52 declined to participate). The approximate duration of the structured interviews was 25 minutes. In the indigenous communities, a Maya-Spanish interpreter participated in order to create a more comfortable environment between the interviewers and respondents and to ensure proper understanding of their answers.

Although the scale of the spatial study was centered on the communities (local level), secondary source information was incorporated, including data from municipal, regional, national and international levels. The time scale was explored through local oral history, which made it possible to identify the context of the relationship between climate variability and the productive activities in each SES selected. The qualitative analysis of the results is mainly based on the transcription and analysis of the answers of all the participants (respondents, focus groups). We present some examples of text in parentheses and an analysis and categorization of the frequency of responses expressed in percentages using QSR N6 (2002), qualitative software used to identify patterns.

Results

Local perception of climate variability and its effects on the primary productive activities of the Maya Zone

In the SES in the Maya zone, attention was paid to traditional knowledge related to climate variability. Firstly, the existence of local terminology for weather in the Maya language was explored. The information recorded was useful for the context of the guide-translator (Maya-Spanish), for the production and application of the extensive questionnaires and for the focal groups to validate the observations. The results yielded terminology covering different types of rain (Table 3).

The term *Nohoch yax k'iin* was used in Mayan to refer to the great drought. Although there was no consensus in terms of the identification of a Mayan term to refer to intense rains in both localities, three types of rain that affected crops were identified (the respondents recognized them as 'bad rains'): *Choco ja'* (hot rain) *Sabak ja'* (acid rain) and *Kankubul ja'* (yellow rain). These types of rain were identified once the phenomena had passed, since they left marks on the crops. For example, when *Choco ja'* or hot rain falls, the following day, the crop foliage has black blemishes, as though it had been burnt. *Choco ja'* is produced by cyclones; it is referred to as saltwater that comes from the sea and burns the corn, making it unserviceable. With *Sabak ja'*, white and grey blemishes appear on the foliage. This is the acid rain that falls during a heatwave. *Kankubul ja'* rain is produced when there are pink and yellow clouds, and when the rain falls, the ear of corn droops and produces small white balls.

Table 3. Terminology used to refer to certain climate events

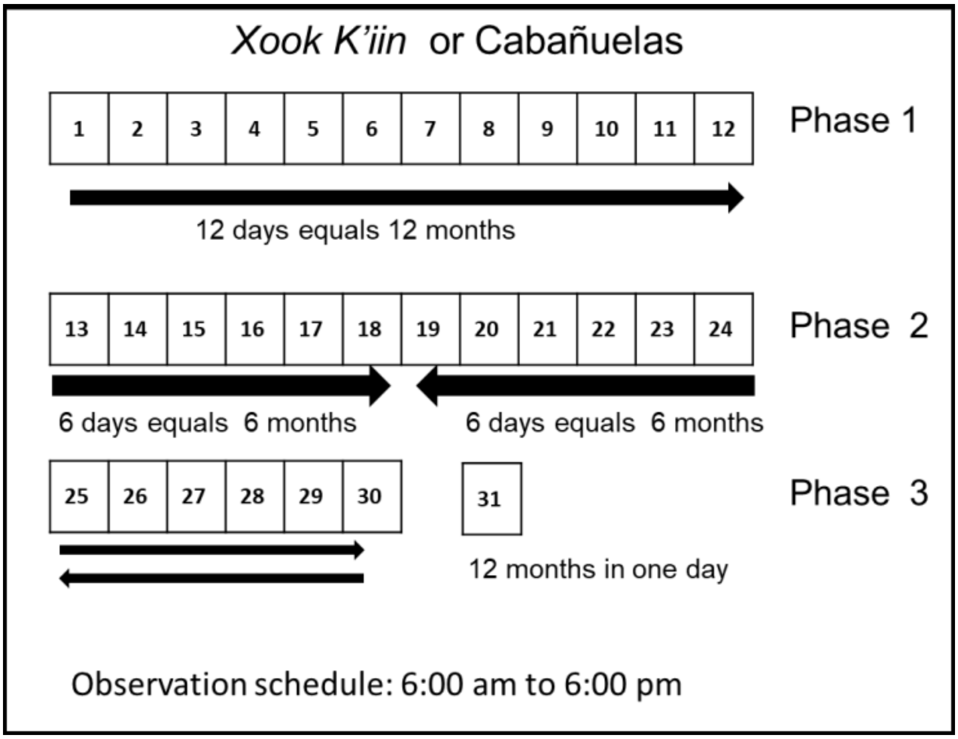
Climate events	Maya Name	Example
Drought	*Nohoch yax k'iin*	"Drought is normal in the first months of the year, but lately it has been *Nohoch yax k'iin*, which lasts until July" A.E. 2015
Hot Rain	*Choco ja'*	"If the crops are thriving and *Choco ja'* falls, they burn and the fruit no longer grows" A.C. 2015
Acid rain	*Sabak ja'*	"This rain leaves black marks on the crops and greatly affects the growth of the corn" A.C. 2015
Yellow rain	*Kankubul ja'*	"This rain leaves white marks on the crops and we lose everything" F.C. 2015

Source: compiled by the authors with data obtained during field and documentary research.

In both localities in the Maya zone, part of traditional knowledge about climate focuses on the "cabañuelas" which, in the Mayan language, are known as '*Xook K'iin*' and are a traditional form of weather forecasting. A total of 58 % of the respondents in Señor and 40 % in Noh Cah agreed that older adults are the main source of knowledge about the "cabañuelas" and that this knowledge is being lost due to the lack of interest among youth to learn and work in the countryside, and also because they consider that the weather has changed so much that it is now difficult to continue using this forecasting system.

Maya elders record observations of '*Xook K'iin*' in three stages in January (Figure 3), by observing the behavior of the weather. During the first phase, observations are made during the first twelve days of January, which are assumed to correspond to the behavior of the weather for the twelve months of the year ahead. In other words, if the first day of January is sunny with very little wind, this means that the month of January of that year will also have these characteristics, and so on for the next 11 days. During the second phase, twelve days are recorded up to January 24, but the months are counted backwards, in other words, the forecast for the thirteenth day corresponds to the behavior of December, while the 14th day corresponds to November and so on. The third phase is registered from January 25 to 31. Here, the observations of the day were divided into two, in which the first half of the day corresponded to one month and the second half of the day to the next month. Finally, all the recorded observations indicated weather variations throughout the year from the outset. A total of 53 % of the respondents in Señor and 40 % in Noh Cah confirmed the validity of this form of weather forecasting. They consider it a useful tool for planning productive activities such as the milpa, apiculture and hunting, amongst others (pers. coms. A.E., 2015).

Figure 3. Monitoring of *Xook Kíin* or "cabañuelas" in January at the Maya zone



Note: The arrows indicate the direction in which the months of the year are located.
Source: compiled by the authors with data obtained during field research with focal groups and interviews.

With respect to the perception of climate variability, questions about extreme climate events were asked, such as their perception of extended droughts, intense rains and hurricanes. Forty per cent of the respondents from Señor acknowledged that 2014 had been a very dry year, otherwise known as a year of extended drought, while 70 % mentioned they had experienced intense rains in 2013. Moreover, the category three hurricane Roxanne occurred in 1995 and, according to the experiences recorded, this was the hurricane that caused the greatest damage in the Maya zone, affecting homes and productive areas.

Changes in normal patterns of climate variability in Noh Cah have been observed. Ninety-six per cent of respondents confirmed that the current temperature in the zone is higher, while 39 % admit that this change has been perceived between the last one to five years. Changes in precipitation were detected by 100 % of the respondents. A total of 44 % reported having perceived these changes in past six to ten years, while 75 % stated that the bad rains (*Choco ja'*, *Sabak ja'* and *Kankubul ja'*) fall with greater frequency. Regarding the frequency of hurricanes, 80 % of respondents failed to report any changes. Participants in the focus groups agreed with these results.

In accordance with the perception of the respondents, 70 % mentioned that the milpa is the productive activity that had been most affected by the changes in climate variability; the remainder mentioned the milpa but associated it with other activities, such as apiculture, horticulture, fruticulture and livestock raising. Nevertheless, 48 % of the respondents did not know what caused these changes in the weather, while 22 % attributed them to “Climate Change”. The respondents in Noh Cah (52 %) consider that the climate will be worse in the future and that “only God knows what it will be like” (17 %). Moreover, the Señor community has perceived changes in the normal patterns of climate variability. Eighty-seven per cent of the respondents observed that the temperature had increased. However, the perception of this change amongst the participants varied over time, with 36 % conceding that these changes had been noted in the past decade.

With respect to precipitation, 96 % of the respondents stated that it had changed, with 36 % reporting that this had been perceived in the past 10 years. A total of 45 % stated that the bad rains had increased in frequency, while 75 % noted changes in the frequency of hurricanes. Of the respondents, 87 % mentioned the milpa as one of the most severely affected activities, while 13 % mentioned the milpa in association with other activities such as apiculture, horticulture, habanero chili production and livestock raising. A total of 51 % of the respondents remarked that they did not know the cause of these changes, whilst 18 % attributed it to divine punishment. In this respect, Mr. P. X., a Maya leader, said during the interview that:

> All this happens to us because we have not prayed; they have not prayed for the milpa, because the milpa has not been productive, they are punishments. Previously, a milpa with one hectare could sustain a family; now it can’t, one hectare is not enough…

As for forecasts of the climate in the Señor locality, 56 % of the respondents thought the climate would be worse, while 26 % did not know what it would be like in the future.

Local perception of climate variability and its effects on the primary productive activities of the coastal zone

In Xcalak, 83 % of respondents confirmed they have perceived changes in the rain pattern, and that they currently experience less rain. Regarding the time frame for this perception, 65 % said that these changes have been observed in the past five years. Ninety-three per cent perceive that the climate has also changed, stating that they currently feel more heat. Again, 70 % remarked that this change has been detected in the past five years.

In Xcalak, 62 % of the respondents considered that fishing is the activity most affected by changes in climate patterns, while;19 % considered that tourism is the most affected, and 19 %

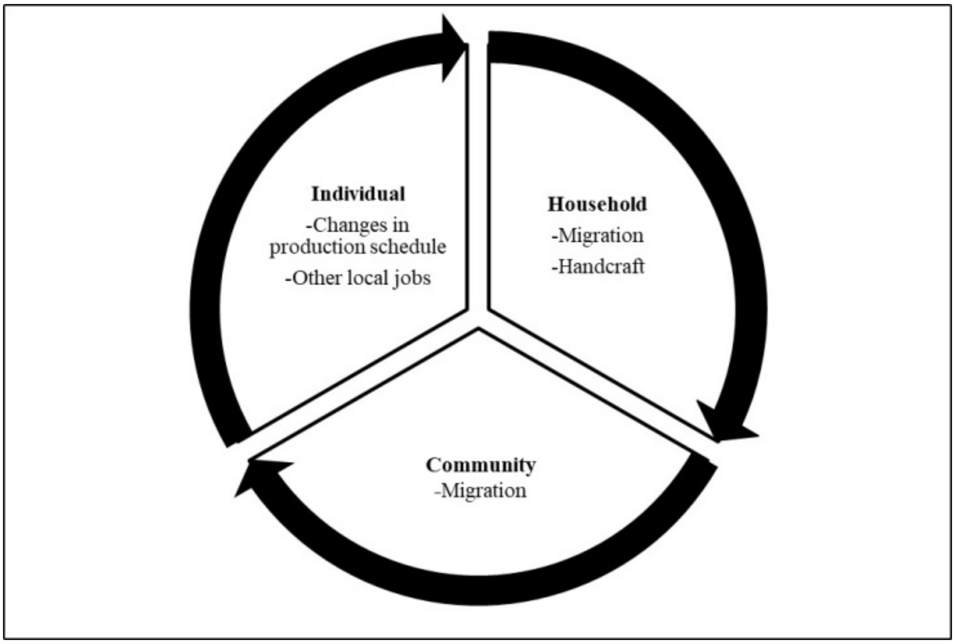
consider that both are affected. In the Xcalak community, 44 % of the population interviewed stated that they "do not know" what causes the changes they perceive, while 24 % commented that they are the result of "Climate Change".

In Punta Allen, 96 % of the respondents have perceived changes in the rain pattern, noting that there is now less rain throughout the year. A total of 84 % reported that these changes had been perceived in the past 10 years, while 92 % of the respondents have also perceived temperature changes, mentioning that currently there is more heat than before. Of those, 89 % concede that this change has been perceived in the past five years. In Punta Allen, 46 % considered lobster fishing and tourism to be the most severely affected activities, while 42 % thought that the fin fishing and lobster fishing are the worst affected and 12 % commented that the most severely affected activity is tourism.

Climate variability adaptation strategies in the Maya zone

The principal responses or strategies employed to minimize the effects on milpa production were two modifications in the traditional agricultural calendar: throughout the year in the months for sowing and throughout the day during the hours of everyday work. Figure 4 shows the main adaptive strategies identified in the Maya zone.

Figure 4. Main adaptive strategies recorded in the Maya zone



Note: The arrows indicate the relationship of the strategies between the different levels of decision
Source: own elaboration with data obtained during field and documentary research (Berkes and Jolly, 2001; Ostrom and Cox, 2010).

According to the respondents, the date of sowing has been delayed in order to coincide with the rain. In Noh Cah, 52 % of the people mentioned that they have changed the dates of their sowing activities from May to June-July, and there were cases in which sowing was even delayed until August, depending on how long the rain was delayed. These changes have consequences for other facets of the milpa process: if sowing is delayed, it means that prior activities such as 'slash and burn' must also be delayed; otherwise the opportunity to obtain produce could be lost.

According to the Quintana Roo Law of Burning and Forest Fires (Ley de Quemas e Incendios Forestales de Quintana Roo), specific dates are established in the municipality of Felipe Carrillo Puerto for burning the milpa during April and May. However, when the drought extends for more than the normal period, these dates become inadequate for completing the agricultural cycle.

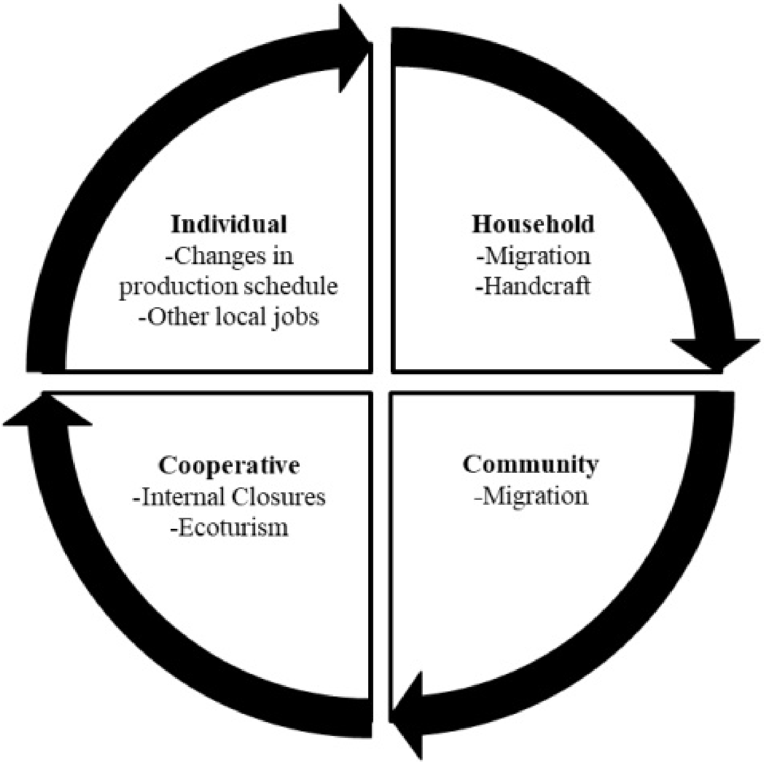
With respect to the working hours in previous years, field labor used to begin at 6 or 7 am, but now begins at 4 or 5 am in order to complete the tasks before the temperature rises. A total of 60 % of respondents in Noh Cah and 75 % in Señor confirmed the adoption of this measure. In Señor, enquiries were made as to what other activities were conducted to compensate for losses in production due to climate variability. A total of 71 % replied that they engaged in other related employment in the field, such as "chapeo" (removing or cutting weeds and grass) or selling firewood, among others, while 26 % wait until conditions improve and the rest of the inhabitant relied on government subsidies that constitute their principal source of income. Only one person remarked that they had sought work as a laborer in Tulum.

In Noh Cah, 50 % of the respondents remarked that, when they saw the effects of climate variability, they did not undertake any other activity and merely waited for conditions to improve, while 31 % mentioned that they had found other jobs, 13 % were supported by government subsidies and 6 % reported that, since they had a fixed salary, the changes did not affect them. As in Noh Cah, there were also modifications in the months for sowing in Señor. In this respect, 34 % of respondents now begin to sow in May, 20 % between May and June while 9 % stated that the date for beginning to sow depended on the delay in the onset of rain. In one case, it was mentioned that the sowing season began in August due to a lack of rainfall. In both communities, major variations in sowing times were recorded as a result of the enormous uncertainty regarding the rainy season.

Climate variability adaptive strategies in the coastal zone

Figure 5 shows the main adaptive strategies identified in the SES in the coastal zone. In the case of local responses in Punta Allen, the impact of climate variability appears to vary. Some respondents reorganize their everyday work activities; for example, fishermen J.L.M and E.P.M. (2015) mentioned that, occasionally, not all the lobster fields are affected in terms of production. Consequently, relying on their friendship ties, the fishermen reorganize and support each other, fishing in the fields that are not too badly affected. At the same time, fishermen V. B., A. A. and T. M. (2015) said that, when the lobster fishery is affected for various days, they prefer to work in the tourism sector, particularly in fly-fishing and boat tours.

Figure 5. Main adaptive strategies recorded in the coastal zone



Note: The arrows indicate the relationship of the strategies between the different levels of decision.
Source: compiled by the authors using data obtained during field and documentary research (Berkes and Jolly, 2001; Ostrom and Cox, 2010).

Another reported is "internal closures" (vedas internas), which is relatively recent. This began to be implemented in 2013 when a year of atypical rains was experienced (SMN, 2014) that had previously negatively affected lobster production in 2013 (40 % below normal). The internal closures involved suspending fishing activities for 10 or 15 days during the fishing season to ensure production and maintain supplies.

E.P.M (2016) stated that this strategy was so beneficial that they decided to continue implementing the closure although there was no meteorological phenomenon present. In addition, the "Vigía Chico" cooperative has a revolving savings fund that is available for use when fishermen have an emergency. However, not all the community of Punta Allen has access to this fund. It was also found that some people are not financially prepared (no savings) and therefore they called the months corresponding to the low fishing and tourism season "September hunger", "October hunger" and "November hunger", referencing the crisis brought about by the lack of income.

In the locality of Xcalak, 51 % of the respondents do not conduct alternative activities to offset production losses due to the effects of climate variability, while 23 % have other employment such as cleaning hotels, and 26 % are supported by Temporary Employment Programs promoted by the National Commission of Protected Natural Areas (Comisión Nacional de Areas Naturales Protegidas, CONANP). Both communities have noted outbreaks of new illnesses such as Chikungunya, which limits their social wellbeing, because adequate health services are unavailable in their communities. This means they must travel elsewhere to receive medical attention, implying expenses they are unable to afford.

Discussion

Global climate change directly affects climate variability at the regional and local level. In a diverse social system, groups of rural producers worldwide are affected by these changes (Adger *et al.*, 2005). In this study, the human component is presented as the active agent, employing a variety of mechanisms and strategies to ensure family subsistence and wellbeing.

The environmental perception of climate variability: "Less rain and more heat"

Within the human component, values and beliefs influence how people perceive the environment and how risks are managed and interpreted. This information and practical knowledge determine how decisions and choices are made in the climate adaptation process (Moser and Ekstrom, 2010). The respondents observed new problems, tasks and solutions through pre-existing values, preferences, beliefs, standards and experiences. These cognitive filters shape their perceptions of ecological systems and can limit our attitudes towards their process of making decisions.

The perception of the ecological system varies according to the worldview of each social system or ethnic group. Blennow and Persson (2009) found that the strength of beliefs related to climate change was a crucial factor in explaining adaptation actions among dry forest owners. In the north of Burkina Faso, cultural values either helped or hindered group adaptations and new life strategies to reduce vulnerability caused by climate change. In the four SES studied, changes in climate variability were mainly perceived in relation to increased temperatures and decreased precipitation during the rainy season, summarized by the general perception of "less rain and more heat". These results coincide with those reported previously in other communities. For example, in a community in Chiapas, Mexico, the Zoque indigenous group also perceived changes in climate variability, particularly higher temperatures and less precipitation, as well as the shorter length of the cold northerly weather front season (Sánchez-Cortés and Chavero, 2011). In Juchitán, Oaxaca, Dunlap (2019) provides qualitative evidence for the decrease in rainfall in that study region.

Nielsen and Reenberg (2010) reported that, according to the perception of the people of the north of Burkina Faso, it has been difficult to predict the arrival of the rainy season in the region over the last 40 years, commenting that every year, this season is shorter and features periods of very intense rains. This coincides with the results of the social component of this study. However, with respect to the time frame, in accordance with the respondents and focal groups, these changes have been more marked in the last decade. For this reason, it is more difficult to sow plants in the milpa in the Maya zone because of the inability to forecast weather conditions. In the SES of the coastal zone, this variability in rainfall patterns has affected the principal economic system in terms of tourism and lobster production. Nevertheless, the measures taken by the cooperative administration in the case of Punta Allen have mitigated the economic risks. In this region, there are many concerns regarding inter-seasonal precipitation, because normal patterns are no longer observed. In both areas, 2013 was a year of marked climate variability because of the intense rain etched in the memories of rural producers. In the Maya zone, the effect was mainly felt in the milpa and coastal lobster production.

Strategies of adaptation of farmers and fishermen

Adaptation of the social system to changes in the ecological system can be motivated by many factors, such as the protection of economic wellbeing or enhanced security (Adger *et al.*, 2005). In the four SES, this adaptation is an ongoing process and continues to counter the effects of climate variability changes. These strategies make it possible to maintain interactions between the social and ecological system (Figure 1).

Sanchez *et al.* (2014) found that adaptation strategies are directly influenced by the socioeconomic status of household groups. If they have a high socioeconomic level, they will have more options for adaptation and greater flexibility in decision making, which in this case translates into improved adoption of productive systems. Another aspect that can drive the at-risk systems studied is described by Mosberg *et al.* (2015), in which an insecure or poor financial situation can foster an increase in illicit activities that can create problems for maintaining social and ecological integrity. The SESs may see an increase in illicit activities because their principal means of support are compromised by the climate variability changes. Furthermore, the degree of marginalization of those that live, for example in communities in the Maya Zone, may also limit their adaptive capacity. In recent studies based on household units, adaptation strategies focus on access to new technology, such as drip irrigation, in areas with a high risk of drought, and the adoption of new crops to adjust to future conditions (Altieri and Koohfkan, 2008; Baca *et al.*, 2014).

The four SESs rely heavily on local resources for subsistence and have major socioeconomic disadvantages. Some have high degrees of marginalization, such as Noh Cah and Señor, which make them highly dependent on government subsidies for everyday living. The social component of Punta Allen has greater organizational and financial capacity (through their savings fund), enabling this community to increase its resilience to extreme events. Their level of organization means that they also have greater access to technology and financial support for their productive activities.

In contrast, access to this technology is limited in the Maya zone by the lack of fixed-income employment and the inefficient organization within the ejidos. The inequality and nepotism existing in the area underline the urgent need for community organization and conflict management to guarantee mutual support in the event of a contingency. Evidence exists that ideologies based on a dominant pattern of values can either trigger or impede the adaptation process (Moser and Ekstrom, 2010).

The milpa system currently accounts for 20 % of the annual income in the Maya zone (Arce-Ibarra, 2007; Chale-Silveira, 2016). However, this activity is of great social and cultural importance since it is related to other activities such as hunting and beekeeping and plays a key role in strengthening kinship ties within the community (Velasco-Te, 1999; Bello and Estrada-Lugo 2011). Since the social organization within the milpa is a characteristic of Maya culture, its importance goes beyond merely domestic support. Several authors have confirmed this interpretation (Bello and Estrada-Lugo, 2011).

Reed (2001: p. 42) introduces the Maya *Xook kíin* or the "count of days" to predict a good harvest, which was used by the local *H-men*.[3] Likewise, Cat Colli (2015) describes the *Xook K'iin* in a Maya community in the state of Yucatán. The findings of this study are complemented by detailed information on the prayers and ceremonies conducted in order to ask the gods for a good harvest. Syncretism between the Catholic Church and the Maya worldview is present in these ceremonies. Likewise, in other parts of central Mexico, such as Xochimilco, there is evidence of monitoring of the "cabañuelas" by native Nahua speakers to have a good harvest in their *chinampas*, fertile arable land in shallow lake beds used for crop growing (D. Xochime, pers. com., 2018).

[3] *H-men* is the name given in the Mayan language to a healer from a community (Villa Rojas, 1987).

Cat Colli (2015) and Romero (1990) refer to the "cabañuelas" as being of Spanish origin. However, Cat Colli also reports that: "To make a prognostic of astronomic events, the ancient Maya devised their own calendars (for the sun, moon, Venus, and eclipses)… among those calendars was the *ha'ab* or sun calendar… which was used to make prognostics of the agricultural activities including sowing and harvesting…" (Cat Colli, 2015: p. 113). Accordingly, this author proposed that although the "cabañuelas" are of Spanish origin, they had probably been merged with the local Maya "counting of days", which resulted in the *Xook K'iin* to predict the best times for the sowing and harvesting of the most important Maya cultural activity, slash-and-burn agriculture.

Many farmers are leaving the milpa in Señor and Noh Cah, citing the lack of rain, while those that continue do so to maintain the tradition rather than because of the yields they obtain. In general, the farmers comment "*The Xook K'iin no longer works*". In addition to the impact on household incomes, this also has an impact at the cultural level in the zone. The Maya milpa that is affected forces those who continue to practice it to depend on other resources for their subsistence, such as government subsidies and migration, amongst. These new activities jeopardize the food sovereignty and wellbeing of a community, increasing its vulnerability to extreme climate events and putting the resilience of the system at risk (Adger *et al.*, 2005; Mosberg and Eriksen, 2015).

Migration as an adaptation strategy also impacts traditional activities. In recent decades, it has been reported that youth in rural zones migrate, leaving the forest in search of better employment opportunities. Some return, but others do not. This leads to the abandonment of fieldwork and the rainforest (Sanchez-Cortés and Chavero, 2011). In the Maya zone, young people prefer work in hotels in the Riviera Maya rather than in the fields. Likewise, in Xcalak and Punta Allen, young people are more attracted by tourist activities than fisheries. This leads to major changes in the social system, which should be documented in future studies conducted in the Peninsula or study area.

Public policies for an uncertain future

During the field visits, people in the four SESs expressed great uncertainty about the future of the climate. While uncertainty also exists in the scientific community, there is evidence that confirms the long-term prognosis. The Mexican government therefore has the data on medium and long-term climate change scenarios to enable it to devise appropriate public policies. Our study contributes by informing policy planners about small-scale rural and indigenous producers' perceptions and adaptive strategies.

However, despite the statement of the National Climate Change Strategy that, in designing transversal and inclusive policy strategies, gender as well as ethnic, disability, health conditions and inequality should be considered in access to public services (ENCC, 2013), current climate change programs at both the national and provincial levels fail to consider these factors (Pereira *et al.*, 2013; SEMARNAT, 2015). Moreover, these programs fail to consider current climate variability coping and adaptive strategies used by the coastal fishermen or indigenous marginal farmers of Quintana Roo (Pereira *et al.*, 2013; SEMARNAT, 2015; Arce *et al.*, 2018). During field stays in the community of Punta Allen, a social program related to climate change was recorded, but only five respondents referred to it. In order to deal with climate variability and climate change, Mexico and the state of Quintana Roo are expected to devise policies addressing the social, environmental, and economic aspects of people's lives. Social aspects in particular will need policies providing social protection (e.g. public employment programs) to promote a fair transition to a climate-resilient society and economy. It is also necessary to protect people's livelihoods and access to essential services (ILO, 2018).

Currently, at national and Quintana Roo state levels, most public climate change policies focus only on economic and environmental aspects. Above all, they embrace the green economy, and several projects to produce alternative energy (e.g. wind energy) have been launched in several regions of Mexico, including Quintana Roo (Pereira *et al.*, 2013; Dunlap, 2017). However, as several authors have pointed out, these projects have primarily been "greening" inequality, as demonstrated in Oaxaca, Mexico (Dunlap and Fairhead, 2014; Dunlap, 2017). On the environmental side, the REDD+ program, as well as a program involving Payment for Environmental Services (Spanish acronym PSA), have been launched in Quintana Roo (Moure-Peña, 2015; Infante-Ramírez and Arce-Ibarra, 2015).

On the coastal side, Mexican public policy has been embracing the blue economy (see Newell and Taylor 2018) in which investment in Quintana Roo includes the construction of docks to support a large-scale tourist industry. In turn, this investment attracts cruise ships and the economies of local coastal communities (Mahahual and Xcalak) are closely tied to them (Daltabuit *et al.*, 2007; Thomassiny-Acosta, 2010). Nevertheless, several studies carried out on the coast of Quintana Roo report that current public tourist policy fails to consider the livelihoods of local people, or their access to essential services (Thomassiny-Acosta, 2010). This policy therefore lacks Blue justice (Moenieba Isaacs, 2018, pers. com.).

Another aspect that should be included in current public policy is capacity building and the dissemination of what climate change is and how we can address it. However, this information is not found in the social component of the four SESs studied. Wood *et al.* (2014) suggest the establishment of policies that guarantee the dissemination of climate information. Moreover, it is essential to establish the necessary conditions to undertake this dissemination, such as securing access to communication networks such as radio signals, the Internet and television. It should be noted that, in the four communities studied, there are zones where the Internet and television signal is limited or non-existent. Compounding the problem, some Mayan speakers are unable to understand the news in Spanish.

The principal criticism of Mexican public policies is that they exclude citizen participation before, during and after extreme weather events. Aguirre and Macías (2006) state that the intervention focuses administrative control in a vertical manner, effectively turning the population into victims. However, the collective memory of past events plays a key role in people's response capacity, hence the importance of integrating them into management and planning processes. This highlights the importance of identifying and engaging in two-way interactions that respect social and ecological systems (See figure 1). It is necessary to understand that adaptation strategies within a determined space must involve decisions from different agents, such as individuals, civil society, local, regional and national governments, as well as international agencies.

Conclusions

Our study found that climate variability in the southeastern Yucatán Peninsula threatens livelihoods as well as the ancestral Maya traditions related to the milpa. In the four SESs, it is perceived that temperatures are rising, and that precipitation is decreasing in the region. However, the effects related to these changes vary because of the differences in people's livelihoods.

In the Maya zone, climate variability affects local livelihoods, but also culture due to the loss of traditional knowledge related to both the milpa and climate forecasting. With respect to the latter, *Xook K'iin* (Maya Forecasting), which had operated to support the organization of productive activities is now less efficient due to extreme variations in normal climate patterns. The loss of other traditions is also assumed to be an effect of the globalization process in which we are immersed, which to date has resulted in public policies —the "Green" and "Blue" economy— that are insensitive to the social and cultural aspects of rural and indigenous communities. This is worrying because it also implies a loss of values, beliefs and practices that can represent pillars of a culture, such as the social organization of the traditional Maya milpa, which would benefit climate adaptation strategies.

In the coastal systems, the principal effect of the perceived changes is felt in fisheries and tourism. In the community of Punta Allen, social organization is recognized as the most effective tool for confronting extreme weather events. Uncertainty surrounding potentially severe climate variability and the effect on the ecosystems was an element present in the four social systems studied. Accordingly, we consider that, in order to socialize the information generated by the climate change experts, it is crucial to improve local adaptive capacities. Moreover, the exchange of results should be promoted among participating communities.

Participatory dialogue and co-creation between rural communities will allow them to learn from the perceptions and adaptive strategies of other rural producers, encouraging timely innovation. An informed community has more opportunities to act than an uninformed one, which will facilitate adaptation and resilience. The four communities analyzed here expressed interest in receiving information on changes in climate variability patterns, thereby demonstrating their willingness to engage in what are ultimately economic, participatory and self-led climate change adaptation strategies. In other words, the human component of the SES is an active agent, because it must use adaptive strategies to ensure the livelihood and wellbeing of families.

Although climate change is a global concern; the consequences cannot be generalized, since their impact can vary. For this reason, in addition to considering the human dimension, it is necessary to explore in detail the environmental dimension (in other words, variables such as precipitation and temperature) in the study area in order to contrast the scope of the perceived changes with the changes documented through observations of comparable time periods.

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