# Perceptions of Climate Trends among Mexican Maize Farmers

by

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# ABSTRACT

Perceptions of climate variability and change reflect local concerns and the actual impacts of climate phenomena on people's lives. Perceptions are the bases of people's decisions to act, and they determine what adaptive measures will be taken. But perceptions of climate may not always be aligned with scientific observations because they are influenced by socio-economic and ecological variables. To find sustainability solutions to climate-change challenges, researchers and policy makers need to understand people's perceptions so that they can account for likely responses. Being able to anticipate responses will increase decision-makers' capacities to create policies that support effective adaptation strategies. I analyzed Mexican maize farmers' perceptions of drought variability as a proxy for their perceptions of climate variability and change. I identified the factors that contribute to the perception of changing drought frequency among farmers in the states of Chiapas, Mexico, and Sinaloa. I conducted Chi-square tests and Logit regression analyses using data from a survey of 1092 maize-producing households in the three states. Results showed that indigenous identity, receipt of credits or loans, and maize-type planted were the variables that most strongly influenced perceptions of drought frequency. The results suggest that climate-adaptation policy will need to consider the social and institutional contexts of farmers' decision-making, as well as the agronomic options for smallholders in each state.

*For those who traveled along with me, Helme, Apurimak and Awki.*

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# CHAPTER 1

# INTRODUCTION

Perceptions of climate variability and change reflect local concerns and the actual impacts of climate phenomena on people's lives. They influence people's decisions to act and suggest what adaptive measures should be taken. However, perceptions are based not only on scientific data, but also on people's knowledge about the climate, which is based on their observations, experiences, and surroundings. In the last two decades, researchers have focused on understanding public perceptions of climate variability and change (e.g., Etkin & Ho, 2007; Fosu-Mensah, Vlek, & MacCarthy, 2012; Halder, Sharma, & Alam, 2012; Leiserowitz, 2006; Patt & Schröter, 2008), including how people recognize, understand, and respond to climate-change risks based on their social, cultural, and economic attributes (Crona, Wutich, Brewis, & Gartin, 2013). Collectively, this research has underscored the relationship between perception and behavior, and thus the salience of perception to understanding why and how society responds to environmental change.

Climate change perceptions studies are place-based and population-specific (e.g., Leiserowitz 2005; Brody et al. 2008; Halder, Sharma, & Alam, 2012; Byg and Salick 2009), this is congruent with Sustainability Science research and important for several reasons. First, climate-change effects will most likely be regionally and locally uneven, as will sensitivity to them. Second, understanding that people make accurate observations of their environment has opened the doors for the appreciation of their knowledge, and can provide valuable models and unique understandings of climate change. Third, climate change perception studies recognize that local perceptions are culturally and ecologically grounded and reflect tangible, real-world concerns. Fourth, perceptions of climate change shape the capacity of individuals to adapt to it (Crona et al., 2013). Based on their risk appraisals, individuals can respond to change adaptively or mal-adaptively (Grothman and Patt, 2005); the latter exacerbates their vulnerability to risk. For all these reasons, local observations and perceptions need to be included in efforts to understand climate change (Halder, Sharma, & Alam, 2012). Such efforts are pivotal for the development of sustainability strategies to adapt to the effects of climate change phenomena in social and ecological systems.

Everywhere in the world, farmers are among the groups most vulnerable to the effects of climate variability and change (Apata, Samuel, & Adeola, 2009; Slegers, 2008; Fosu-Mensah, Vlek, & MacCarthy, 2012; Bryan et al., 2013). Studies have shown that in some cases, farmers' perceptions of climate variability and change are shaped more by their personal experience than by empirically measured climate patterns (Bryan et al., 2013). Moreover, while farmers' perceptions are based in part on a lifetime of observations, several studies have suggested that farmers emphasize recent observations in forming their perceptions of climate risk and making decisions about their adaptive behavior. For example Bryan et al. (2013) found that although the majority of the Kenyan farmers they studied perceived changes in average yearly temperatures and precipitation over the last 20 years, their perceptions appeared to be formed by recent variability in precipitation; actual climate data showed no significant trends in either climate variable. However, other studies (Apata, Samuel, & Adeola, 2009; Li et al., 2013; Vedwan & Rhoades, 2001; Wii, & Ziervogel, 2012) have shown that farmer's perceptions of climate variability and change are in sync with climate trends in their regions. Accurate perceptions of climate variability and change can help farmers to take effective measures to protect their livelihoods against threats from local environmental change; conversely, understanding how farmers perceive threats from climate change (or not) can help policymakers anticipate the diversity of strategies and behaviors that will ultimately shape the vulnerability of agriculture in the coming decades.

## Objectives and Research Questions

In this research, I aim to analyze the perception of climate change by identifying the factors that contribute to shaping them. I focused on Mexican maize farmers whose livelihoods are affected by climate variability first-hand in the states of Chiapas, Mexico, and Sinaloa. I argue that perceptions are not always aligned with empirical observations because they are affected by a combination of cultural, agro-ecological, and institutional factors. I analyzed perceptions of drought variability as a proxy for perceptions of climate change because climate change is often manifested in terms of increases in variability and extreme weather events (IPCC, 2007).

I will answer the following questions:

a. To what extent do perceptions of climate change by maize farmers in Mexico align with what climate scientists are observing and predicting?
b. What factors (e.g. socioeconomic, demographic, and agronomic) influence maize farmers' perceptions of drought variability and change in the states of Sinaloa, Mexico, and Chiapas?

# CHAPTER 2

# LITERATURE REVIEW

## Adaptation, Adaptive Capacity and Risk

Much recent research has discussed the need for adaptation to climate change, and the forms that adaptation might take (e.g. Adger et al. 2009; Pelling 2010; Smith et al. 2011). In most of these studies, adaptation has been defined as discrete policy or technology options to instigate effective responses to perceived threats. But such a definition limits the credibility and usefulness of adaptation policies because it skews priorities away from long-term system viability (Nelson et al., 2007). Some scholars have proposed that adaptation should be understood as decision-making processes in which certain actors have the power to implement the decisions (e.g., Pelling, 2010; Nelson et al., 2007). In this view, adaptation is an ongoing process that involves actors, actions, and agency. Pelling (2010, p.21) described adaptation "as the process through which an actor is able to reflect upon and enact change in those practices and underlying institutions that generate root and proximate causes of risk, frame capacity to cope and further rounds of adaptation to climate change." Adaptation can take place at various scales, from local to global (Grothman & Patt, 2005), and it is linked to reversible and irreversible changes in the state of a specific system (Pelling, 2010).

By 1980, researchers were studying how cultural adaptation (human ingenuity including technological innovation and long-range planning) affected adaptation to climate change (Butz 1980 as cited in Smit & Wandle, 2006). Since then, researchers have focused not only on adaptation strategies, but on adaptive capacity at different levels: individual, community, and system. Adaptive capacity varies from region to region and over time. It is similar to a host of other concepts, including coping ability, management capacity, stability, and robustness (Smit & Wandel, 2007). Adaptive capacity can be defined as the necessary preconditions to enable adaptation, including social characteristics, and physical and economic elements (Nelson et al., 2007). It is influenced not only by economic development and technology, but also by social factors such as human capital and governance structures (Nelson et al., 2007; Berkhout et al., 2006; Brooks et al., 2005).

At the individual level, a person's evaluation of her or his ability to prevent being harmed by a threat (in this case climate change) and the cost of taking such actions result in a specific perceived adaptive capacity. This adaptive capacity follows a risk perception process in which the person assesses the threat's probability and damage potential to things she or he values without a change in behavior; this results in a particular individual perception of risk (Grothman & Patt, 2005). Perceptions of risk depend upon a number of factors, including the extent to which a hazard is involuntary, catastrophic, dreaded, fatal, known, delayed, or controllable (Slovic, 1999). Other factors that contribute significantly to risk perception include emotions like trust, perceived benefits, ideology, and environmental and social values (Etkin & Ho, 2007). Risk perception, as well as habits, social status, and age operate at individual decision-making levels but also constrain collective action. Climate-change effects will be unequally distributed around the world, and risk perception, as one element affecting adaptive capacity, will be an important determinant of which areas will adapt successfully to climate change (Lemos et al., 2013).

## The Study of Perceptions

### *Philosophical Approaches*

Individuals cannot prevent loss from a hazard unless they are aware of the nature of the nature of the hazard and its consequences to them personally (Tobin & Montz, 1997). Researchers have taken a number of approaches to understand individual perceptions of risk before, during, and after hazardous events. These approaches are neither independent nor mutually exclusive; all study interacting forces that can be viewed and evaluated differently. The approaches fall into four categories.

**Economic utility models** are based on the "rational individual theory," which assumes that an "economically rational person who is in command of all the facts [is] capable of making a logical decision" (Tobin & Montz, 1997, p. 144). This model assumes that in a hazardous situation individuals will consider a series of options and select the actions most likely to provide the greatest benefits prior to a hazard event. However, most individuals do not have or cannot assimilate all the necessary information on which to base a decision; thus, their ability to make optimal decisions is limited.

**Behavioral studies** from the mid-20$^{th}$ century recognized that traditional economic cost-benefit analyses for hazard zones were simplistic. Cost-benefit analyses were unable to explain individuals' decisions about responding to hazards, and certainly could not account for many of the seemingly irrational activities found within hazard zones. To explain this irrationality, Gilbert F. White and the Chicago School redirected hazards research to incorporate more social analysis in framing the research question, based on their premise that social factors were instrumental in governing behavior.

White (1974) analyzed more than 30 studies from around the world to show that socioeconomic constraints influence individuals' perceptions of hazards, and thus their actions in relation to hazardous events.

Whatever perception or information an individual has about a hazard, he or she has a choice of how to behave in response to the perception or information, and preferences influence choice. **Preference models** attempt to understand how people behave with respect to hazards, using the concepts of "expressed" or "revealed" preferences. The expressed-preferences approach looks at what individuals say they would do in hypothetical hazard situation. In other words, it assesses what individuals perceive as acceptable behavior in a hazardous situation. This approach has been criticized for not considering the fact that individuals may not always do what say they would. Under the revealed approach, disaster victims are interviewed after an event in order to analyze what they did before, during, and after it (their actions are interpreted as a manifestation of risk perception).

Finally, **political economy** approaches point out that vulnerability to hazards is not distributed equally among individuals or classes: marginalized groups suffer more than others (Tobin & Montz, 1997; Wisner, 2004). These groups are the product of complex socioeconomic relationships which distribute power unequally. Political economists would argue that marginalized individuals do not necessarily have the power to adapt to hazards such as climate change, regardless of the risk they perceive. For example, on a study in nine villages across India researchers found that marginalized communities have already visualized the impacts of climate change on both their natural surroundings and in their socio-economic conditions, however they lack the adaptive capacity to face such changes (Halder, Sharma, & Alam, 2012). The current vulnerabilities of these communities are linked to the historical socio-economic changes that took place in their settlements. Thus, today's climatic conditions exacerbate their existing vulnerability and decrease their capacity to adapt.

## Psychological Processes of Risk Perception

To understand perceptions of climate change, researchers have focused on psychological and attitudinal characteristics, also known as cognitive variables. Cognitive variables include personality characteristics, cultural background, sense of control over one's surroundings, and attitudes towards risks, among others. These variables influence individuals' perceptions of the environment, and their propensity to take or avoid risk (Tobin & Montz, 1997). Thus, individual perceptions of climate change are influenced by cognitive characteristics. Two processes, judgment heuristics and cognitive bias, influence perception of the degree of a risk. When evaluating a risk, people search their memories for vivid examples of the risk (Grothman and Patt, 2005). Events that create vivid memories, as well as events that have occurred recently are the ones judged by those who have experienced them to be most likely to happen again (Crocker, 1981; Kahneman & Tversky, 1979; Grothman and Patt, 2005). For example in Kenya, farmers' perceptions of long-term decreases in rainfall were found to be based more on their experiences with shifts in timing and distribution of rainfall than on average annual rainfall (Bryan et al., 2013). Several studies have found that farmers' memories of climate conditions are most accurate within the most recent half decade (Vedwan & Rhoades, 2001; Wii & Ziervogel 2012).

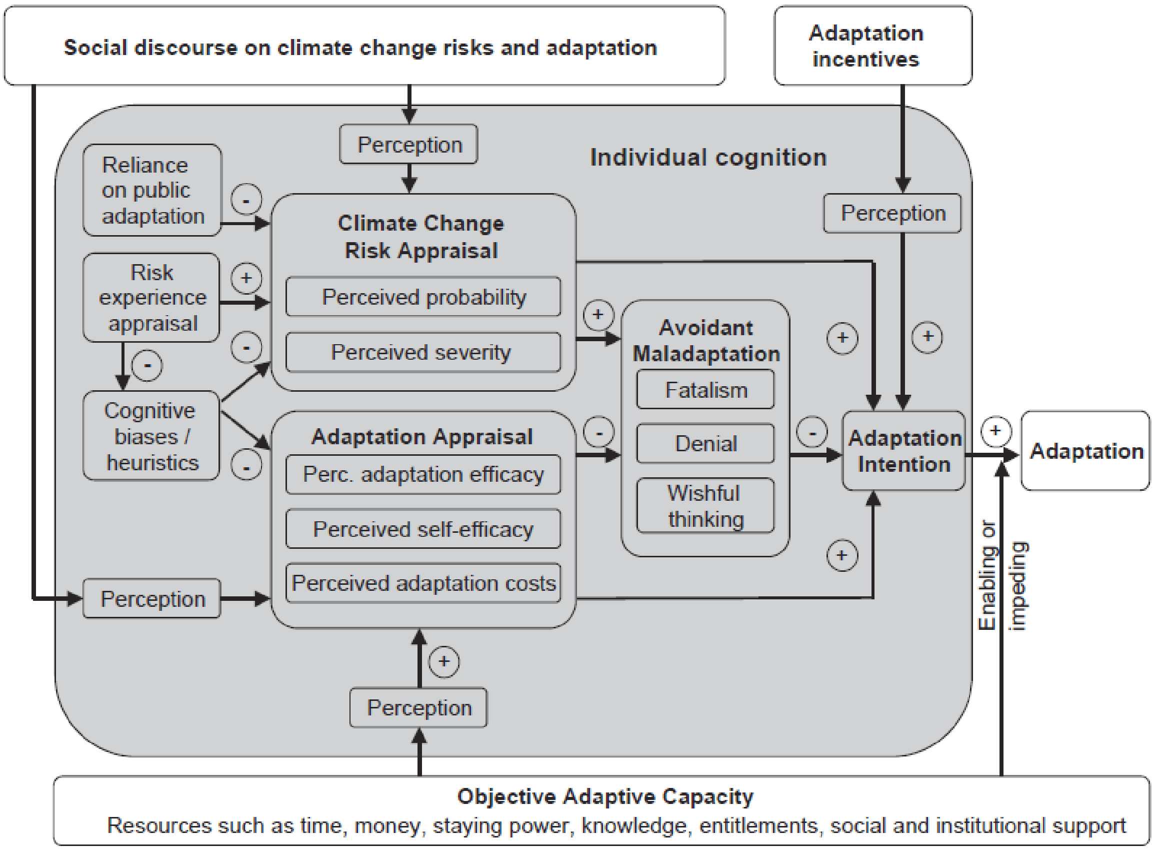


Fig. 1 Model of Private Proactive Adaptation to Climate Change (MPPACC). (Source: Grothmann and Patt, 2007)

Situational variables—those related to physical characteristics of a hazard and socio-economic factors that limit a person's range of choices—also influence perceptions of climate change. They include what people hear about hazard events (in the media, from friends, colleagues, public agencies, etc.), not just what they personally experience (Grothmann & Patt, 2007).

To explain why individuals adapt differently to risks from climate change, Grothmann and Patt (2007) developed the Model of Private Proactive Adaptation to Climate Change (MPPACC; Fig. 1). The model differentiates two perceptual processes, *risk appraisal* and *adaptation appraisal*. Risk appraisal, which occurs first, is how "individuals assess a threat's probability and damage potential to things s/he values, under the condition of no change in his or her own behavior" (Grothmann and Patt, 2007, p.203). In the *adaptation appraisal* process, "a person evaluates his or her ability to avert being harmed by the threat, along with the costs of taking such action" (Grothmann and Patt, 2007, p.203). Whereas the cognitive process of risk appraisal results in risk perception, the result of adaptation appraisal is a specific perception of one's own adaptive capacity or self-efficacy. An individual will respond to a threat by either preventing damage if adaptive capacity is high (adaptation), or by choosing a maladaptive strategy such as denial, wishful thinking, or fatalism. Those who choose an adaptive response form an adaptation intention to take action, but this is different from actual behavioral adaptation because people often have intentions that they do not carry out. An intention to adapt can be minimal or unproductive if individuals objectively lack adaptive capacity (e.g., lack of time, money, staying power, knowledge, entitlements, social or institutional support). Objective adaptive capacity also influences perceived adaptive capacity, since people's perceptions of their adaptive capacities are only partly realistic (Grothmann and Patt, 2007, p.203).

Although the main focus in the literature on adaptation to climate change has been to model adaptation processes based on resources (or, in the MPPACC framework, objective capacities) that determine individual capacity to act, motivation and perceived abilities are equally important determinants of human action. The MPPACC has proven to make accurate predictions and descriptions about adaptation processes in two case studies, in urban Germany and rural Zimbabwe; and could make accurate predictions of future adaptations by including socio-cognitive indicators (Grothmann and Patt, 2007).

Socio-cognitive variables also play an important role in shaping perceptions of risk and these factors, too, need to be considered.

# CHAPTER 3

# BACKGROUND

## Mexico

The Federal Republic of Mexico is located between latitudes 14° and 33°N and longitudes 86° and 119°W in the southern portion of North America. It is bordered by the United States on the north; the Pacific Ocean on the west; Guatemala, Belize, and the Caribbean Sea on the southeast; and the Gulf of Mexico on the east. By total area,

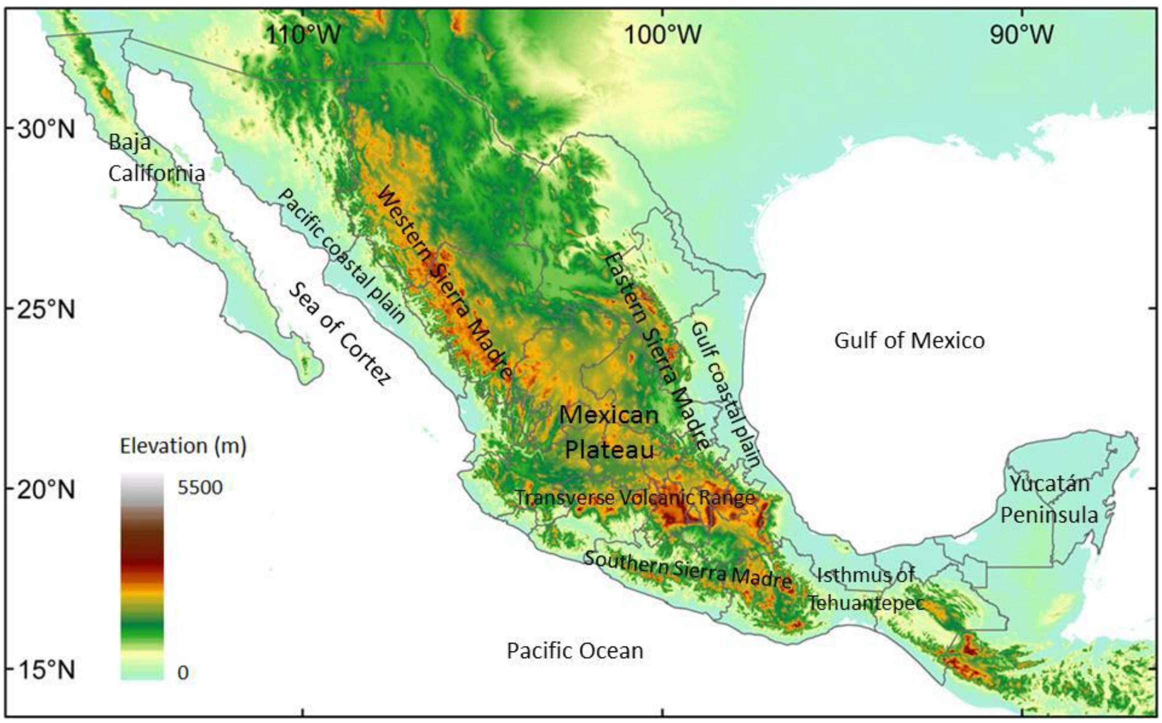


Fig. 2 Mexican topography and relief features. Elevation map generated with a HydroSHED digital elevation model product (http://hydrosheds.cr.usgs.gov), (Dewes, 2013).

Mexico is the fifth-largest country in the Americas and the eleventh most populous country in the world. It has an estimated population of 118 million inhabitants and an average population growth of 1.07% per year. The population is ethnically diverse, composed of seventeen indigenous groups, as well as populations of European and North

American origins and mixed cultural and ethnic groups (mestizos[1]) (Instituto Nacional de Estadistica y Geografia [INEGI], 2013).

Mexico is crossed in multiple directions by several mountain ranges including the Western Sierra Madre, the eastern Sierra Madre, and the Transverse Volcanic Range, among others. The Mexican Plateau is located in the center of the country, and it is home to the Valley of México, which contains most of the México City Metropolitan Area, parts of the State of Mexico, Hidalgo, Tlaxcala and Puebla (See Fig. 2; Dewes, 2013). Thanks to its complex topography and geographic location Mexico has a large variety of climates. In general these climates can be classified by their temperature as warm or temperate, and their humidity levels as very dry, humid, and sub-humid (See Table 1; CONAGUA, 2014).

As for the seasons, the rainy season runs from May to October, with August being the wettest month of the year. The rainy season begins over eastern and southern Mexico and progresses northward providing the country over 70% of its annual precipitation. In the south-east, the rainy season is interrupted during the summer months which leads to a mid-summer drought and a reduction in precipitation of approximately 40% in the region. The dry season takes place during the winter and brings light rain in the northwest and cold surges in the eastern portions of the country (Dewes 2013).

[1] Term traditionally used in Spain and Spanish-speaking America to mean a person of combined European and Native American descent

Table 1. Temperature and Precipitation by Climate Type.

| Climate Type | Country coverage (%) | Average Temperatures (°C) | Annual average Precipitation (mm) |
|---|---|---|---|
| Dry | 28.3 | 22-26 | 300-600 |
| Very dry | 20.8 | 18-22 | 100-300 |
| Warm Humid | 4.7 | 22-26 | 2,000-4,000 |
| Warm Sub-humid | 23 | 22-26 | 1000-2000 |
| Template humid | 2.7 | 18-22 | 2,000-4,000 |
| Template sub-humid | 20.5 | 10-18, 18-22 | 600-1000 |

Source: CONAGUA (2014)

### *Mexican Maize*

In Mexico the vulnerability of maize to climate change is especially important because maize is a "keystone" crop with deep significance for food security, national political stability, culture, and environment (Sweeney et al., 2013; Eakin et al., 2013). Maize is grown throughout the year during two seasons: spring-summer (April to October) and fall-winter (October to February) (SIAP, 2009). Although it is produced across the whole country in a wide range of agro-climatic conditions, eight Mexican states (Sinaloa, Jalisco, México, Chiapas, Michoacán, Guerrero, Guanajuato, and Veracruz) are the major producers, accounting for about 70% of the total production. Domestic maize production in Mexico has increased over the past 20 years from 14 million tons in 1990 to 23 million tons in 2010, despite the changing nature of the maize food system (Appendini, 2013). Mexico's population is currently 118 million and has become increasingly urban (76 %). Per capita consumption of maize has increased to an estimated 315 kilograms (2009), up from 223 kilograms in 1990. The demand for maize for industrial uses has also increased with growth in the processed food and livestock-feed industries. In 2006, 38% of the total maize supply was destined for human consumption for tortillas; 51 % went to the animal-feed industry, and 11% went to other food industries such as starch, cereal, and snacks (SAGARPA, 2007). Maize production has gone through a number of geographical shifts and changes in production associated with distinct but subtle shifts in maize policy (Sweeney et al., 2013).

Before the 1990's, central and southern Mexico were the primary areas of maize production. Jalisco, Mexico, and Chiapas (where maize is produced under rainfed conditions) were the main spring-summer growing areas, responsible for 39% of non-irrigated maize production; by 2006 their production had dropped to 28%. Meanwhile, from 1989 to 2006, the state of Sinaloa in the northwest increased its output of irrigated maize (produced in the winter season) from 6.9% to 21.3% (Appendini, 2013). Although the contribution of irrigated maize to national production has increased over the last three decades (Sweeney et al. 2013), three-quarters of Mexico's maize is still produced during the spring-summer growing season, and 65% is grown on non-irrigated farmland (Juarez & Ford, 2010). The state of Sinaloa alone accounts for over 70% of the fall-winter irrigated production—nearly a quarter of Mexico's annual production of white maize (Eakin, Baush, & Sweeney, 2013). Although Sinaloa's farmers enjoy the benefits of irrigation, their success still depends on seasonal rainfall accumulation to recharge the reservoirs that supply water to the irrigation systems. Central and Southern Mexico rely primarily on the timing and abundance of rainfall for maize farming (Sweeney, 2013). Seasonality determines the rate of plant growth in both production regimes because even when water availability is controlled through irrigation, temperature still affects growth (Dewes, 2013).

### ***Current Climatic Trends***

A study by Dewes (2013) of climate trends between 1950 and 2008 reveals that Mexico's climate has been changing. I used these results to understand the current and projected climate trends in Mexico and analyze perceptions climate events among maize farmers.

Temperature and precipitation measurements in Mexico indicate that the beginning of the rainy season is shifting, annual precipitation totals are changing, and the number of days without precipitation is also changing. Over the slopes of the Southern Sierra Madre and the Transverse Volcanic Range, the rainy season has been delayed at a rate of 0.3-1.4 day/yr; the same trends are observed over western Michoacán and Sinaloa. The opposite is observed over the Yucatan Peninsula, the south-Pacific coast, and the northern Mexican Plateau, where the rainy season is starting earlier.

Average rainy-day precipitation has been increasing slowly over low-lying areas in Jalisco, Oaxaca, Chiapas, and the Yucatan Peninsula at a rate of 0.1mm/yr. Along the southeastern slopes of the highlands, trends indicate a decrease in average daily precipitation (both wet and dry days) ranging from 0.05 to 0.15 mm/yr. Annual precipitation totals differ by region as well. Over the state of Sinaloa annual precipitation is decreasing at a rate of 5mm/yr, which reduces water discharge from rivers that fill Sinaloa's dams. Decrease rates in annual precipitation totals range from 10 to 40mm/yr in parts of Hidalgo, Veracruz, Puebla, and eastern Oaxaca. Precipitation increases range from 5 to 10 mm/yr over Guerrero, western Oaxaca, and the Yucatan Peninsula.

Reduced annual precipitation is a function of an increase in dry days. In Sinaloa, the number of dry days is increasing at a rate of 0.3-07 day/yr, and by 0.5-1.5 day/yr along the Gulf coast. Meanwhile, a decrease in dry days is observed over the Yucatán Peninsula, the Isthmus of Tehuantepec, parts of Oaxaca and Guerrero, and across the northern Plateau.

For the state of Mexico, Dewes did not find significant changes in the climatic trends. Nonetheless a study by Groisman, et al., (2004) that there has been a substantial decrease in precipitation and an increase in heavy precipitation events during the period 1974-2004.

***National and Regional Climate Projections and Agriculture***

Climate projections suggest that Mexico will experience a decrease in precipitation combined with increasing average temperatures and more frequent and intense extreme events (Dewes, 2013; IPCC, 2014; See Table 2), with droughts as the major risk for maize farmers. Cultivation of irrigated maize is more efficient than cultivation of rainfed maize, but among the three states in this study, only Sinaloa has extensive irrigation infrastructure. Rainfed maize remains more widely produced all over Mexico (Dewes, 2013); its cultivation is productive because farmers have developed maize varieties to adapt to different growing conditions (Ruiz Corral et al., 2008). Nevertheless, continued cultivation of rainfed maize is threatened by changing climate conditions (Perales et al., 2003). Rainfall alone will no longer supply enough moisture for maize to mature, and moisture-stress over time may reduce both yields and soil fertility (Dewes, 2013). Lower yields might lead to abandonment of maize cultivation, or make it dependent on irrigation (Thornton, 2012). Therefore, some researchers advocate for government intervention to offset the effects of climate change on maize production and encourage adaptations to increase maize farmers' resilience (Dewes, 2013).

In Sinaloa, average temperatures are expected to increase between 0.5 and 1.0°C by 2020, and precipitation patterns are expected to vary from +10 to -20% by 2050 (Flores et al., 2012). In addition, the coast of Sinaloa, where much of the population and economic activity (including irrigated agriculture) are located, is highly vulnerable to a sea level rise. A sea level rise would result in coastal-zone erosion and salinization of groundwater, changes in vegetation, and damage to coastal wetlands, among other impacts (Flores et al. 2012).

Table 2 Observed and Projected Climatic Trends by State.

| | **References** | **Projected Period** | **Observations** |
|---|---|---|---|
| **Sinaloa** | Dewes (2014) | Current | Delayed start of the rainy season at a rate of 0.3-1.4 day/yr.<br>Decrease of precipitation at a rate of 5mm/yr, which threatens water discharge from rivers that fill Sinaloa's dams.<br>Increase in the number of dry days at a rate of 0.3-07 day/yr, and 0.5-1.5 day/yr along the Gulf coast. |
| | Rivas et al., (2012) | 2030 | Projected increase of 1.3 and 1.5°C and reduction of precipitation between 15 and 20mm. |
| | Flores et al. (2012) | 2050 | Increase of 1.5-2.5°C and a variation in precipitation between +10% and -20%. |
| | INE (2011) | 2050 | Variation in total annual precipitation between +10 and -20%, and 1.5 and 2.5°C in average annual temperature. |
| **State of Mexico** | Groisman, et al., (2004) | 1974-2004 | Substantial precipitation decrease in the last 30 years, but heavy precipitation events increased during the same period (1974-2004) |
| | Rivas et al., (2012) | 2030 | Projected increase of 1.3 and 1.5°C and reduction of precipitation between 15 and 20mm. |

Table 2 Continued

| State of Mexico | References | Projected Period | Observations |
|---|---|---|---|
| **State of Mexico** | INE (2011) | 2050 | Decrease in total annual precipitation between 5 and 10%, and an increase average annual temperature between 1.0 and 2.0°C |
| **Chiapas** | GEC (2011) | Current & 2015-2039 | *Current trends:*<br>An increase of 1.8°C in average temperatures and a decreased of 500mm in annual precipitation.<br>Increase of heat/high temperature events (of at least 6 consecutive days).<br>*Projected trends*:<br>-Increase of maximum temperatures between 3 to 3.6°C, and 2.5 to 2.8°C for minimum temperatures.<br>-By the end on the century increase of precipitation higher than 0.7mm/day for Soconusco area and a reduction between -0.7 and -1 for the Altos, Sierra, Fronteriza and Selva.<br>-Dry days are projected to last between 30 to 50 consecutive days in the near future (2015-2039). |
| | Rivas et al., (2012) | 2030 | Temperatures projected to increase between 1.5 and 2°C, and decrease of precipitation between 20 to 50 mm. |
| | Schroth et al., (2009) | 2050 | Increase of 2.1 to 2.2°C and decrease in precipitation between 80 to 85mm (4 or 5%). |
| | INE (2011) | 2050 | Variation in precipitation between +10% and -10%, and an increase in average annual temperature between 1.0 and 2.0°C. |

In the state of Mexico, average temperatures are expected to increase between 1.0 and 2.0°C, while precipitation is expected to decrease by 5 to 10% (INE, 2011). An increase in average temperature of +2°C and precipitation of -10% will favor the warm, humid climates with tropical evergreen forests (Villers, & Trejo, 1995) and  maize production at higher regions, such as Atlacomulco and Toluca (Ferrer, 1995). Land erosion is expected to increase during the dry periods and might imply a loss of up to 25 tons of soil per year (Zárate, 1995).

Global circulation models for Chiapas concur that the state will experience an increase in average temperatures and a decrease in rainfall (Schroth et al., 2009). These changes will be different in each of the nine economic regions of the state, which include the Centro, Altos, Fronteriza, Frailesca, Norte, Selva, Sierra, Soconusco and Istmo-Costa (Schroth et al., 2009). In Chiapas, maximum temperatures will increase between 3°C and 3.6°C and minimum temperatures between 2.5°C and 2.8°C. Precipitation is expected to increase in the Soconusco by 0.7 mm/day and reduce drastically in the Altos, Sierra, Fronteriza and Selva by an order of -0.7 to -1.0. In the near future, drought events are expected to last longer from 30 to 50 days, and up 60 days by the end of the century in Itsmo-Costa, Frailesca, Centro and Fronteriza (Gobierno del Estado de Chiapas (GEC), 2011). In addition, the coastal region will be affected by a higher frequency of natural disasters such as hurricanes and droughts (Saldaña-Zorilla, 2008).

## Research Sites

### *Sinaloa*

The state of Sinaloa is located on the Pacific Northwest coast of Mexico. It is bordered to the east by the Sierra Madre Occidental Mountain Range, which separates it from the states of Sonora, Chihuahua and Durango. Sinaloa's climate is warm and sub-humid with an average annual temperature of 23.8°C (Schmidt Jr., 1976). Annual precipitation is about 80 cm, with most precipitation falling during the monsoon season

(Comrie & Glenn, 1998; Liebmann, et al., 2008). Sinaloa has a population of approximately 2.7 million people of which 151,944 are farmers. There are very few organized indigenous groups in the state and overall they constitute 0.9% of the state's population. The main indigenous groups are the Mayo, followed by the Nahuatl, Taramahura, and the Mixteco.

In terms of agricultural productivity, Sinaloa is the most prominent state in Mexico. Agriculture occupies 25% of the state's landscape (Gobierno del Estado de Sinaloa (GES), 2009b) and represents 14.9% of Sinaloa's GDP. Most crop production in the state is irrigated with surface water channeled from one or more of eleven river dams (GES, 2009a). The main crops are maize, tomatoes, beans, wheat, sorghum, potatoes, soybeans, sugarcane and squash. Since 1990 Sinaloa has emerged as a large-scale producer of irrigated maize in Mexico, departing from the traditional small-scale, rain-fed maize cultivation that is typical in the rest of the country (Aguilar Soto, 2004; Sweeney et al. 2013). Maize production in Sinaloa expanded rapidly from 140,727 ha planted in 1989 to a peak of 606,917 ha in 2008. This is the result of federal neoliberal economic reforms in the late 1990's, new high-yielding seeds varieties, and the cultivation maize under irrigation (Bausch, 2012; Eakin et al. 2014). Today, maize constitutes the most important agricultural production in the state being a monoculture in Sinaloa during the winter growing season (Eakin, Bausch, & Sweeney, 2014).

### *State of Mexico*

The state of Mexico is located in the center of the country and it has a territory of 22,499.95km$^2$ that surrounds the Federal District (Mexico City, of which is independent in its economy and population) and borders the states of Querétaro, Hidalgo, Guerrero, Morelos, Puebla, Tlaxcala and Michoacán. Mexico's climate is mostly humid with an average temperature between 12°C and 18°C and an annual precipitation of 70cm. Highlands in the center and east, about 13% of the state, have a semi-cold climate, with average temperatures as low as 16°C. Hotter climates are in the relative lowlands in the south-west with an average temperature between 18°C and 22°C and constitute about 8% of the territory. The hottest regions occupy 5% of the state in the extreme southwest with temperatures averaging over 22°C. The coldest areas in the highest elevations such as the Nevado de Toluca, Popocatepetl, and Iztaccihuatl. Snow can be found on these elevations year round. There are some arid areas along the borders of Hidalgo and Tlaxcala with annual precipitation between 500 and 700 mm.

Mexico is the most populous and densest state in the country with over 15.2 million people (520 people per square km) as recorded in the 2010 national census. The main indigenous groups in the state are the Mazahua, the Otomi, the Nahuatl, the Matlazincas and the Ocuitecos or Tlahuicas; overall these groups constitute 2.8 % of the population. The state of Mexico is responsible for 9.7% of the country's gross national product. The most important sector of the economy is industry and manufacturing, with over 10 % of the state's land urbanized. Most of the state's land is devoted to agriculture (38.1%) or to forest (34.9%); and along with fishing and hunting these activities represent 8.92% of the state of Mexico's GDP (INEGI, 2011) . Much of the crops and forest lands are under ejido[2] or communal tenure. The main crop is maize, with peas, barley, beans, potatoes, alfalfa, wheat, avocados and guava also grown. In 2012 the total volume of

[2] In Mexico an ejido is an area of communal land used for agriculture, on which community members or ejidatarios individually possess and farm a specific parcel.

maize produced in the state was 1,575 thousand tones which represented 7.1% of the national production (Secretaria de Hacienda y Credito Publico [SHCP], 2014).

***Chiapas***

Chiapas is the southernmost state of Mexico, bordered by the states of Tabasco to the north, Veracruz to the northwest and Oaxaca to the west. To the east Chiapas borders Guatemala, and to the south the Pacific Ocean. It possesses a highly complex geography that includes different geographic regions, including the Pacific Coast Plains, the Sierra Madre de Chiapas, the Central Valley, the Central Highlands, the Eastern Mountains, the Northern Mountains and the Gulf Coast Plains. The regional climate is tropical in essence with rainfall on the north averaging 3,000 mm (120 in) per year. Chiapas is the eighth most populous state in Mexico with over 4.8 million people. In addition, the state has about 13.5 % of all of Mexico's indigenous population. The main indigenous groups are Tseltal, Tsotsil, Ch´ol, Zoque and Tojolabal. These indigenous peoples are characterized for a strong resistance to assimilation into the broader Mexican society, which is best depicted in the retention of indigenous languages and political and territorial demands. Economically, Chiapas accounts for 1.73 % of the Mexico's GDP. Agriculture is the primary economic sector in the state, which produces 15.2 % of the state’s GDP. Agricultural production relies on rainfall either seasonally or year around since only 4% of fields are irrigated. Major crops include maize, beans, sorghum, soybeans, among others (SIAP, 2011). In 2012 the total volume of maize produced in the state was 1,404 thousand tones which represented 6.4% of the national production (SHCP, 2014). Despite being rich in resources, Chiapas lags behind the rest of the country in almost all socioeconomic indicators (Shuster, 2009), which are the lowest in the country including income, education, health and housing.

## CHAPTER 4

## METHODS

I studied maize famers' perceptions of drought variability and change in the states of Sinaloa, Mexico, and Chiapas. Fig. 3 shows the location of each state in Mexico, and Table 3 presents a comparison of several of the states' attributes.

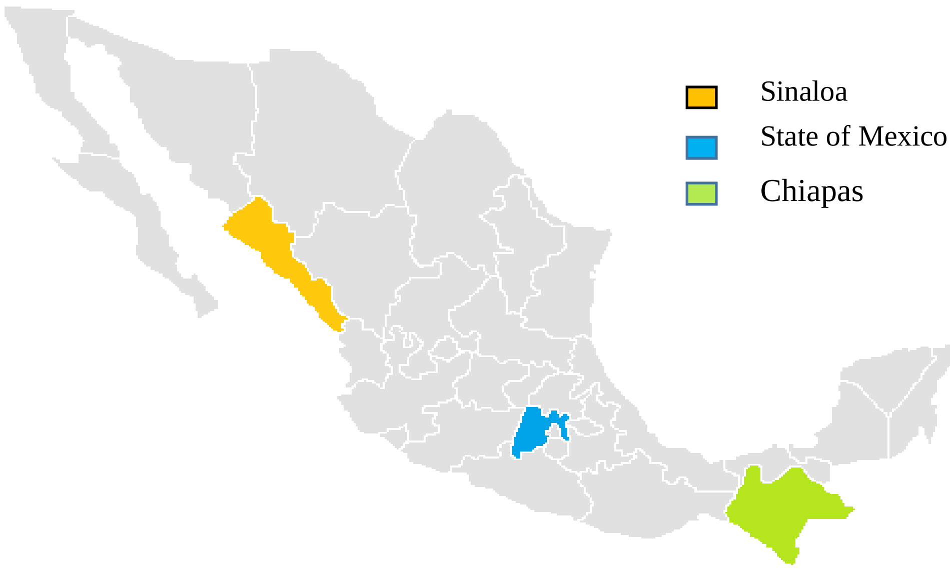


Fig. 3 Research Sites.

Table 3 Demographic, Economic, and Ecological Attributes of the Study Sites.

| | **Sinaloa** | **State of Mexico** | **Chiapas** |
|---|---|---|---|
| Land Area (km$^2$) | 57,365 | 22,499 | 73,311 |
| Population (millions) | 2.8 | 15.2 | 4.8 |
| Percent of Population Belonging to Indigenous Groups (%) | 0.9 | 2.8 | 27.2 |
| Annual Average Temperatures (°C) | 25 | 12-18 | 18-28 |
| Annual Average Precipitation (cm) | 79 | 70 | 120 |
| Contribution to GDP (%) | 2.1 | 9.2 | 1.9 |

Source: INEGI

## Sampling Plan

Data was collected through surveys administered in rural development districts (DDR's) in the states on Chiapas and Mexico, and an irrigation district in Sinaloa. In Chiapas and Mexico DDRs were selected based on their maize production characteristics including contribution to total state production, land area planted and the degree of change in land area planted since 1990. In Chiapas, three DDRs were selected to account for the variability in agro-ecological conditions for maize production. The survey sample for Chiapas covered maize grown in the highlands, where primarily indigenous populations farm on small plots, as well as the lowlands, which are better known for commercial grain production and mixed livestock–grain operations. In the state of Mexico, the DDR of Atlacomulco, located in the central highlands, was selected based on its long history of maize farming. Within the DDRs in Mexico State and Chiapas, researchers used publicly-available database of the direct-support programme PROCAMPO[3] to select a series of communities to participate in the survey at random, as well as households for the sample.

In Sinaloa, researchers focused on the coastal irrigation district of Culiacan. A random sample of farmers was taken in four irrigation modules (administrative units within the irrigation district), also selected at random from the complete list of modules in the district. Researchers used a list of registered water users as the sampling frame within each module. The sample was stratified by landholding size, as reported in the

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[3] Programa de Apoyos Directos al Campo (PROCAMPO, Direct Field Support Programme), provides direct payments to farmers for acreage planted in any of nine basic grains including maize. The programmer was established in 1994, with the objective of easing farmers' transition from being semi-subsistence maize and bean farmers, to competing in the international market in specialty crops or products of higher value.

water user database, to ensure that the survey captured larger-scale private-tenure producers in this sample.

## Data Collection

I used data from 1459 surveys administered across four DDR's and one module in Chiapas (n=603), Mexico (n=407), and Sinaloa (n=449). The surveys were administered as part of a study by Eakin et al. (2014). The surveys collected information about household demographics and sources of livelihood, agricultural practices, yield and crop choice, changes in land area over the previous decade, maize marketing and consumption patterns, and perceptions of climate variability and climate change. Households that had produced maize at any time during the period 1990-2009 were surveyed, including those that had ceased production prior to the survey. In Chiapas and Mexico, data was collected from November to February and questions pertained to the 2009 spring crop that had just been harvested. In Sinaloa, the surveys took place in January 2010 and targeted the winter crop from the prior year (harvested May/June 2009), as well as the spring/summer crop that would have been harvested just prior to the survey. (For more information see Eakin et al., 2014.)

## Data Analysis

### *Maize Farmers Perceptions and Empirical Observations*

In order to answer my first research questions, I focused on the current climatic patterns in Mexico (mostly temperature and precipitation patterns). I reviewed multiple authors with a special focus on Dewes (2013) and compared their findings on trends in climatic variables with results of a set of questions in the household survey. The survey questions asked: "*Which climatic factors affected your production?* (i.e. drought, heat/high temperatures, hail, colds/frosts, changes in seasons/wet days, and floods); and "*How do you think that bad weather has changed in the last ten years?"*

### ***Situational Factors that Influence Maize Farmers' Perceptions of Climate Change***

Based on a review of the literature on perceptions of climate change, I hypothesized that certain situational factors would influence maize farmers' perception of drought, in Chiapas, Sinaloa, and the state of Mexico. Below are the hypotheses for each factor.

*Ethnicity*. Perception is strongly associated with worldviews, and although worldviews can vary at the individual level, there is also a shared cultural component to perceptions about human-environment relationships (Slegers, 2008). Therefore, I hypothesized that cultural values shape people's perceptions of climate variability and the decisions and actions they take to adapt to it. The cultural values held by an individual are determined, at least in part, by that individual's ethnicity. We do not yet know how ethnic identification influences perceptions of drought, although there is some indication that, for example, coffee-producing households in Chiapas have a fatalistic attitude about environmental change that could be associated with their ethnic identity (Frank, Eakin, & Lopez-Carr, 2011). The literature suggests that members of indigenous cultures are more aware of environmental variability because of their traditional knowledge based on a combination of biological, agronomic and cultural indicators (e.g. Boillat and Berkes, 2013; Lopez, 2011) than members of non-indigenous cultures. Therefore, I hypothesized that indigenous farmers would be more aware of climate variability than those who are not indigenous. I used language spoken as an indicator of ethnic identity.

*Public support*. Economic support may provide farmers with access to information about climate risks and adaptation strategies available in the market (Fosu-Mensah, Vliek & MacCarthy, 2012). While a better understanding of both risk and adaptation might help farmers make decisions that would shield them from current and future climate risks, farmers who receive public support and/or have access to credit or loans might feel protected from risk and thus take no action to adapt. In Mexico, forms of public support include insurance and technical assistance such as the "Componente de Apoyo a la Cadena Productiva de los Productores de Maíz y Frijol" (PROMAF, Component of Support to the Production Chain of Maize and Bean Producers).

*Access to credit*. Getting credit might give individuals greater access to information via the supplier of credit, and aid in realizing adaptations (i.e., making intention to act actionable), but it also exposes them to financial risk that might make them more sensitive to the possibility of loss.

*Agricultural Dependence*. Perceptions of climate variability might be influenced by the degree of household dependence on agriculture. Farmers whose incomes are supplemented by off-farm activities might not be as sensitive to climate variability as those whose incomes depend solely on farming (Eakin & Bojorquez-Tapia, 2008; Eakin & Appendini, 2008). I hypothesized that households whose income comes primarily from agriculture would be more aware of climate variability than those whose primary incomes are from nonagricultural work.

*Maize varieties grown*. Maize varieties have different sensitivities to drought and thus to climatic variability (Brush & Perales, 2007; Eakin, 2000). I hypothesized that farmers who grow several rainfed varieties of maize may have a more accurate perception of climate variability than those who grow a single irrigated variety, because they depend on rainwater and thus need to be aware of prevailing climate conditions (particularly season-to-season). However, growing several maize varieties may also reduce their sensitivity and thus their perception of risk because they have self-efficacy or high perceived adaptive capacity. On the other hand, farmers who plant criolla (indigenous) varieties may be better adapted to existing climatic variability and thus less perceptive of climatic trends. After weighing these possibilities, I hypothesized that farmers who plant several criolla varieties of maize are most perceptive about climate variability than those who do not.

In addition to the factors above, which I derived based on the literature, I hypothesized that three other factors would influence farmers' perceptions of climate change: irrigation vs. rain-fed watering, and access to regional and national media.

*Irrigation vs. rain-fed agriculture*. Mexico and Chiapas states produce primarily rainfed maize, while Sinaloa produces irrigated maize. Nevertheless, a small number of households in both Mexico and Chiapas have access to some irrigation, albeit at different times in the season. In Mexico, for example, irrigation is used primarily as an auxiliary source of water, allowing farmers to plant prior to the start of the rainy season. In Chiapas, some households in the Central Valley have more regular access to water during the entire growing season. Irrigation is likely to shield farmers from some inter-annual climate variability, particularly in the short-term. Thus, I hypothesized that farmers' perceptions of climate variability will be affected by whether their production is rainfed or irrigated.

*Access to regional and national media*. Farmers with access to regional and national media are have access to local and national conversations about climate variability than those without access to such information sources. Therefore, I hypothesized that the more sources of information a farmer has, the more likely their perceptions are to align with scientific observations.

*Changes in maize yield.* I hypothesized that changes in yield would signal environmental changes to farmers, and thus influence their perceptions of climate variability.

### *From Factors to Variables*

To analyze the survey data quantitatively, I derived eight independent variables from the factors discussed above as possible predictors of perception of drought in Mexico (See Table 4). I used the variable "perception of drought" as my dependent variable. This variable was measured using one question from the survey that asked participants who reported having been affected by drought, "*How do you think drought has changed in the last ten years*." Farmers could choose one of three answers: "has not changed," "decreased," and "increased." For statistical analysis purposes, I recoded this variable and made it a binomial variable with the values "has not increased" and "increased."

Table 4 Predictor Variables and their Respective Questions.

| Variable | Survey question |
|---|---|
| Language | Do you speak a language other than Spanish? If so, what language? |
| Support | Do/have you participate(d) in a support program? |
| Credit | Do you received/have received loans or credits? |
| Agprimary | Does your primary income come from agriculture-related sources? |
| Irrigation | Do you use irrigation water to grow maize? |
| Criolla | Do you Grow criolla varieties of maize? |
| Infolevel | How many sources of information do you have? (TV, internet, computer) |
| Yield | Have your maize yields changed in the last 20 year? (decreased, increased, remained the same). |

To further analyze and discuss the influence of these variables in our population sample I used other socio-economic variables in the survey such as land ownership, production contracts, crop insurance, and technical assistance.

***Independent Variables in Sinaloa***

In Sinaloa maize is highly commercial, with yields comparable to the United States. Producers are large-scale farmers with different socio-economic attributes in comparison with the other states (Eakin et al. 2014). Because of these attributes there are many variables that cannot be used to predict the perception of drought in the state. For example, language cannot be used because Spanish is the predominant language among the farmers surveyed. The same happens with the variable irrigation because all farmers produced maize under irrigation. Another variable that is not a good fit for the state of Sinaloa is “criolla” because none of the farmers surveyed planted criolla varieties. This leaves us with five variables to test, credit, agprimary, support, yield and Infolevel.

### *Statistical Tools*

**The chi-square test** is a statistical analysis that is employed to determine the association between two categorical variables, or, in other words, the influence of one variable over another. By doing this analysis, we measure the divergence of the observed data from the values that would be expected under the null hypothesis of no association. The null hypothesis ($H_0$) assumes that there is no association between the variables (or that one does not influence the other), while the alternative hypothesis ($H_a$) claims that some association/influence does exist. The chi-square test allows us to reject or retain the $H_0$. If we retain the null hypothesis, then we can say that the association/influence between variables could have been caused by chance. If we reject the $H_0$ and accept the $H_a$, then we can say that it is unlikely that the association/influence between variables is due to chance alone. Since $H_a$ does not specify the type of association between the variables, we need to pay close attention to the data in order to interpret the results. To identify the variables that are associated with perception, I chose an $\alpha = 0.05$, meaning that those variables with a p-value $< 0.05$ are significantly associated with the perception of drought. Traditionally, we choose an $\alpha$-value of 5 or 1% because we want the data to give strong evidence against the $H_0$. This means that the $H_0$ will only be true no more than 5% of the time.

**The logistic regression** or "logit" regression, is a statistical model, used to estimate a proportion (the dependent variable is coded 0/1) as a function of multiple independent variables. In other words, the model is used to predict the outcome of a categorical variable in the presence of multiple predictor or independent variables. If the coefficient of the independent variable is not significantly different from zero, that indicates there is no significant association between it and the dependent variable. The P-value of this test obtained in the logistic regression model is the principal measure I used to determine if there is an association between variables.

The Chi-squared test was used to determine the univariate association between each of the independent variables and the perception of drought in each state. The logistic regression was used to assess the collective influence (if any) of these variables over the perception of drought. To determine the significant level ($\alpha$-value) of association between variables I focused on a P-value $< 0.05$.

# CHAPTER 5

# RESULTS

The purpose of the study was to assess if 1) the perceptions of climate change among maize farmers in the states of Sinaloa, Mexico and Chiapas are aligned with empirical observations; and 2) the factors that influence them. Out of 1459 total observations, 1092 were used for this analysis; those observations with incomplete data for the variables selected were not used.

I expected that perceptions among maize farmers in the states of Mexico and Chiapas would be more in sync with empirical observations than perceptions of maize farmers in Sinaloa because farmers these states are more dependent on rainfall than those in Sinaloa. I found that perceptions in each state differed from scientific observations, and the primary influences on perceptions were language or receipt of credit or loans.

Table 5 Demographic Characteristics by State. Count on Percentages or means.

| **Variable** | **Chiapas** | **State of Mexico** | **Sinaloa** |
|---|---|---|---|
| **Number** | 476 | 377 | 239 |
| Male | 406 (85%) | 286 (76%) | 214 (96%)* |
| Age | 48.6 | 51.7 | 53.7† |
| House hold size | 3.7 | 4.1 | 3.5† |
| Number contributing to HH income | 3.1 | 3.6 | 2.1† |

* Significant different between states at the 5% level, according to Chi-squared test.
† Significant different between states at the 5% level, according to one-way ANOVA.

Table 5 shows a summary of demographic statistics by state. Notice that the vast majority of farmers in the states were men but in the state of Mexico 24% of the farmers are women. In Chiapas, farmers are slightly younger than farmers in Mexico and Sinaloa.

On average the household size across the states is of four members per household; of which only two contribute to the household (HH) income in Sinaloa.

Table 6 Responses of households by variable.

| **Variable** | **Chiapas (%)** | | **State of Mexico (%)** | | **Sinaloa (%)** | |
|---|---|---|---|---|---|---|
| | No | Yes | No | Yes | No | Yes |
| Language | 75.8 | 24.2 | 55.4 | 44.6 | 100 | 0* |
| Irrigation | 87.4 | 12.6 | 53.1 | 46.9 | 0 | 100* |
| Agprimary | 48.3 | 51.7 | 71.6 | 28.4 | 5.9 | 94.1* |
| Support | 98.1 | 1.9 | 95.1 | 4.9 | 1.7 | 98.3* |
| Credit | 76 | 24 | 96.1 | 3.9 | 7.5 | 92.5* |
| Infolevel | 58.4 | 41.6 | 58.3 | 41.7 | 20.6 | 79.4* |

| **Variable** | **Chiapas (%)** | | | **State of Mexico (%)** | | | **Sinaloa (%)** | | |
|---|---|---|---|---|---|---|---|---|---|
| Criolla | Non | Some | All | Non | Some | All | Non | Some | All |
| | 76.5 | 23.5 | 0 | 2.5 | 91.9 | 5.7 | 99.8 | 0.2 | 0* |
| Yield | - | ↓ | ↑ | - | ↓ | ↑ | - | ↓ | ↑ |
| | 13.9 | 68.1 | 18 | 1 | 88.1 | 10.9 | 2.8 | 9.2 | 88* |
| Perception of Drought | 27.5 | 1.7 | 70.8 | 6.4 | 4.2 | 89.4 | 19.7 | 72.4 | 7.9* |

- No change ↓ Decreased ↑ Increased

* Significant different between states at the 5% level, according to Chi-squared test

Table 6 shows percentages of responses to the questions selected for this study. Notice that in Sinaloa responses for the variables language and irrigation responses were homogenous; everyone speaks only Spanish, and has irrigation water. These characteristics differentiate Sinaloa from the other two states that do have a portion of the population that speaks another language in addition to Spanish.

**Are Perceptions Aligned with Scientific Data?**

Current climatic trends in Mexico indicate that precipitation and temperature patterns are changing across the country. These changes influence the probability of climatic events and inter-annual climatic variability that can be detrimental to maize production. Among these events are droughts, high temperatures, hail, frosts, floods, and changes in seasons. How do farmers' perceptions of climate variability align with current observations, where such observations are available?

Farmers from all three states reported that maize production was more affected by drought than other events (see Table 7). In Chiapas and Mexico more than 80% of the farmers surveyed had experienced drought, while in Sinaloa only 53.4% of farmers reported this. In Chiapas, 68.8% of farmers had also experienced heat and high temperatures events; in the other two states these events were much less frequently reported. Collectively, other climatic events (i.e., hail, frost, floods, etc.) were far less frequent: together these events were reported by an average of 22% of farmers across the three states (see Fig. 6-9).

Table 7 Percentages of Households that Suffered/Did Not Suffered a Climatic Event.

| **Climatic Events** | **Chiapas (%)** | | **State of Mexico (%)** | | **Sinaloa (%)** | |
|---|---|---|---|---|---|---|
| | No | Yes | No | Yes | No | Yes |
| Drought | 18.7 | 81.3 | 7.6 | 92.4 | 46.5 | 53.5* |
| Heat/High Temperatures | 31.2 | 68.8 | 81.8 | 18.2 | 74.6 | 25.4* |
| Hail | 77.6 | 22.4 | 84.3 | 15.7 | 98.2 | 1.8* |
| Colds/Frost | 78.9 | 21.1 | 67.6 | 32.4 | 75.3 | 24.7* |
| Changes in seasons/Wet days | 67 | 33 | 79.9 | 20.1 | 88.6 | 11.4* |
| Floods | 75.6 | 24.4 | 57 | 43 | 78.6 | 21.4* |

*Significant different between states at the 5% level, according to Chi-squared test.

The perception of drought as "increasing" was higher in the states of Chiapas and Mexico, where 70.8% and 89.4% of the farmers who experienced drought reported this perception (Fig. 4). On the other hand, in the state of Sinaloa, while over half of farmers had experienced drought, 72.4% of them reported that drought had decreased in frequency, in comparison with an average of 6% for the other two states.  In contrast, in all three states a majority of farmers who experienced heat/high temperatures perceived this phenomenon to be increasing, with the highest percentage (90.5%) in the state of Mexico (Fig. 5).

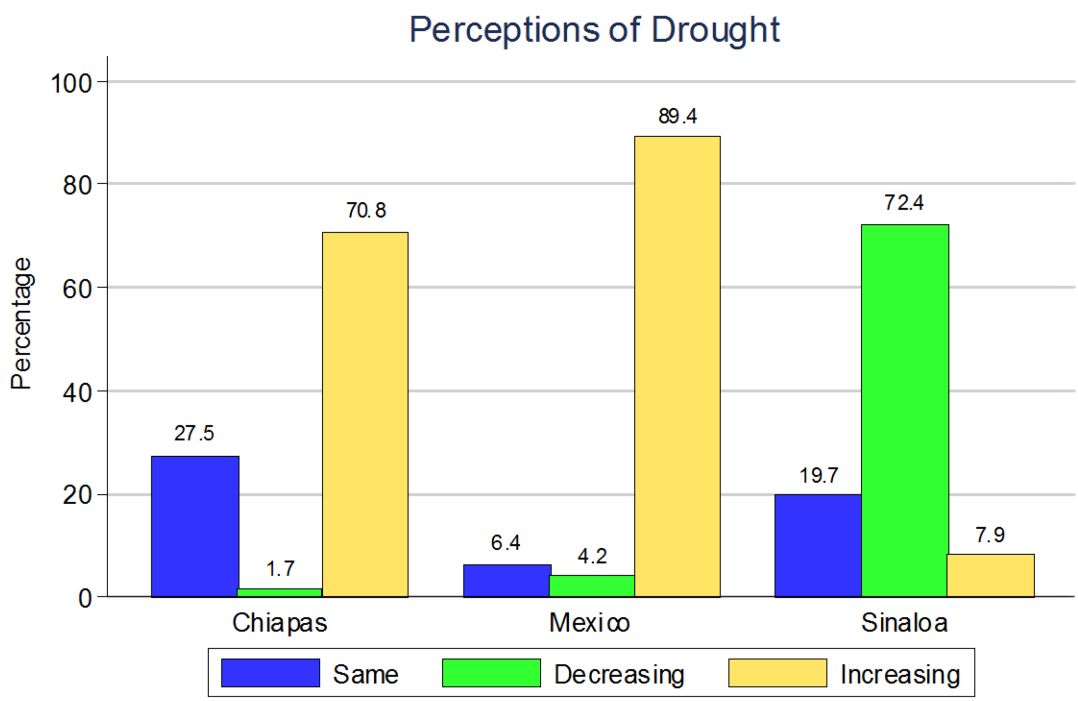


Fig. 4 Perceptions of Drought. Farmers in the states of Chiapas and Mexico believe drought is increasing; however, in the state of Mexico studies have not shown significant drought events in the region in the last decades. Sinaloa is the only state where a vast majority of farmers believe drought is decreasing.

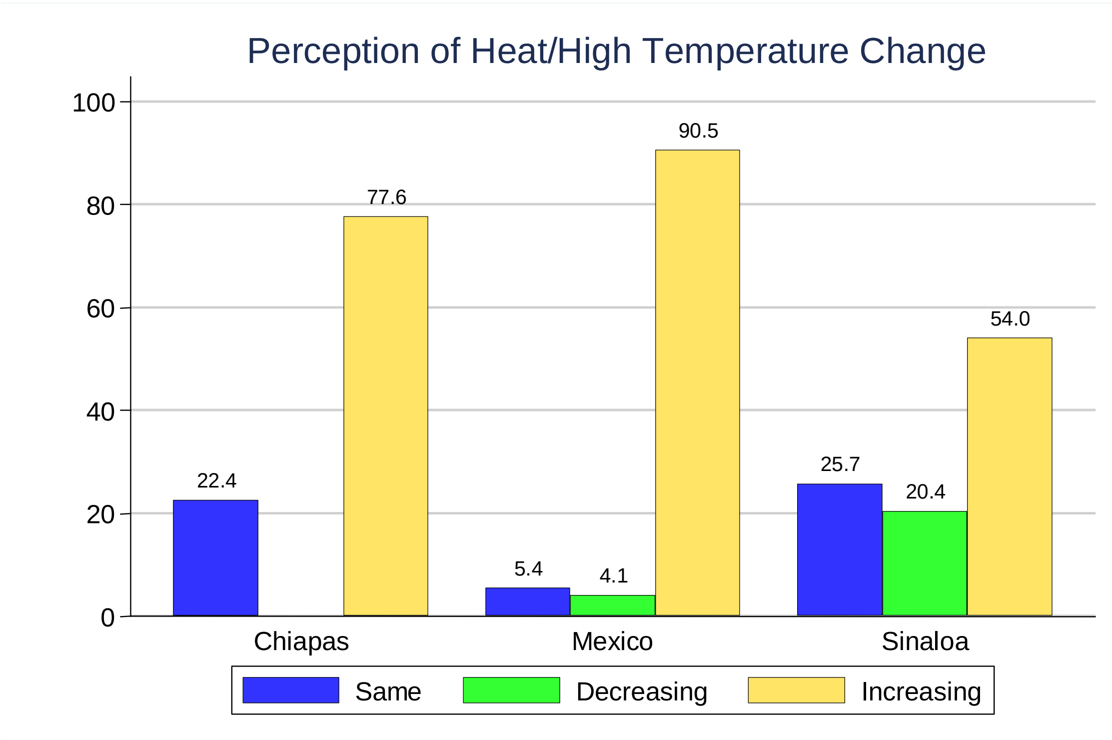


Fig. 5 Perceptions of heat/high temperature change. More than 75% of farmers in the states of Chiapas and Mexico believe temperatures are increasing. In Sinaloa slightly more than half of the farmers believe this.

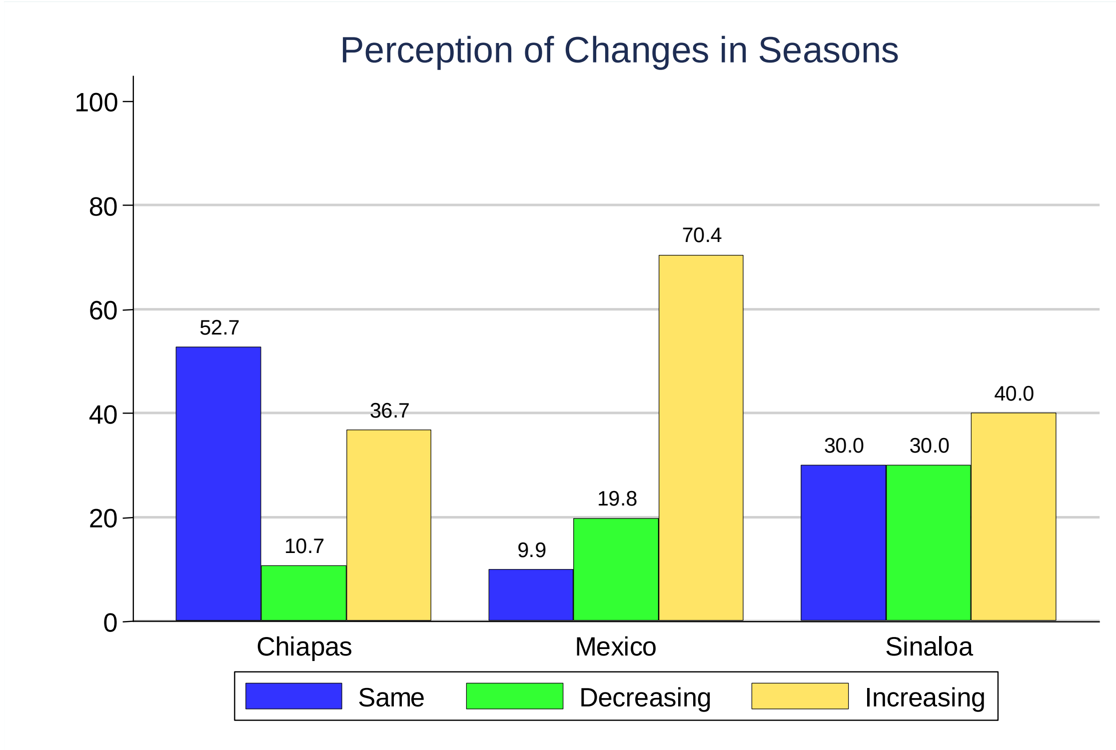


Fig. 6 Perceptions of change in seasons. The vast majority of farmers in the state of Mexico believe seasons have been changing in comparison with farmers in the other states.

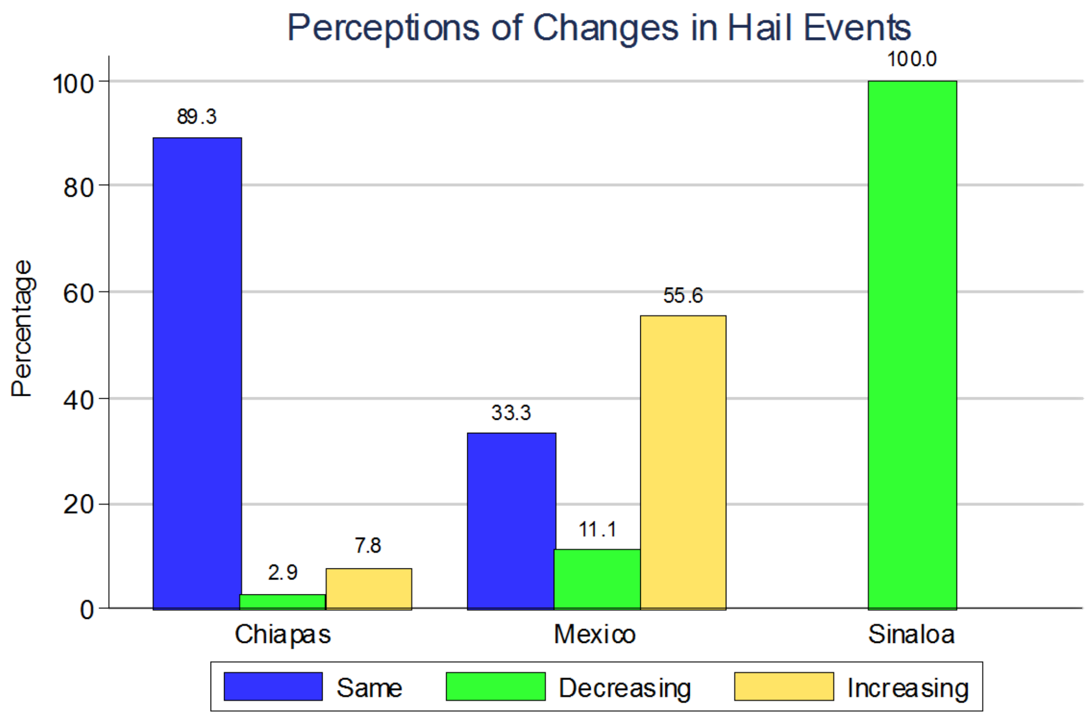


Fig. 7 Perceptions of changes in hail events. Every farmer in Sinaloan sample believe hail events have decreased, in Chiapas the vast majority of farmers have not seen changes in this events. Only in the state of Mexico a significant number of farmers agree that hail events are increasing in their state.

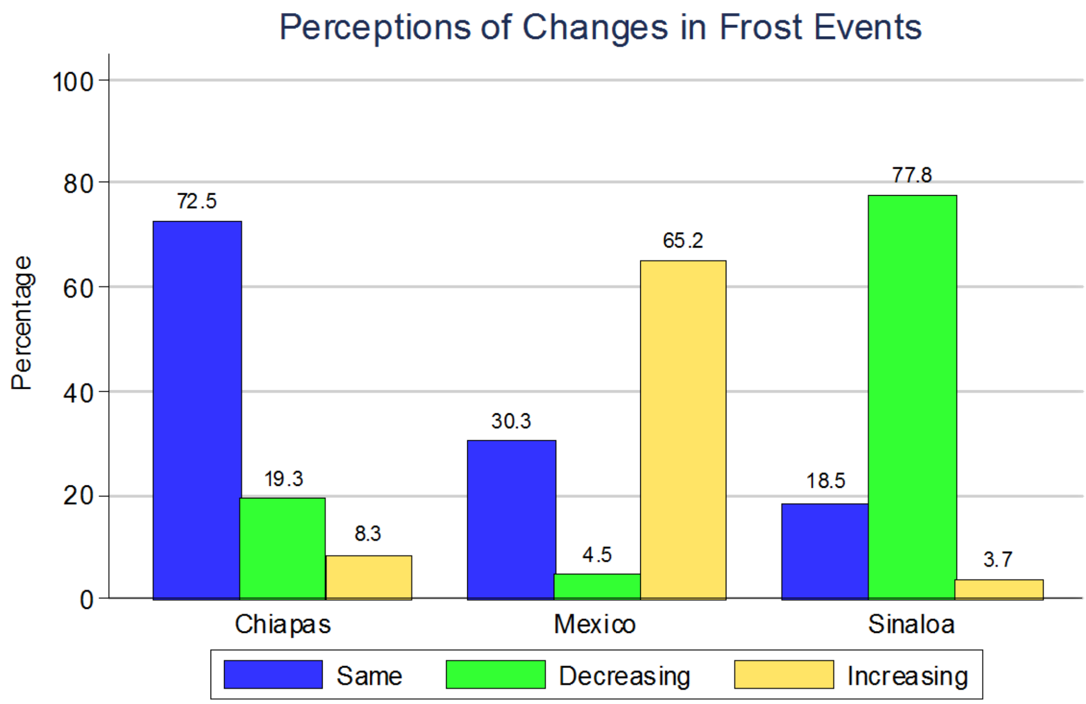


Fig. 8 Perceptions of changes in frost events. Frost events are not significant among Sinaloan and Chiapan farmers. Nonetheless, in the state of Mexico more than half of the farmers believe frost events have been increasing.

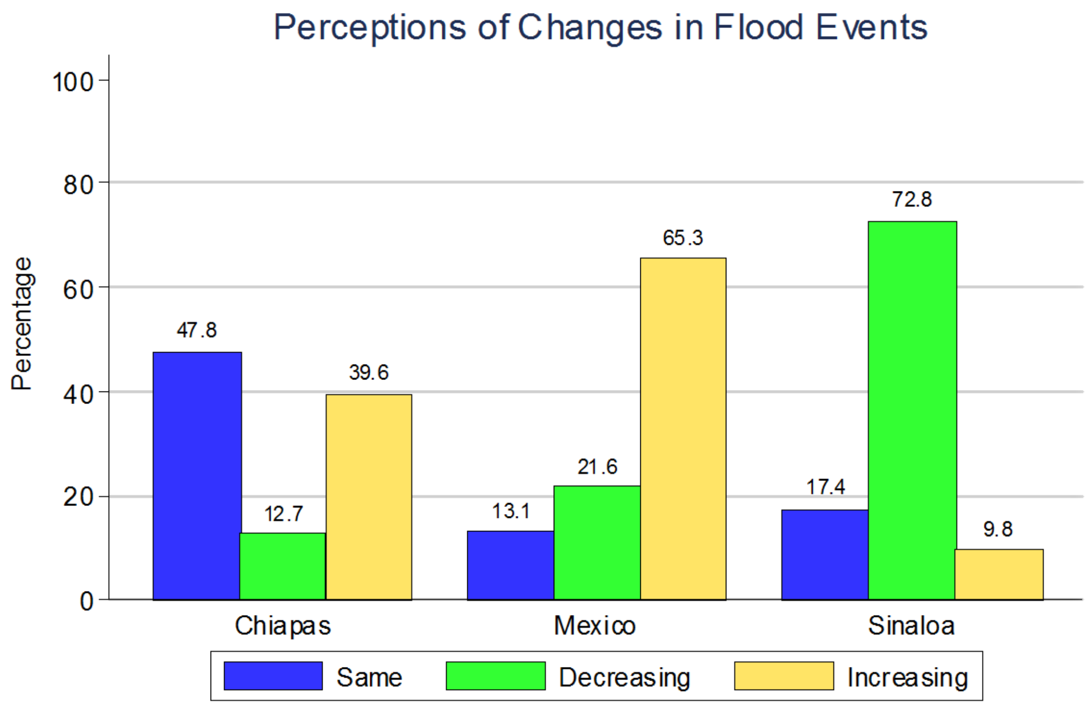


Fig. 9 Perceptions of changes in flood events. Only a significant number of farmers in the state of Mexico perceive flood events as increasing. In Sinaloa, the vast majority believe have floods have been decreasing. In Chiapas a small fraction of the sample reported they have been increasing in the state.

In summary, perceptions of climate variability depend on the farmers' location. This is especially true of perceptions of drought events among farmers in all states. In Sinaloa, although scientific data indicates that the state is experiencing and will experience a decrease in annual precipitation totals, an increase in dry days, and delayed starts of the rainy season, the majority of farmers do not perceive drought as increasing; even though almost half of them reported being affected by it. On the other hand, although there is little available empirical evidence as yet that the state of Mexico has experienced significant changes in climatic parameters (especially drought events), farmers there perceived drought as increasing, along with floods and cold/frosts. Finally, in Chiapas, while current climatic trends are towards an earlier start to the rainy season (which in turn is associated with a longer season), farmers perceive drought and heat/high temperatures as increasing.

### Factors that Influence Perception of Drought

Perception of drought of maize farmers in Mexico varies from state to state. In order to capture a deeper understanding of the social determinants of different perceptions of drought in this population, I performed the statistical analyses by state.

Table 8 Chi-square Associations of Variables by State.

| | **Chiapas** | | **State of Mexico** | | **Sinaloa** | |
|---|---|---|---|---|---|---|
| | Pvalue | Chi2 | Pvalue | Chi2 | Pvalue | Chi2 |
| Language | <0.001 | 135.44 | 0.006 | 7.57 | . | . |
| Primary income agriculture | 0.523 | 0.41 | 0.810 | 0.06 | 0.257 | 1.28 |
| Irrigation | 0.003 | 8.72 | 0.565 | 0.33 | . | . |
| Criolla | <0.001 | 17.44 | 0.375 | 1.96 | . | . |
| Support programs | 0.053 | 3.74 | 0.495 | 0.47 | 0.002 | 9.83 |
| Credit | <0.001 | 31.91 | 0.674 | 0.18 | 0.001 | 10.46 |
| Yield | 0.005 | 7.86 | 0.828 | 0.05 | 0.588 | 0.29 |
| Infolevel | <0.001 | 135.44 | 0.006 | 7.57 | . | . |

Based on the chi-square tests, overall, seven of the eight of the independent variables were associated with the perception of drought (see Table 8). In Sinaloa, only credit and support were associated with the perception of drought, while language was the only associated variable for the state of Mexico. In Chiapas, six variables were associated with the perception of drought: language, irrigation, criolla, credit, yield, and infolevel. Nonetheless, the logistic regression model showed that only two variables actually influenced the perception of drought: credit and language (see Table 9).

The logistic regression analysis for the states (Table 9) revealed that for Sinaloa the perception of drought was influenced only by the receipt of credit or loans (odds Ratio= 0.176 and pvalue=0.003). Those who received credit or loans were less likely to believe that drought was increasing than those who did not receive them. In this sample 28% of those without credit believe drought events have been increasing in the last ten years, whereas only 6% of those that receive credit and loans believe this (Fig. 10).

Table 9 Odds ratios of Predictor Variables for the Perception of Drought is Increasing, by State

| **Variable Name** | **Chiapas** | | **State of Mexico** | | **Sinaloa** | |
|---|---|---|---|---|---|---|
| **Number** | 476 | | 377 | | 239 | |
| | OR | P | OR | P | OR | P |
| Spanish, No Credit | 1.00 | | | | | |
| Native Language, No credit | .069 | <0.001 | | | | |
| Spanish, Credit | 3.16 | 0.007 | | | | |
| Native Language and Credit | 1.06 | 0.943 | | | | |
| Native Language (with or without credit) | | | .392 | 0.007 | | |
| Credit (all Spanish speakers) | | | | | .176 | 0.003 |

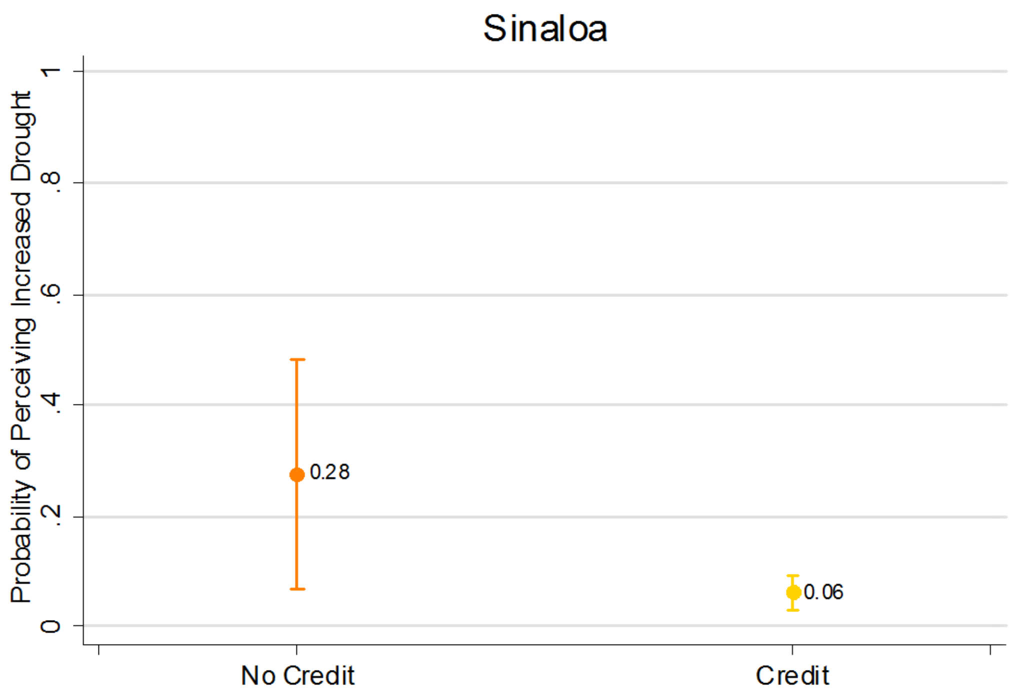


Fig. 10 Probability of perceiving drought as increasing in Sinaloa, with 95% confidence intervals.

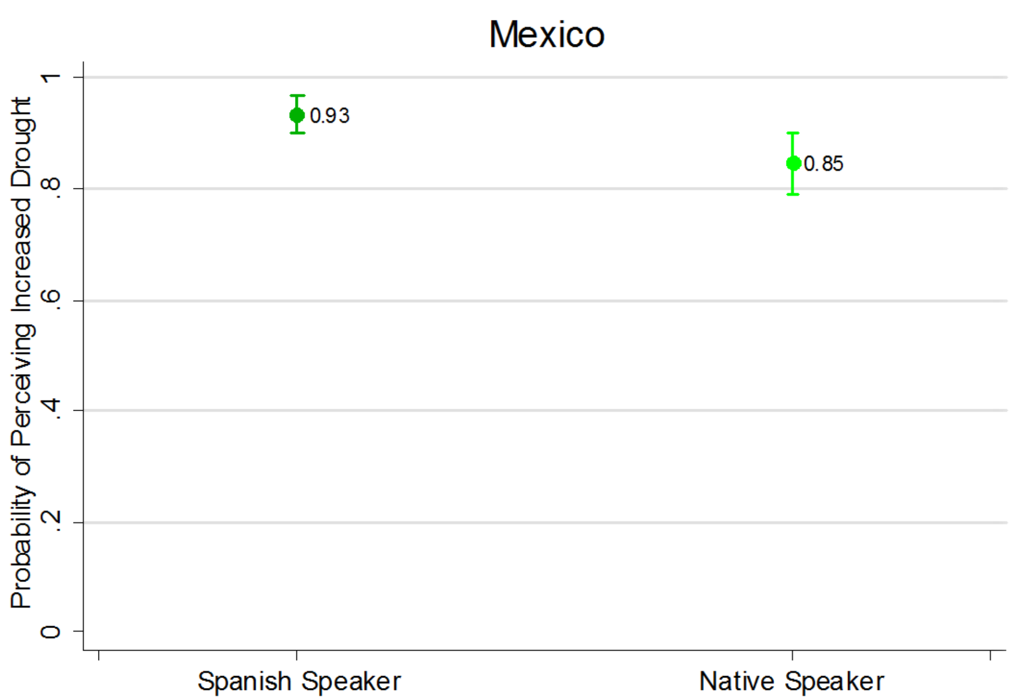


Fig. 11 Probability of perceiving drought as increasing in Mexico, with 95% confidence intervals.

In the case of the state of Mexico, perception of drought is influenced only by language (odds ratio= 0.392 and pvalue=0.007), and, contrary to the hypothesis, households in which Spanish was the only language spoken were more likely to believe that drought was increasing. In the state of Mexico 93% of Spanish speakers perceived drought as increasing, whereas only 85% of native speakers perceived the same (Fig. 11).

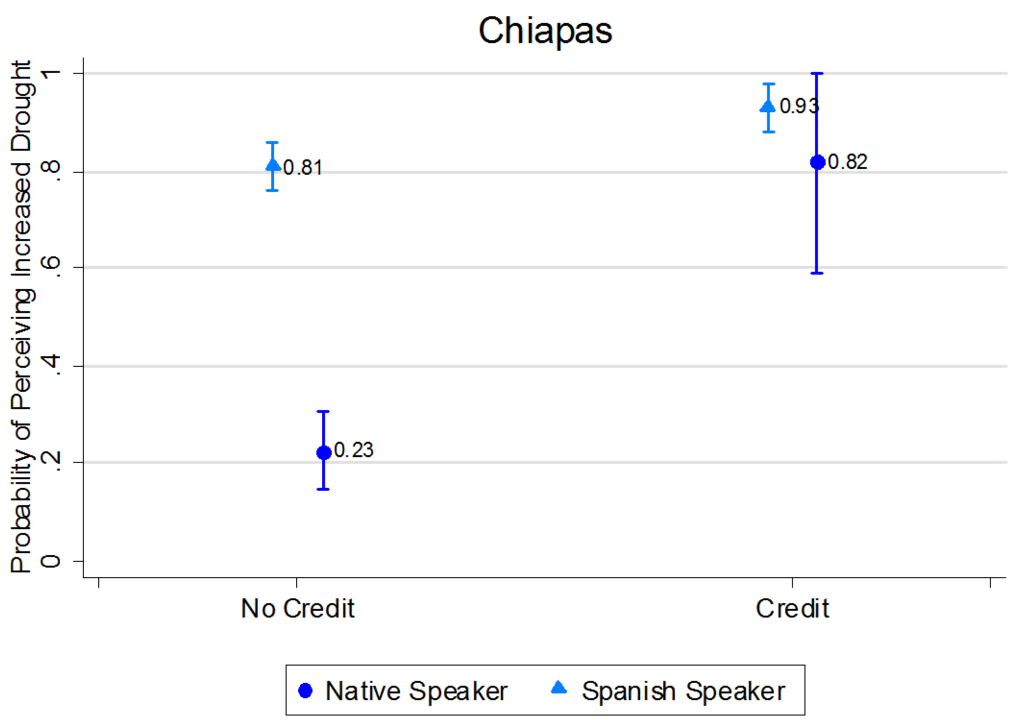


Fig. 12 Probability of perceiving drought as increasing in Chiapas, with 95% confidence intervals.

In Chiapas, language and credit affected perception of drought. The model showed that in this state, among people who do not use credit, native speakers were less likely to believe drought is increasing than those who only spoke Spanish (odd ratio=0.69, pvalue<1). In addition, Spanish speakers that receive credit or loans are more likely to believe drought is increasing in comparison to native speakers with credit or loans (odd ratio= 3.16, pvalue=0.007; odds ratio= 1.06, pvalue=0.943, respectively). In this sample, 81% Spanish speakers, without credit, believe drought is increasing in comparison with only 23% in the native group. On the other hand, among those with credit or loans, 93% of the Spanish speakers believed drought is increasing in comparison with 82% in the native speaker group (Fig. 12).

# CHAPTER 6

# DISCUSSION

Perceptions of climate trends in Mexico may not always be aligned with scientific observations. Mexico is experiencing changes in temperature and precipitation that are not consistent across the country. According to climate observations, the west coast is experiencing a decrease in rainfall and an increase in temperatures while the south-west and the Yucatan Peninsula experience the opposite.

## Sinaloa

The state of Sinaloa is experiencing delays in the start of the rainy season, decreasing annual precipitation totals, and increasing number of dry days. Climate projections for the state are parallel to this trends and suggest a maximum increase of 1°C in temperatures, variation in precipitation from +10 to -20 % by 2050, and a decline in water availability. Given current climate trends and projections one would expect farmers in Sinaloa to be aware of the climatic conditions either by personal observations or through media coverage.

In Sinaloa, fewer farmers reported being affected by climate events, slightly more than half if compared with 80% in the other states (Table 7). I found that perceptions of climate trends among farmers are not always aligned with current empirical observations. While farmers accurately perceived a decreased in hail (100%), frost (77.8%), and floods (72.8%) events, they were not able to perceive increases in drought, and high temperature/heat events, or changes in the seasons (see Fig. 4-9). Only 54% of the farmers perceived that temperatures are increasing, and 40.0% perceived changes in the seasons/wet days (Table 10); but the most interesting result is that farmers perceived drought as decreasing (72.4%). Given the current and projected climatic trends in the region (that lean towards a drier climate) perceptions of climate trends among maize farmers are not parallel to scientific observations.

Table 10 Perceptions of Climatic Events Among Sinaloan Farmers (%).

| Climatic Events | Same | Decreasing | Increasing |
|---|---|---|---|
| Drought | 19.7 | 72.4 | 7.9 |
| Heat/High Temperatures | 25.7 | 20.4 | 54 |
| Hail | 30.0 | 30.0 | 40.0 |
| Colds/Frost | 0 | 100 | 0 |
| Changes in seasons/Wet days | 18.5 | 77.8 | 3.7 |
| Floods | 17.4 | 72.8 | 9.8 |

Perceptions of drought in the Sinaloan sample are influenced by the receipt of credit or loans. The results show that those who receive credit or loans are less likely to believe that drought is increasing. In the survey sample, 90.9% of the households receive credit or loans, 49.9% from parafinancieras and 38.9% from public banks (see Table 11). These suggest that credit and loans may act as a buffer against climate events, and households that receive it have the means to counteract the effects of drought on their production without putting extra attention to it.

Table 11 Financial Support Received by Farmers by State (%).

| | Sinaloa | State of Mexico | Chiapas |
|---|---|---|---|
| Credit | 90.0 | 3.6 | 20.2 |
| Credit from public bank | 38.9 | 33.3 | 0 |
| PROCAMPO | 88.8 | 61.8 | 65.48 |

Based on the literature on risk perception, those that do not believe drought is increasing might judge themselves to be at less-than-average risk because they do not have vivid memories of recent drought events (Crocker, 1981; Kahneman & Tversky, 1979; Grothman and Patt, 2005). Sinaloan farmers are protected from drought by irrigation and thus would be unlikely to have vivid memories of drought events. In Sinaloa, only 54.4% and 25% of farmers in the survey reported having been affected by drought and high temperature, respectively, in the last ten years. A further explanation for this level of perception, following Grothman and Patt (2007), may be that farmers believe they have a high adaptive capacity for dealing with drought events. According to Grothman and Patt (2007), adaptive capacity is enhanced by access to knowledge, entitlements, and institutional supports, as well as to credit/loans. Sinaloan farmers depend heavily on federal financial resources and agricultural support programs tailored specifically for them (Eakin, Bausch, & Sweeney, 2014). According to the Model of Private Proactive Adaptation to Climate Change, reliance on public adaptation negatively affects farmers' risk appraisal, and thus their expectation of being exposed to drought and their evaluation of a drought event's potential to reduce their production (Grothman and Patt, 2007). In other words, farmers are relatively unconcerned with drought events and do not believe they will affect them much.

The high adaptive capacity of farmers in Sinaloa may be rooted in the recent establishment and development of maize production in the state. Starting in the 1990's Sinaloa experienced an abrupt and profitable expansion of maize. This expansion was a response to the abolishment of price guarantees for all crops but maize and beans, and the fall of import restrictions for sorghum, soybeans and other oilseeds. Thanks to a combination of highly capable farmers, changes in the market, technological innovation and public investment (Eakin, Bausch, and Sweeney, 2014, p.13), maize became the primary crop in the state. Today, Sinaloa is consecrated as one of the main producers of high-quality maize in the country, with high yield rates, that according to locals support Mexico's food sovereignty (Eakin, Bausch, and Sweeney, 2014).

This success story has been criticized for concentrating a large amount of federal resources in the state, including credit or loans, federal programmes and subsidies for diesel, electricity, and irrigation equipment among others (Eakin, Bausch, and Sweeney, 2014). This concentration is evident in the number of households that received credit/loans, and those that benefited from the programme PROCAMPO. Table 11 shows that farmers in Sinaloa received more credit/loans (38.9% from public banks) and benefited more from the PROCAMPO programme than farmers in Mexico and Chiapas. The concentration of resources in the state is well known, and many argue it is justified since they are the most "significant" maize producers in the country (Eakin, Bausch & Sweeney, 2014). This self-proclaimed relevancy of Sinaloa's maize farmers, along with substantial financial security, can explain why the variable credit influences the perception of drought in the state.

The difference in perception of drought between those that receive credit or loans and those that do not is especially interesting because all farmers in the sample share the same attributes. All of the surveyed farmers in Sinaloa are commercial farmers who use irrigation water and whose primary source of income are agricultural activities. There are not many significant differences among these farmers. The survey data indicates that the most significant differences among Sinaloan survey respondents may be receipt of credit or loans, production of maize under contract, purchase of insurance against weather contingencies, and technical assistance (see Table 12). The data on technical assistance, insurance and contracts suggest that the production of those who do not have credit is generally less secure, and that this lack of security, and lack of information and assistance, may increase their risk perception.

Table 12 Attributes of Farmers with (Yes) and Without Credit or Loans (No) in Sinaloa (%).

| **Attributes of Farmers** | **No** | **Yes** |
|---|---|---|
| **Number** | 41 | 408 |
| Own land. | 58.5 | 69.6 |
| Rent land from others. | 41.0 | 30.4 |
| Produced maize under contract? | 56.3 | 83.9 |
| Did you buy insurance against climate events for your production? | 22.0 | 94.6 |
| Received technical assistance for your production? | 29.3 | 80.1 |
| Has anyone in the household been part of a farmer's organization? | 62.9 | 78.8 |

Regarding insurance, in Sinaloa, those that receive credit might have more means to acquire insurance against weather contingencies, since 94.6% of them bought one in comparison with only 22% of those that did not receive credit or loans. The purchase of insurance is associated with the access to credit or loans in Sinaloa (odds ratio= 62.38384, Pvalue=0.000) but not with the perception of drought (odds ratio= .3544776, Pvalue= 0.090). These results suggest that recipients of credit or loans may not have bought insurance based on their perception of the climate; many may have been required by parafinancieras and banks to purchase insurance as a way to guarantee their credit or loans.

**State of Mexico**

For the state of Mexico, current climate observations do not show significant changes in changes in climate trends; nonetheless there has been a decrease of precipitation in the last 30 years and an increase in heavy rain events in the state. Regardless of this, farmers in the state of Mexico reported being affected by all climate events, and believe these are increasing (see Fig. 4-Fig. 9). This belief might be based on farmer's experience with recent climate events and particularly shifts in timing and distribution of precipitation during the year. In other words, farmers reported those climatic events of which they have more vivid memories; for example floods, which are associated with the heavy precipitation events in the region.

In the state of Mexico perception of drought is influenced only by language, and Spanish-speaking households were more likely to believe that drought was increasing. No other social or economic attribute of the surveyed farmers explains why language was the only variable that influenced perception of drought in the state; or why indigenous farmers, in this case, the Mazahua people, are more likely to believe drought is not increasing (see Table 13). One possible explanation could be the misinterpretation, by Mazahua-speaking farmers of the word "drought" (in Spanish sequía) in the question: "How has drought changed in the last 10 years?" Qualitative research on flood risk undertaken by Eakin and Guadarrama (2008) in Mazahua communities in the state found that some respondents interpreted sequía as the "dry season" and not as anomalous dry spells during the rainy season.  If this interpretation was prevalent in the responses of the Mazahua-speaking farmers to the survey, this may have influenced their perception that drought had not increased. A study of a maize-farming Mazahua community in the municipality of San Felipe del Progreso (within the DDR where the survey was implemented) found that farmers there did, in fact, perceive changes in the regional climate, and the Mazahua's knowledge about climate patterns appeared to be accurate (Lopez, 2011). Mazahua farmers understand the changes in precipitation patterns in the region (late start of the rainy season), and they have taken adaptive measures to cope with the change (Lopez, 2011).

Table 13 Summary of Responses by Spanish Speaking-only Households and Native Households in Mexico.

| **Independent Variables** | **Only Spanish (%)** | **Spanish + Other Language (%)** |
|---|---|---|
| Use irrigation | 48.0 | 46.2 |
| Agricultural income primary | 24.4 | 31.9 |
| Participate in support programs | 5.9 | 4.0 |
| Receive credit/loans | 5.2 | 1.7 |
| Have more than 1 info. source | 55.3 | 27.7 |
| Yields decreased in the last 20yrs | 87.9 | 88.2 |
| Perceive Drought as increasing | 93.3 | 84.5 |

## Chiapas

In Chiapas current climatic trends show that the state is experiencing intense climatic events including droughts, heat waves, heavy rains, and floods (G.D.E., 2011); and in some regions an early start of the rainy season. The three principal climatic events that have affected farmers are drought, heat/high temperatures, and changes in seasons (Table 2). Nonetheless, even when the state is experiencing multiple events, farmers perceive only drought and heat/high temperatures as increasing. The rest of the events, according to farmers, have not changed. Thus in Chiapas one might say that perceptions of climate events are not aligned with current climate observations, however this could be attributed to the fact that some these events are not happening with the same intensity in the region where the survey took place, and the complex topography of Chiapas can mean high variability in climatic patterns within the state (Dewes 2013).

On the other hand, in Chiapas, language and credit influenced the perception of drought. Language was the proxy for ethnicity, and I expected that farmers who spoke another language in addition to Spanish would believe that drought was increasing; however, the results showed the opposite as in the state of Mexico. Spanish-only speakers are more likely to believe drought is increasing, and those that speak another language in addition to Spanish are less likely to believe that drought has increased. The higher risk appraisal among farmers who spoke only Spanish was unexpected; however, it might be explained by one or both of two factors. First, Spanish-only speaking farmers reported higher exposure to or experience with drought, perhaps because Spanish speakers live in the lowlands while indigenous farmers are concentrated in the highlands, and climate differs according to altitude (see Table 14). Second, a higher percentage of Spanish-only speakers reported decreases in yields (see Table 15)

Table 14 Summary of the Responses to the Question "Which Climate Events Affected your Production in the Last 10 years?" in Chiapas.

| **Climate Events** | **Only Spanish (%)** | **Spanish + Other Language (%)** |
|---|---|---|
| Drought | 92.8 | 58.2 |
| High Temperatures | 90.3 | 25.9 |
| Hail | 14.7 | 37.8 |
| Colds/Frosts | 7.9 | 47.3 |
| Change in Seasons | 31.6 | 35.8 |
| Floods | 28.1 | 16.9 |

Table 15 Summary of Responses by Spanish Speaking-only Households and Native Households in Chiapas.

| Independent Variables | Only Spanish (%) | Spanish + Other Language (%) |
|---|---|---|
| Use irrigation | 17.6 | 0.0 |
| Agriculture primary income | 50.5 | 48.8 |
| Participate in support programs | 1.8 | 1.0 |
| Receive credit/loans | 27.6 | 6.6 |
| Have more than 1 info. source | 46.3 | 25.6 |
| Yields decreased in the last 20yrs | 83.9 | 31.3 |
| Perceive Drought as increasing | 84.5 | 27.8 |

The relationship of credit access to risk perception is different from that of Sinaloa. In Chiapas, it is farmers who have credit that are more likely to believe drought frequency is increasing; whereas credit-receiving Sinaloans believe it is decreasing. The percentage of farmers in Chiapas who received credit or loans was the second highest in the three states studied, but it was a small percentage –20.2%-- compared to Sinaloa, where 90% of farmers surveyed reported receiving credit or loans. In Chiapas credit is associated with ethnicity: 27.6% of Spanish-only speaking farmers received credit or loans, while only 6.6% of farmers who spoke a native language in addition to Spanish received credit or loans. According to the literature, receipt of credit should enhance the adaptive capacity of farmers to climate variability and change (Fosu-Mensah, Vlek, & MacCarthy, 2012; Gbetibouo, 2009). A higher adaptive capacity would encourage these farmers to take action against the effects of drought in their production. Based to Grothman and Patt (2005) this "adaptation intention" would be fueled by their access to credit or loans, and such resource access should enhance farmers' self-efficacy and reduce risk salience.

Table 16 Summary of Sources of Credit Mentioned by Households in Chiapas.

| **Credit Type** | **Percentage of people with this credit** |
|---|---|
| Informal lender | 65.0 |
| Civil Association | 5.1 |
| Public Bank | 0 |
| Commercial Bank | 5.1 |
| Parafinaciera | 23.1 |
| Other | 1.7 |

The difference between Sinaloa and Chiapas may have to do with the source of credit received. In contrast to Sinaloa, the majority of those who received credit in Chiapas obtained it from informal lenders (65%) or parafinancieras (23.1%); none received it from public banks (see Table 16). This suggests that the farmers did not meet the requirements of public banks (e.g. land size, yields, etc.) for receiving credit and loans, and that they have therefore resorted to informal credit institutions or agents.

Informal lenders can be moneylenders, traders, landlords (large farmers), or friends and relatives (Chaudhuri & Gupta, 1996; Campero & Kaiser, 2013). Studies have found that the flexibility of these informal lenders and rapid access to loans are some of the most attractive characteristics for those who seek loans from these sources. However, these positive features may be negated by the high-interest rates typically charged by informal credit institutions or credit agents. In Mexico, agiotistas (moneylenders) are famous for their high-interest rates (as high as 20%), and their demands for collateral in the form of land titles and car deeds, for example. Regional newspapers report the discontent of many borrowers who feel deceived by agiotistas (Burguete, 2013; Fuente, 2013). Borrowers complain of high interests rates, charges above the amounts agreed to, and threats by agiotistas to report them to the authorities for non-payment. In these conditions, most households would likely avoid taking out any loans if at all possible; farmers seeking money from informal lenders would likely be in financially difficult circumstances. Farmers involved with agiotistas would need good crop yields to repay loans, and careful attention to climate variability would be necessary to achieve such yields.

# CHAPTER 7

# CONCLUSION

While this study only covered a sample of the households that produce maize in Mexico, I found that farmers' perceptions of climate events are not always aligned with scientific observations. Issues of the temporal and spatial scale, resolution of climatic analyzes, and farmers' observations may explain in a large part the differences I found. Nevertheless, it is also clear that other cultural, agro-ecological and institutional factors play a role in farmers' perceptions.

The results of the Chi-square tests and logistic regression models showed similar and contradictory results among the three states. In the state of Sinaloa, the majority of farmers do not believe that drought events are increasing; this may be because they have not experienced drought since they irrigate their crops. According to the literature, the lack of recent memories might be the reason for this belief. The receipt of credit or loans is the only factor that influence farmers' perceptions of drought. Those that do not receive them are more likely to believe that drought is increasing. Since these farmers might be categorized as high-risk clients by financial organizations, their economic position and vulnerability might be the reason they are more aware of drought events.

In the state of Mexico, a high percentage of farmers believe climate trends have been changing with droughts and flooding increasing; nonetheless there is little evidence of climatic variability in the state.  The only factor that influence the perception of drought is language (ethnicity). Spanish-speaking farmers are more likely to believe that drought is increasing. This belief may be the result of a misinterpretation of the word drought by Mazahua farmers in the sample. When asked about how drought has changed in the last 10 years, Mazahua farmers may have interpreted it as the dry season instead of anomalies during the rainy season.

Although multiple climatic changes are taking place in Chiapas, households only perceive changes in drought and high temperatures. The factors that influence the perception of drought are language and receipt of credit or loans.  In this case, language decreases the belief that drought is increasing while receipt of credit or loans increase it. Between Spanish and native speakers, the firsts are more likely to believe that drought has increased.  Spanish speakers, which are concentrated in the more commercial region of the valley, also have more vivid memories of drought events, and a larger number of them reported decreases in yields. Experiences with climate variability may have driven these maize farmers to look for adaptive strategies to counteract the effects of climate variability in their production, two of them credit and loans. However, receipt of credit or loans may increase farmers' losses during droughts because they do not have insurance to support these; thus they are at higher economic risk if they experience drought.

The overall results of my research suggest that maize farmers will adapt differently to climate variability and change based on their ethnicity and credit resources. For example, farmers in Sinaloa might not develop, or fully embrace comprehensive adaptation plans for their region without recent experiences with climatic changes. On the other hand, Spanish-speaking farmers in the states of Mexico and Chiapas, might be more open to engaging in adaptation strategies to climate change because their perceptions are more aligned with scientific predictions. Consequently, to create effective adaptation policies for climate change, the government needs to understand people's perceptions of it so that they can account for likely responses. Adaptation policies should focus on how ethnicity and access to credit or loans influence differently perceptions of climate change, and the disposition of farmers to adapt to it. Because worldviews among ethnic groups are different, information about climate change should be disseminated in clear and compelling ways to every ethnic group.

This is the first time a research of this kind is performed in Mexico, and it serves as a base for future research on climate perceptions in the country. Further research could improve our understanding of perceptions of climate change and adaptation strategies. Future research should focus on four different aspects. First, it should go deeper on the role of ethnicity and receipt of credit or loans on perceptions in the three states. Since these factors have the potential to shape the communication of climate information and adaptation strategies between the government and farmers, more research is necessary. Second, in the state of Mexico it will have to confirm or discard the misinterpretation hypothesis of the word “sequía” among native speakers. Third, given the extreme frost events of 2010 in Sinaloa, it would be ideal to collect new data on perceptions of climate events among maize farmers and compare it with this data. Fourth, future work should analyze the contradictory relationship of credit and perception of drought between farmers in Sinaloa and Chiapas. A better understanding of these cultural and economic factors, among others, will improve our knowledge of maize farmers decision-making and adaptation strategies in the face of climate change.

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# APPENDIX A

# CHI-SQUARE TESTS BY STATES

*Sinaloa*

Table 17 Credit and Perception of Drought

| Received Credit or Loans | Perception of Drought | | Total |
|---|---|---|---|
| | No | Yes | |
| No | 13 | 5 | 18 |
| | *16.6* | *1.4* | *18* |
| Yes | 207 | 14 | 221 |
| | *203.5* | *17.6* | *221* |
| **Total** | 220 | 19 | 239 |
| | *220* | *19* | *239* |

Pvalue= 0.001;
chi2= 10.458;

Based on the p-value and chi-square number, the variable credit is associated with the perception of drought. This sample is heavily weighted toward those households that receive credit. Unlike the findings for Mexico and Chiapas (see below), those who do not receive credit are more likely to believe drought is increasing than those who do receive credit. There are only slight differences between observed and expected values overall.

*Variables not associated with the perception of drought in Sinaloa:*

Table 18 Primary Income from Agricultural Related Sources and Perception of Drought.

| Primary Income from Agricultural Related Sources | Perception of Drought | | Total |
|---|---|---|---|
| | No | Yes | |
| No | 14 | 0 | 12 |
| | *12.9* | *1.1* | *14* |
| Yes | 206 | 19 | 225 |
| | *207.1* | *17.9* | *225* |
| **Total** | 220 | 19 | 239 |
| | *220* | *19* | *239* |

Pvalue= 0.257;
chi2= 1.284;

Table 19 Participation in Support Programs and Perception of Drought.

| **Participates in Support Programs** | **Is Drought Increasing?** No | Yes | **Total** |
|---|---|---|---|
| No | 2<br>*3.7* | 2<br>*0.3* | 4<br>*4* |
| Yes | 218<br>*216.3* | 17<br>*18.7* | 235<br>*235* |
| **Total** | 220<br>*220* | 19<br>*19* | 239<br>*239* |

Pvalue= 0.002;
chi2= 9.830;

In Sinaloa the majority of the households participate in support programs; thus this sample is heavily weighted towards this group. Since there are only four households in the "do not participate in support programs" it is not possible to evaluate any relationship between this variable and the dependent variable.

Table 20 Changes in Maize Yield on 2009 and Perception of Drought.

| **Changes in Yield** | **Is Drought Increasing?** No | Yes | **Total** |
|---|---|---|---|
| No Change | 8<br>*7.3* | 0<br>*0.7* | 8<br>*8* |
| Decreased | 15<br>*16.5* | 3<br>*1.5* | 18<br>*18* |
| Increased | *189*<br>*188.1* | *16*<br>*16.9* | *205*<br>*205* |
| **Total** | 212<br>*212* | 19<br>*19* | 231<br>*231* |

Pvalue= 0.292;
chi2= 2.464;

Table 21 Levels of Information and the Perception of Drought.

| **Access to information Sources** | **Is Drought Increasing?** | | **Total** |
|---|---|---|---|
| | No | Yes | |
| Has one or less. | 45 | 3 | 48 |
| | *44.1* | *3.9* | *48* |
| Has more than one. | 169 | 16 | 185 |
| | *169.9* | *15.1* | *185* |
| **Total** | 214 | 19 | 233 |
| | *214* | *19* | *233* |

Pvalue= 0.588;
chi2= 0.293;

### *State of Mexico*

Table 22 Language and Perception of Drought.

| **Speaks a Native Language** | **Is Drought Increasing?** | | **Total** |
|---|---|---|---|
| | No | Yes | |
| No | 14 | 195 | 209 |
| | *22.2* | *186.8* | *209* |
| Yes | 26 | 142 | 168 |
| | *17.8* | *150.2* | *168* |
| **Total** | 40 | 337 | 377 |
| | *40* | *337* | *377* |

Pvalue= 0.006;
chi2= 7.566;

The chi-square test shows slight differences between the observed and expected values, and a p-value lower than 0.05; thus the variable language influences the perception of drought in the state of Mexico. These results suggest that, like Chiapas (see below), there are more households than would be expected that do not speak an additional language and also believe that drought risk is increasing. Conversely, there is also fewer native speaking households than would be expected that believe that drought risk has increased.

*Variables not associated with the perception of drought:*

Table 23 Primary Income from Agricultural Related Sources and Perception of Drought.

| **Primary Income from Agricultural Related Sources** | **Perception of Drought** | | **Total** |
|---|---|---|---|
| | No | Yes | |
| No | 28 | 242 | 270 |
| | *28.6* | *241.4* | *270* |
| Yes | 12 | 95 | 107 |
| | *11.4* | *95.6* | *107* |
| **Total** | 40 | 337 | 377 |
| | *40* | *337* | *377* |

Pvalue= 0.810;
chi2= 0.058;

Table 24 Irrigation and Perception of Drought.

| **Use Irrigation Water?** | **Perception of Drought** | | **Total** |
|---|---|---|---|
| | No | Yes | |
| No | 19 | 180 | 199 |
| | *20.7* | *178.3* | *199* |
| Yes | 20 | 156 | 176 |
| | *18.3* | *157.7* | *176* |
| **Total** | 39 | 336 | 375 |
| | *39.0* | *336.0* | *375* |

Pvalue= 0.565;
chi2= 0.331;

Table 25 Criolla Maize and Perception of Drought.

| **Plant Criolla Maize?** | **Perception of Drought** | | **Total** |
|---|---|---|---|
| | No | Yes | |
| No | 1 | 9 | 10 |
| | *1.1* | *8.9* | *10* |
| Some | 35 | 312 | 347 |
| | *36.8* | *310.2* | *347* |
| All | *4* | *16* | *20* |
| | *2.1* | *17.9* | *20* |
| **Total** | 40 | 337 | 377 |
| | *40* | *337* | *377* |

Pvalue= 0.375;
chi2= 1.964;

Table 26 Support Programs and Perception of Drought.

| **Participates in Support Programs?** | **Perception of Drought** | | **Total** |
|---|---|---|---|
| | No | Yes | |
| No | 37 | 313 | 350 |
| | *36.1* | *313.9* | *350* |
| Yes | 1 | 17 | 18 |
| | *1.9* | *16.1* | *18* |
| **Total** | 38 | 330 | 368 |
| | *38* | *330* | *368* |

Pvalue= 0.495;
chi2= 0.465;

Table 27 Receipt of Credit or Loans and Perception of Drought.

| **Receive Credit or Loans?** | **Perception of Drought** | | **Total** |
|---|---|---|---|
| | No | Yes | |
| No | 37 | 310 | 347 |
| | *36.1* | *310.5* | *347* |
| Yes | 1 | 13 | 14 |
| | *1.5* | *12.5* | *14* |
| **Total** | 38 | 323 | 361 |
| | *38* | *323* | *361* |

Pvalue= 0.674;
chi2= 0.177;

Table 28 Changes in Maize Yield on 2009 and Perception of Drought.

| **Changes in Yield** | **Is Drought Increasing?** | | **Total** |
|---|---|---|---|
| | No | Yes | |
| No Change | 1 | 3 | 4 |
| | *0.4* | *3.6* | *4* |
| Decreased | 35 | 294 | 329 |
| | *34.5* | *294* | *329* |
| Increased | *3* | *36* | *39* |
| | *4.1* | *34.9* | *39* |
| **Total** | 39 | 333 | 372 |
| | *39* | *333* | *372* |

Pvalue= 0.541;
chi2= 1.230;

## Infolevel and Perception of Drought

Table 29 Levels of Information and the Perception of Drought.

| **Access to information Sources** | **Is Drought Increasing?** | | **Total** |
|---|---|---|---|
| | No | Yes | |
| Has one or less. | 21 | 183 | 204 |
| | *20.4* | *183.6* | *204* |
| Has more than one. | 14 | 132 | 146 |
| | *14.6* | *131.4* | *146* |
| **Total** | 35 | 315 | 350 |
| | *35* | *315* | *350* |

Pvalue= 0.828;
chi2= 0.047;

### *State of Chiapas*

Table 30 Language and Perception of Drought.

| **Speaks a Native Language** | **Is Drought Increasing?** | | **Total** |
|---|---|---|---|
| | No | Yes | |
| No | 56 | 305 | 361 |
| | *105.4* | *255.6* | *361* |
| Yes | 83 | 32 | 115 |
| | *33.6* | *81.4* | *115* |
| **Total** | 139 | 337 | 476 |
| | *139* | *337* | *476* |

Pvalue= 0.000;
chi2= 135.439;

This sample is heavily weighted towards people who believe that drought is increasing with three times as many people in the non-native group than in native group. The chi-square test shows a significant difference between the observed and expected values, and a p-value lower than 0.05; thus the variable language influences the perception of drought in the State of Chiapas. These results suggest that there are more

Spanish-speaking households than would be expected that believe drought has increased. There is also a higher number of native-language speaking households than would be expected that are more likely to believe that drought risk has not increased, while fewer native speaking households believe drought is increasing.

Table 31 Primary Income from Agricultural Related Sources and Perception of Drought.

| **Primary Income from Agricultural Related Sources** | **Perception of Drought** | | **Total** |
|---|---|---|---|
| | No | Yes | |
| No | 64<br>*67.2* | 166<br>*162.8* | 230<br>*230* |
| Yes | 75<br>*71.8* | 171<br>*174.2* | 246<br>*246* |
| **Total** | 139<br>*139* | 337<br>*337* | 476<br>*476* |

Pvalue= 0.523;
chi2= 0.407;

There is no observed relationship between income from agriculture sources and perception drought.

Table 32 Irrigation and Perception of Drought.

| **Use Irrigation Water?** | **Perception of Drought** | | **Total** |
|---|---|---|---|
| | No | Yes | |
| No | 124<br>*114.6* | 273<br>*282.4* | 397<br>*397* |
| Yes | 7<br>*16.4* | 50<br>*40.6* | 57<br>*57* |
| **Total** | 131<br>*131* | 323<br>*323* | 454<br>*454* |

Pvalue= 0.003;
chi2= 8.722;

In Chiapas a small number of households use irrigation water for their maize production; thus this sample is heavily weighted towards households that do not use irrigation water. The chi-square test shows small differences between the observed and expected values for those households that do not use irrigation, and for those that use it. These results suggest that there are slightly fewer households than it would be expected that do not use irrigation water and believe that drought is increasing. Conversely, there is a higher number of households than would be expected that use irrigation water and believe drought is increasing, in comparison to those that do not hold this belief.

Table 33 Criolla Maize and Perception of Drought.

| **Plant Criolla Maize?** | **Perception of Drought** | | **Total** |
|---|---|---|---|
| | No | Yes | |
| No | 119<br>*100.5* | 225<br>*257.6* | 344<br>*344* |
| Some | 20<br>*38.5* | 112<br>*93.5* | 132<br>*132* |
| All | 0<br>*0* | 0<br>*0* | 0<br>*0* |
| **Total** | 139<br>*139* | 337<br>*337* | 476<br>*476* |

Pvalue= 0.000;
chi2= 17.440;

The chi-square test for the variable criolla shows differences between the observed and expected values. The sample is weighted towards households that do not plant criolla maize. There are more households than would be expected that plant some criolla maize and believe that drought is increasing. The results suggest that planting some criolla varieties is a predictor of the perception that drought is increasing in Chiapas.

Table 34 Support Programs and Perception of Drought.

| **Participates in Support Programs?** | **Perception of Drought** | | **Total** |
|---|---|---|---|
| | No | Yes | |
| No | 135 | 322 | 457 |
| | *132.4* | *326* | *457* |
| Yes | 0 | 9 | 9 |
| | *2.6* | *5* | *9* |
| **Total** | 135 | 331 | 466 |
| | *135* | *331* | *466* |

Pvalue= 0.053;
chi2= 3.743;

There is no observed relationship between support programs and perception drought.

Table 35 Receipt of Credit or Loans and Perception of Drought.

| **Receive Credit or Loans?** | **Perception of Drought** | | **Total** |
|---|---|---|---|
| | No | Yes | |
| No | 127 | 227 | 354 |
| | *103.3* | *250.7* | *354* |
| Yes | 9 | 103 | 112 |
| | *32.7* | *79.3* | *112* |
| **Total** | 136 | 330 | 466 |
| | *136* | *330* | *466* |

Pvalue= 0.000;
chi2= 31.907;

Table 36 Changes in Maize Yield on 2009 and Perception of Drought.

| **Changes in Yield** | **Is Drought Increasing?** | | **Total** |
|---|---|---|---|
| | No | Yes | |
| No Change | 32 | 9 | 41 |
| | *11.3* | *29.7* | *41* |
| Decreased | 53 | 274 | 327 |
| | *90* | *237* | *327* |
| Increased | *35* | *33* | *68* |
| | *18.7* | *49.3* | *68* |
| **Total** | 120 | 316 | 436 |
| | *120* | *316* | *436* |

Pvalue= 0.000;
chi2= 93.008;

The differences between the observed and expected values and p-value are evidence that the variable yield is a predictor of drought perception in Chiapas. The sample is heavily weighted towards households that reported that their maize yields have decreased. The largest difference between expected and observed values comes from the group of households that reported a decreased in yield and believe drought is increasing. This result suggests that households in Chiapas who have experienced a decline in yield are more likely to believe drought is increasing.

Table 37 Levels of Information and the Perception of Drought.

| Access to information Sources | Is Drought Increasing? | | Total |
|---|---|---|---|
| | No | Yes | |
| Has one or less. | 93<br>*79.4* | 182<br>*195.6* | 275<br>*275* |
| Has more than one. | 43<br>*56.6* | 153<br>*139.4* | 196<br>*196* |
| **Total** | 136<br>*136* | 335<br>*335* | 471<br>*471* |

Pvalue= 0.005;
chi2= 7.863;

Based on the slight differences between the observed and expected values and the p-value, the variable access to information does influence the perception of drought in the Chiapas. The results suggest that there are slightly more households than it would be expected that have more than one information source and that believe drought is increasing, compared to those with fewer sources of information