ANALYZING CHANGES IN THE BEEF CATTLE RANCHING COMMUNITIES OF ACATIC AND TEPATITLÁN DE MORELOS, JALISCO, MEXICO RELATED TO LAND COVER AND CLIMATE VARIABILITY

By

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A Thesis
Submitted in Partial Fulfillment of the Requirements for the
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TITLE: ANALYZING CHANGES IN THE BEEF CATTLE RANCHING COMMUNITIES OF ACATIC AND TEPATITLÁN DE MORELOS, JALISCO, MEXICO RELATED TO LAND COVER AND CLIMATE VARIABILITY

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The impacts of climate change on the environment at the global scale can be determined through the use of large-scale circulation models; however, the results from these models are difficult to interpret at the regional or local levels. Regional vulnerability analyses consider the knowledge of locals, which may provide insight into the effects of climate variability on the environment at smaller scales, and most importantly, the effects that these developments are having on society. The objective of this research was to analyze the vulnerability to climate variability of the beef cattle ranching communities of the municipalities of Acatic and of Tepatitlán de Morelos, Jalisco, Mexico. These municipalities are found in a region of the state referred to as "Los Altos". The economy of Los Altos largely relies on agricultural and farming practices; these sectors provide the largest source of employment in the area. In the two municipalities that comprise the study area, the beef cattle industry is one of the strongest economic activities. Climate variability poses great threat on these communities because the main economic activities of the region are highly dependent on natural resources.

To have a better understanding of the human-environment interactions in this region, remote sensing methods were applied. Three Landsat Thematic Mapper ™ images (years: 1985, 1993 and 2000) were employed to generate land use and land cover classification maps of the study area; these maps were then subjected to a change detections analysis. Some of the land use

and land cover categories experienced more change than others; among those was the category of water, shrub land and crop land. The area covered by water nearly doubled from 1985 to 1993 and then nearly decreased by half by the year 2000. From 1985 to 1993, here was a decrease in the shrub land of about 1200 ha and concurrently an increase in the crop land of about 1400 ha. From 1993 to 2000 there was an increase in the shrub land category of about 430 ha and a decrease in the crop land category of about 690 ha.

To gain insight into the effects of climate variability on the livelihoods of these communities, nine local beef cattle ranchers were interviewed on a one-on-one basis. All participants believe that the local beef cattle industry is highly valuable to the economy and culture of the region. All participants also mentioned that notable variations in to the climate have been occurring in recent decades; mainly precipitation scarcity and higher temperatures. The locals believe that these changes are the result of extensive deforestation. In past decades, deforestation of native vegetation has been intensely performed in order to make land available for agricultural purposes. Therefore, among the various adaptation measures to the changes presented in the climate, the cattle ranchers talked about planting trees. People believe that the "vision" of the region is changing and that reforestation has become a priority in this land.

To determine the exact causes of the climate changes experienced in this region, further investigations have to be done. However, it is certain that these changes are having implications on the economic activities of the region; the people of these communities will continue facing difficulties if the present changes in the regional climate continue to develop. The employment of proper adaptation measures has the potential to reduce climate-related losses within the livestock and agricultural sectors. Therefore, it is crucial that preventive measures are taken by the members of these communities before the effects of climate change worsen in the region.

DEDICATION

I dedicate this project to various members of my family, for their immense help and support on this thesis. To my parents, Luis Ernesto and Melva Treviño, for their encouragement throughout my entire academic career; to my uncle, Jorge Luis Peña, without his help completing this thesis would not have been possible; and to Miguel Treviño and Anaís Guzmán for taking the time to send me much needed INEGI data all the way from Monterrey, Nuevo León, Mexico.

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CHAPTER 1

INTRODUCTION

Introduction

Scientific research indicates that climate change is occurring at unprecedented rates. From global to local scales, variations of weather patterns have been noted. Additionally, there is an increase in the occurrence and intensity of extreme climate events. These changes will have an impact on the living organisms of the planet; however the extent of this impact is highly uncertain. For evident reasons, this has become a topic of great interest and heated debate among the scientific community. Despite the disagreements that accompany the discussions regarding the topic of climate change, a common ground has been reached: it is crucial to identify the climate variations presently occurring, how these will develop, and to expand our knowledge of the potential effects that these changes impose on the inhabitants of the planet. Different areas of the world are experiencing different changes and the effect of these varies greatly from region to region. While some regions may experience beneficial changes to their regional climate, others may experience undesirable changes. Advanced global circulation models (hereafter GCMs) provide insight into what could result from these types of developments. However predictions at global scales are difficult to interpret at the regional or local level. To gain a deeper understanding of the effects of current and future climate variability, assessments at the regional or local level are vital. Regional vulnerability studies can focus on a variety of issues at more specific spatial scales, as well as analyze them at various temporal scales. These studies can provide the knowledge to ameliorate the impacts of climate change at the local level (Byg et al. 2009; Fosu-Mensah et al. 2012; Magaña et al. 1997; Webhe et al. 2009). The first step in conducting a regional vulnerability study concentrating on societal impacts is to identify the important sectors within the area of study that are potentially vulnerable to climate change (e.g., agriculture, livestock, forests) (Magaña et al. 1997). For developing countries, where large portions of the population live in rural areas, the agricultural and livestock sectors are the largest sources of employment (Fosu-Mensah et al. 2012; Roder et al. 2008; Tambo and Abdoulaye 2013). The prosperity of those sectors is significantly affected by the availability of natural resources. Climate change has the potential to harm rural communities whose livelihoods are highly dependent on the environment.

In recent decades, the introduction of new technologies has resulted in increased productivity within the agricultural and livestock sectors of Mexican states, such as the state of Jalisco (Flores López et al. 2012). Jalisco is located on the southwestern coast of Mexico along the Pacific Ocean (Figure 1), between 22˚45' and 18˚55'N latitude and 101˚20' and 105˚42'W longitude (INEGI 2013). With a total surface area of 78,588 km^2, Jalisco comprises about 4% of the total area of the country; it is the seventh largest state (INEGI 2013). Its agricultural contribution to the national gross product makes it one of the most important states in Mexico (Flores López et al. 2012). The population of Jalisco largely relies on natural ecosystems to support its economy. Uses associated with the type of land cover in the state can be identified by the main economic activities of the region: i) wildlife and forestry, ii) wildlife and agriculture, iii) agriculture and forestry, iv) agriculture, v) livestock, vi) human settlement, and vii) mixed agriculture and livestock (Ibarra-Montoya et al. 2011). Changes in temperature and precipitation are projected to modify the production and distribution patterns of plant species, as well as the availability of water resources throughout the state (Monterroso Rivas et al. 2011; Reich et al. 2010). Modifications made to the capacity of these lands enabling them to sustain the current natural ecosystems will have an impact on the economy of the state.

Figure 1. The state of Jalisco, Mexico

Research Problem

For decades, Jalisco has been among the top producers of beef and milk. In 2010, the contribution of the state was 20.4% of the total livestock production of the country. It was the second largest producer of beef and largest producer of milk in the country. The bulk of these products are for domestic consumption (SAGARPA 2012). The purpose of this research was to analyze the effects of climate variability on the beef cattle industry in two municipalities of Jalisco, Mexico: Acatic and Tepatitlán de Morelos. The aim of this research was to determine how climate variability may affect the cattle ranchers whose livelihoods depend on this industry. Many studies have been conducted to assess the vulnerability of various systems to climate change in Mexico; however most of these investigations have been made at the national level (Tinoco-Rueda et al. 2010). Such studies can provide an overview of the vulnerability that the country is currently exposed to (in regards to climate change), but are less useful for implementing policies or management decisions at the state or county level.

Aside from natural phenomenon, human activities have the potential to greatly modify the landscape at various spatial and temporal scales. Land cover change processes induced by anthropogenic influences are more complex than those resulting from natural processes because they occur at faster rates (Lasanta and Vicente-Serrano 2012). Surveing the current land use/land cover (hereafter LULC) of a region does not provide sufficient information to determine the impacts of human activities on the environment. The employment of satellite imagery can contribute to a deeper understanding of such developments. The information gathered by remote sensing techniques, such as change detection analyses, offers a unique historical perception of the human-environment interactions within the area of interest. Having a deeper understanding of these dynamics ultimately promotes better decision making regarding future changes of the land, as well as the use of available resources (Lu et al. 2003). In order to gain insight into the relationship between humans and the environment in this area, this research employed remote sensing change detection-derived techniques to assess LULC changes in the municipalities of Acatic and of Tepatitlán de Morelos. This research aimed to identify how human-environment intercactions affect the productivy of the beef cattle industry of the region, which in turn would have an impact on the lives of its inhabitants.

This research also explored the perceptions of local beef cattle ranchers of climate variability in the region and how it is personally affecting them. Any research aimed at understanding the impacts of climate variability and the socioeconomic responses to these changes should take into consideration the awareness of the locals to the present weather fluctuations (Vedwean and Rhoades 2001). Local knowledge can make valuable contributions to research regarding the effects of climate change at the local or regional levels (Byg and Salick 2009; Fosu-Mensah et al. 2012; Mandleni and Anim 2011). To assess the level of vulnerability of a community and to determine its capacity to effectively manage present and future stress, it is important to understand the current range of choices that a community can make to mitigate the effects of climate change (Eakin 2005). Understanding the perceptions of community members and the adaptation measures that they have taken as a response to climate variability offers insight into the level of vulnerability of an area and provides information regarding necessary interventions to ameliorate the impacts of climate change at the local level (Tambo and Abdoulaye 2013).

Research Questions

1. *How has the land use/land cover of the study area changed in the last three decades?*

2. *What are the perceptions of the study area's beef cattle ranchers of the local beef cattle industry and how do they believe weather and climate variability can affect it?*

3. *What are the perceptions of the study area's beef cattle ranchers of global, regional, and local weather and climate variability and how do these accord to historical climate data?*

4. *What adaptation measures (if any) have the beef cattle ranchers taken to mitigate against the impacts of the apparent weather and climate variability?*

Importance of Study

Climate change has caused various ecological and environmental effects; consequently these developments can impact the socioeconomic sectors (Magrin et al. 2007). The agricultural sector has been one of the most affected (Brodziak et al. 2011). GCMs and crop models project decreased yields for numerous crops (maize, wheat, barley) (Magrin et al. 2007). Other economic activities that are linked to or dependent on agricultural activities, such as the livestock sector, will also be affected. It is projected that in Mexico the percent of national territory adequate to grow crops will decrease from 40% to about 25%. It is estimated that this has the potential of directly affecting 24 million Mexicans that currently live and work in rural areas (Brodziak et al. 2011). There has been a notable migration to urban areas; increases in urban population increase will result in further social problems.

The adaptive capacity of a group of people and how sensitive their livelihoods are to climate events are two key attributes of vulnerability (Webhe et al. 2006).When assessing the vulnerability of a community, information about local perceptions of climate change can be useful. Local knowledge influences their decision to act (or not to act), as well as what adaptive measures to take in the short- and long-terms (Byg and Salick 2009). Aside from the effects of climate variability, there are other factors that play a role in the decisions of communities that depend on the agricultural and livestock sectors. Other features that affect the nature and evolution these communities include: local environmental characteristics, economic opportunities, cultural preferences, capital to purchase animals and/or proper equipment, and farming methods and technologies (Thorton et al. 2009; Silvestri et al. 2012). It is important to conduct analyses at the local level because these factors will vary extensively from region to region. Investigating these components will provide a better vulnerability assessment at the local level. Understanding the level of vulnerability of a certain area can allow for the implementation of appropriate adaptation techniques and give rise to the development of efficient mitigation measures. In a country like Mexico where the people of rural areas may not have the adequate resources to adapt competent mitigation practices, it is crucial that they take efficient adaptation measures (Brodziak et al. 2011).

CHAPTER 2

LITERATURE REVIEW

Climate Variability

The climate system of our planet is the result of interactions and relationships between complex variables and systems such as the atmosphere, the ocean, the continents, planetary rotation, planetary life and human activities. Changes made to any of those variables results in a change within the climate system. Pronounced changes have been noted on the climate since the middle of the last century −average annual temperatures are rising at the global scale and precipitation patterns are changing. Additionally, human activities have generated increasing concentrations of carbon dioxide, as well as of other greenhouse gases, during that period (Magrin et al. 2007). Increases in the concentrations of these gases over the past several centuries have caused notable changes to climate. If concentrations of greenhouse gases in the atmosphere continue to grow, current change in the climate will continue to exacerbate. Climate change has the potential to cause severe variations in regional and local climates, thus has the capacity to transform the ecosystems of those environments.

In the last decade, Mexico experienced the reality of climate change. Since the year 2000, there has been an increase of about 1°C in the average temperature of the country, the number of severe hurricanes that have affected the country has increased since the beginning of this century, and sea level along the coast of the state of Veracruz (along the Gulf of Mexico) has risen about 10 centimeters in the last 70 years (Brodziak et al. 2011). The experienced effects of these developments give insight into the potential impacts that further change could result in and the impacts these could have on the Mexican population.

Indirect Impacts of Climate Variability on Livestock

Research shows that the agricultural and livestock systems of less developed countries are more sensitive and vulnerable to climate variability than those of the developed world (Seo et al. 2008). For instance, livestock in less developed countries heavily depend on forage from natural ecosystems for nutrition (Seo and Mendelsohn 2008; Monterroso et al. 2011). Changes to in quantity of forage available for feeding ultimately has an impact on the productivity of the livestock industry. Consequently, the lives of those who rely on that industry are also affected (Seo and Mendelsohn 2008; Monterroso et al. 2011).

Climate variability causes changes in forage growth and quality, as well as the composition and distribution of pastures. As a result, climate change indirectly affects the livestock industry through different processes. The quantity, quality, and distribution of feedstuffs such as pasture, forage and grain are highly susceptible to changes in temperature and precipitation (Seo and Mendelsohn 2008; Thorton et al. 2009; Craine et al. 2010). Low precipitation and rising temperatures result in the reduction of soil moisture, affecting the net primary productivity of plants and diminishing the capacity of an area to support livestock (Thorton et al. 2009; Monterroso et al. 2011). Areas that experience a decrease in precipitation will experience a decrease in net primary productivity, resulting in a loss of nutritional resource for the animals (Monterroso et al. 2011).

In Mexico, the productivity of grazing lands is directly related to the highly variable quantity and distribution of seasonal precipitation (Monterroso et al. 2011). In the tropical and subtropical climate regions of the country, the quantity of rainfall received during the warm season is inversely related to surface air temperature, and this conditioning influence carries over to the cool season (Englehart and Douglas 2004). Rising average temperatures could lead to extended warm seasons, causing an overall decrease in precipitation and reduction of grassland productivity. Ibarra-Montoya el al. (2011) conducted a study to assess the LULC in the Huichol-Antengo sub-watershed of the Lerma-Chapala watershed located in central and northern Jalisco. According to this study, the types of vegetation most vulnerable to climate change are those that are at risk of being exposed to drier and warmer conditions (i.e. 10% decrease in precipitation and temperature increase of 2˚C in the future) (Ibarra-Montoya el al. 2011). The researchers concluded that the areas of Jalisco that are most likely to experience these types of changes are those of the temperate zones. The grazing lands of regions with temperate climates are highly vulnerable to drought (Magrin et al. 2007). The areas where the livestock industry has thrived in Jalisco are found in the temperate and the semi-arid regions (Ibarra-Montoya el al. 2011; Tinoco-Rueda et al 2011). The temperate zones are located in the central part of the state and transition into the semi-arid zones of the northeast, a region referred to as "Los Altos de Jalisco" ("The Highlands of Jalisco"). The rainfall this region receives is essential for its productivity. Reich et al. (2010) conducted a study to describe the relationships of tree species richness to components of forest structure, topography and climatic variability in the state of Jalisco. The researchers found a trend at the state level: regardless of climatic zone or topography, species richness increased with increasing rainfall (Reich et al. 2010). This also is true for the plant output and vegetation species richness of grasslands found within the state (Monterroso et al. 2011). The productivity of the livestock industry in these areas will be drastically affected if precipitation rates substantially decrease. About 80% of this land cover currently produces forage that can be utilized by the livestock sectors (Flores López et al. 2012). Any variability made to the capacity of these lands to produce forage, whether it is beneficial or detrimental, is therefore economically important.

Direct Impacts of Climate Variability on Livestock

Another reason that the livestock sectors of developing countries are more vulnerable to climate change is that most animals in these countries live outside, whereas in developed countries (such as the case of the United States) the livestock live in barns and sheds (Seo and Mendelsohn 2008). As a result, the livestock animals of developed countries are less exposed to outside environments than those of less developed or developing countries (Seo and Mendelsohn 2008). Although the livestock sector is more resilient to extreme climate events than crop production (Seo and Mendelsohn 2008), the direct effects from air temperature, sunlight, humidity, and wind have a strong impact on the productivity of the animals (Arias et al. 2008). The environment the livestock are exposed to greatly influences their physiology and performance (such as growth and reproduction), their health, and their behavior (Thorton et al. 2009). Exposure to extreme oscillations in temperature or to a combination of negative factors that affect cattle, even for short periods of time, could impose stress on the animals. Stress can cause a reduction of productive performance of the animals, and this could greatly affect the economic productivity of the industry (Arias et al. 2008).

Importance of Local Perspective on Climate Change

Until recently, local knowledge of climate change and its impacts on society have been discounted by most climate change studies (Byg and Salick 2009). However, this type of knowledge is crucial for any research aimed at understanding the societal impacts of climate change. Climate change is a “social ecological system” and these types of systems cannot be understood relying on science alone – human perceptions and reactions must be taken into account (Byg and Salick 2009). Understanding local perspectives of climate change is of value when assessing the vulnerability of a community. The extent to which climate change can affect a community largely depends on awareness and the level of adaptation in response to perceived changes (Fosu-Mensah et al. 2012). However, how climate change will affect the population of a given area is not only dependent on the adaptation measures taken against the changes, but also on ecological, social, and economic factors (Byg and Salick 2009). Climate change is not solely a physical environmental phenomenon, it has implications for the social, cultural, and economic realms (and in some cases even spiritual and moral concepts) (Byg and Salick 2009). The ability of people to react and adapt to such changes depends on factors such as the availability of resources for adaptation, motivation, and most importantly, the level of information locals have regarding the state of the environment, as well as their understanding of the links between human decisions and the environment (Fosu-Mensah et al. 2012; Silvestri et al. 2012). The literature regarding adaptation to climate change indicates that there are certain adaptation choices that farmers are making throughout the world. Some examples include: changing to new crops or adding heat resistant varieties, or in the livestock sector: switching to other types of livestock or acquiring more resistant breeds. However, the spectrum of adaptation options is broad and the measures taken can be specific to a certain region. This indicates that the impacts of climate change are localized and context specific (Hisali et al. 2011). As a result, regional analyses are valuable sources of information.

Scientists are often skeptical about the reliability of observations made by non-scientists (Byg and Salick 2009), however, local knowledge can provide valuable information regarding climate change at smaller scales. This can be a valuable tool for understanding climate variability in regions where long-term climatic data is sparse (Vedwan and Rhoades 2001). Although anecdotal observations cannot substitute for scientific measurements and models, they provide substantial information regarding the local phenomenon and the perceptions of the people provide insight into local impacts and concerns (Byg and Salick 2009). The locals can explain the manifestation of climate change at the local level, as well as how it is evaluated, interpreted, and handled by the those that are being affected. Understanding local perceptions of the relative amount, direction, and impact of climate change are imperative when aiming to understand the patterns in human response to the phenomenon occurring in the specific region of study (Silvestri et al. 2012). Local-level analyses can also be a valuable contribution when attempting to address the primary constraints to adaptation and the differential nature of vulnerability of particular groups (Webhe et al. 2006). Regional vulnerability evaluations support the prioritization of adaptation and intervention as well as the promotion of taking sustainable and efficient adaptive measures for the region of study (Tambo and Abdoulaye 2012).

Land Use and Land Cover Change

The climate of a region is determined by long-term variability in temperature, precipitation, evaporation, and other on factors peculiar to the region such as topography, vegetation cover and ocean-land interactions. As a result, changes in the land cover can cause changes to the local and/or regional climate. Drastic changes in land use can have detrimental impacts on the environment of a region. In Mexico, deforestation for agricultural purposes, grazing use, or for urban expansion (all of which are relevant to the state of Jalisco) have resulted in a continuous decline of natural land cover (Vásquez and Liverman 2004). These types of human activities are exacerbating the effects of drastic climate variability on the local environments. The presence or absence of vegetation influences the regional climate (Nobre et al. 1991). Transforming forests into pasture or agricultural lands has a pronounced effect on the local climate (Dubreuil et al. 2012). Deforestation can also have an impact on the water source beneath the surface. Nobre et al. (1991) found that the water-holding capacity of soils is modified when deforested. The soils of lands converted from forest to pasture lands hold less water and have a lower hydraulic conductivity, meaning that infiltration rates at the surface are lower for pasture lands than for forested areas (Nobre et al. 1991).

Methods and techniques derived from Geographic Information Systems (hereafter GIS) can provide the operational framework to integrate biophysical and socioeconomic information over extensive areas. Among its numerous applications, GIS be used to evaluate hypotheses related to various relationships within an ecosystem, including the degree of environmental and human controls on ecological processes or patterns (Paruelo et al. 2004). This type of knowledge cannot be obtained by making simple observations in the area of interest at a point in present time. Some of the most common GIS applications employed to analyze these relationships are those of remote sensing, more specifically, change detection techniques (Song et al. 2001). “Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times” (Singh 1989). These remote sensing applications are largely employed because a great deal of land-cover information can be obtained from remotely sensed data and monitoring changes in the landscape through these methods is economically feasible for the researcher. Information collected using these methods provides a deeper understanding of the relationships between humans and natural phenomena because they offer knowledge from a "historical perspective". These analyses give insight to the current LULC situation and how this has changed over time (Lu et al. 2003).

The purpose of change detection investigations is to analyze the changes of the LULC of a region over a specific period of time. These analyses involve the application of multi-temporal datasets. The temporal effects of the phenomenon can be analyzed and explored through the use of quantitative approaches (Lu et al. 2003). Change detection analyses determine the changes of the land cover by assessing the changes in radiance values of each pixel on the image. Conducting a change detection analysis using remotely sensed data requires careful considerations of the remote sensor system, the environmental characteristics, and image processing methods. Utilizing imagery from different dates results in differences of atmospheric conditions, or in soil moisture contents, or in Sun angles; this can introduce error to the analysis (Más 1999; Song et al. 2001). To minimize this error it is crucial to use data with the same spatial, spectral, and thematic resolutions (Ioannis and Meliadis 2011; Lu et al. 2003). Another important factor in determining the success of a change detection analysis is the timing of the data acquisition. Anniversary (or near anniversary) acquisition dates of the imagery are necessary to conduct an efficient change detection analysis. This would reduce the impacts of differences in the Sun angle and as well as phonological differences in the vegetation (Ioannis and Meliadis 2011; Lasanta et al. 2012; Lu et al. 2003; Más 1999).

Conclusion

The actions and decisions that humans make have an impact on the climate system and consequently have an impact on the global and regional environments. How the phenomenon of climate change will evolve is highly unpredictable, however, analyzing the interactions between humans and the environment at the regional and/or local levels is important because the direction of future changes in the climate system are dependent on the decisions made by the people (Byg and Salick 2009). Regional vulnerability analyses can provide useful information regarding the impacts of climate change at the regional and local levels because they can explore human-environment dynamics at smaller scales. These studies are essential for understanding these processes and helpful tools when assessing the vulnerability of the communities found within the region under study. Understanding interactions among the socioeconomic, ecological, and climate factors of a region can allow for the proper mitigation of climatic effects projected for an area. Identifying the potential risks a community is exposed to can help decision makers alleviate the potential current (and future) changes in climate (Thorton et al. 2009). The results provided by regional vulnerability analyses can be used for the planning of land and resource use, as well as contribute to a social, ecological and economic development that is sustainable and adequate for the specific location of interest.

CHAPTER 3

RESEARCH METHODOLOGY

Introduction

This research included investigating the level of vulnerability to climate change of the beef cattle ranchers living in the municipalities of Acatic and of Tepatitlán de Morelos (hereafter Tepatitlán). Both municipalities are located in the northeastern part of the state of Jalisco, Mexico, in a region referred to as "Los Altos de Jalisco”. The Highlands of Jalisco are divided into two regions, Los Altos Norte (the Northern Highlands) and Los Altos Sur (the Southern Highlands) (Figure 2).

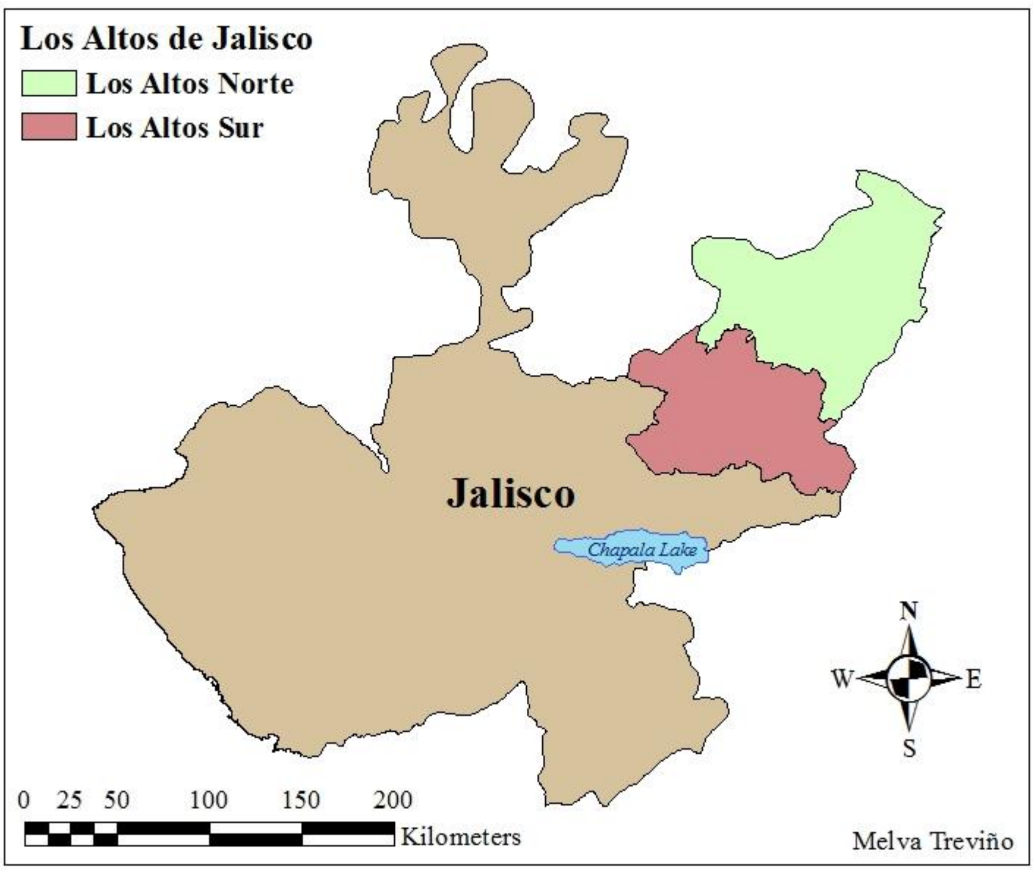

Figure 2. The Highlands of Jalisco

The economy of Los Altos largely relies on agricultural and farming practices; these sectors provide the largest source of employment in the area (Flores López et. al 2012). Combined, Los

Altos Norte and Los Altos Sur cover about 15,540 km^2, comprising about 16% of the territory of the state (INEGI 2013). Within this region, more than 241,000 hectares are utilized for agricultural activities. About 90% of the land covered by the Highlands produces maize; 40% of that production is utilized as forage for cattle (Flores López et. al 2012). Within this region of the state, there are approximately 226,000 cattle (SIAP - SAGARPA 2012).

The municipality of Acatic encompasses approximately an area of 288 km^2 and the municipality of Tepatitlán an area of 1176 km^2 (DIVA-GIS Data 2013) (Figure 3). The beef cattle industry is one of the strongest economic activities of these two municipalities. Drastic climate variability poses great threat on these communities because the main economic activities of the region are highly dependent on natural resources.

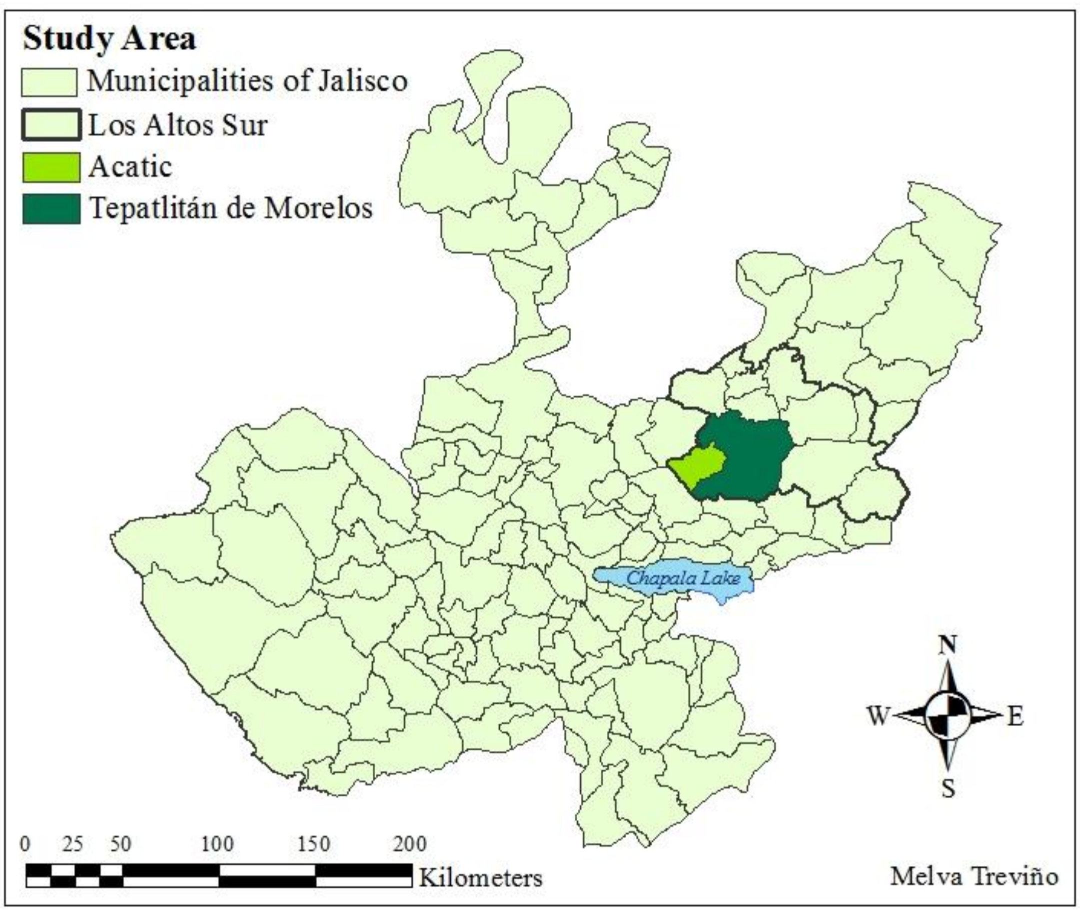

Figure 3. The Study Area

LULC Change Detection Phase

The purpose of this phase was to answer the first research question:

1. *How has the land use/land cover of the study area changed in the last three decades?*

To answer the first research question, subsets of three Landsat Thematic Mapper ™ (hereafter Landsat TM) images were employed to generate LULC classification maps of the study area. The derived classification maps were subjected to a change detection analysis. Change detection analyses can indicate the temporal variation found within two datasets through the assessment of spectral, spatial and temporal characteristics (Milne 1988). For the purpose of this project, the change detection analysis was employed to assess the level of change between determined LULC categories of the study area.

Data Acquisition

The Landsat TM imagery that was used to conduct this change detection analysis was obtained from the USGS Global Visualization Viewer (glovis.usgs.org) at no cost. To ensure an effective change detection analysis, maintain consistency within the data, and reduce the errors introduced by external factors, the imagery employed had to meet the following criteria:

1) The imagery had to belong to the Landsat Thematic Mapper ™ archive. Using imagery from different sensors introduces substantial error.

2) All images had to have been acquired during the same time of the year, and that period had to be the one with the highest phenological activity possible. The peak vegetation phenology in this region occurs after the wet season, which takes place during the months of June-August. Taking this into consideration, the objective was to choose imagery acquired during the months of August or September.

3) The portion of the Landsat TM image where the study area lies could not contain more than 10% of cloud cover.

The three images that were employed to perform this analysis were captured by the Landsat TM sensor (path 29, row 46) on the following dates: October 3, 1985, October 17, 1993 and September 10, 2000 (hereafter these will be referred to as Image 1, Image 2, and Image 3, respectively). Due to limitations posed by the availability of the data, an exception had to be made regarding the desired month time-frame of the imagery: it was extended to the month of October. Performing multi-date analyses that require imagery acquired at the same time of the year can be difficult, especially when the area of interest is located within the tropics, where cloud cover is common (Más 1999). The extensive presence of cloud cover introduced further limitations to the collection of imagery for the time-series. For unknown reasons, there are no data available for the desired (and adjusted) time-frame from the year 2000 until the year 2007. After the year 2007, images within the desired time-frame were unavailable. The image obtained for the year 2007 (September) was not employed in this study due to the extensive amount of cover on this image. As a result, the time-series was terminated in 2000.

Image Preprocessing

The downloaded images were delivered as individual TIFF files. Each file contained one image for each of the seven spectral bands of Landsat TM. These individual images were then merged and converted into a single multi-band image using ERDAS Imagine (version 11.0.4). The spatial resolution of bands 1, 2, 3, 4, 5, and 7, is of 30 x 30 meters and that of band 6 is of 120 x 120 meters. To maintain uniformity and carry out the analysis, band 6 was excluded from the generated multi-band images.

Radiometric Correction

Each image was corrected for atmospheric disturbances by employing relative radiometric correction methods using ERDAS Imagine (version 11.0.4). First, haze reduction was applied to ameliorate the effects of the clouds. Secondly, the empirical line calibration method was employed. To perform the second task, the entire Landsat TM image was used because it was too difficult to identify bright objects within the subset image. The city of Guadalajara (second largest metropolitan area of Mexico) is found within the downloaded Landsat TM images; the area encompassed by this city was used to collect the bright objects (concrete) required for the completion of the empirical line calibration process. The Landsat TM images cover much more than the necessary area (170 x 183 km) for the purpose of this research project, therefore once the images had been radiometrically corrected a subset image encompassing the study area was extracted.

Geometric Correction

It is crucial to have accurate spatial registration of the imagery intended for a change detection analysis; misalignment of pixels will reduce the accuracy of the analysis (Campbell 2011). The images employed in this research were geometrically corrected and registered to each other. Due to the clarity of the image (lack of clouds) and its recent acquisition date, Image 3 was georeferenced to a determined reference image and rectified to UTM Zone 13N, GWS 1984. The reference image employed for the geometric correction process was a mosaic image comprised of six topographic maps with a spatial resolution of 5 x 5 meters. These maps were obtained from the National Mexican Institute of Geography and Statistics (INEGI). Image 1 and Image 2 were then registered to Image 3. Depending on the image, 10-12 well distributed ground control points were selected for the resampling process. The nearest neighbor resampling method was employed to preserve the original values of the pixels (Campbell 2011). The RMSE was less than 30 meters (1 pixel) for each of the images. All of the steps regarding the geometric correction process were made using ERDAS Imagine (version 11.0.4).

Supervised Classification

ERDAS Imagine (version 11.0.4) was employed to generate a supervised classification map for each of the images. The informational classes used to determine the LULC classification categories were: 1) water, 2) urban, 3) crop land, 4) bare soil, 5) shrub land, 6) rangeland and 7) unclassified (clouds present in the imagery were assigned to the last category). With the exception of the urban category, at least 10 training areas were selected for each LULC category to ensure that at least 100 pixels were selected per category. Due to the scarcity of pixels clearly identifiable as urban, only 3-5 training areas were selected for that category. In order to assign training areas to the determined LULC categories, the spectral reflectance curve of each category had to be identified. Numerous spectral reflectance curves were analyzed (Ashraf et al. 2011; Asner 1998; Le et al. 2009; Lee at al. 2012) to use as reference. In addition, two Google Earth images taken on April, 2001 and on October, 2003 were employed as a reference when identifying the spectral reflectance of certain features on Image 3 (since its acquisition date was the closest to the Google Earth images). Having the spectral reflection graphs that were found in the literature and the Google Earth images as a reference enabled the analyst to confidently identify suitable training areas for each LULC category pertaining to Image 3. Once the spectral reflectance curves of the LULC categories of Image 3 were established, these were used as a reference when making the classification maps of the other two images. Although there were some differences between the spectral reflectance curves of the LULC categories from year to year, having all of the images set to the same radiometric allowed for the comparison and referral of image to image. The minimum distance classifier was employed to generate all of the supervised classification maps.

Classification Accuracy Assessment

Eighty-four black and white orthophotos (with a spatial resolution of 1 meter x 1 meter) were obtained from INEGI - 42 pertaining to November, 1993 and 42 to April, 2000. A mosaic image was created for each dataset using ERDAS Imagine (version 11.0.4). These mosaic images were utilized to perform the accuracy assessments of the supervised classification maps for Image 2 and Image 3. At least 10 stratified random points were used to assess the accuracy of each LULC category, with the exception of the urban category (only 2 points for Image 2 and 4 points for Image 4). Due to the unavailability of adequate data for the year 1985, no accuracy assessment could be conducted for Image 1.

LULC Change Detection Analysis

The subset images used to generate the supervised classification maps covered regions outside of the study area (the area comprised by the actual municipalities). A polygon of the study area was utilized to extract the final subset images from the classification map images using ArcGIS (version 10.1). Unfortunately, the entire area covered by the study area (the polygon) was not covered by the Landsat TM image. As a result, parts of the northern part of the municipality of Tepatitlán (area of about 9 mi^2) had to be excluded from the final subset (Figure 4). The final subsets were used to conduct the change detection analysis. The percentage covered by each LULC classification category for every year of the time-series was determined by dividing the total amount of land covered by a specific category by the total area of the final subset. This information was utilized to assess the total amount of change within each LULC classification category from year to year.

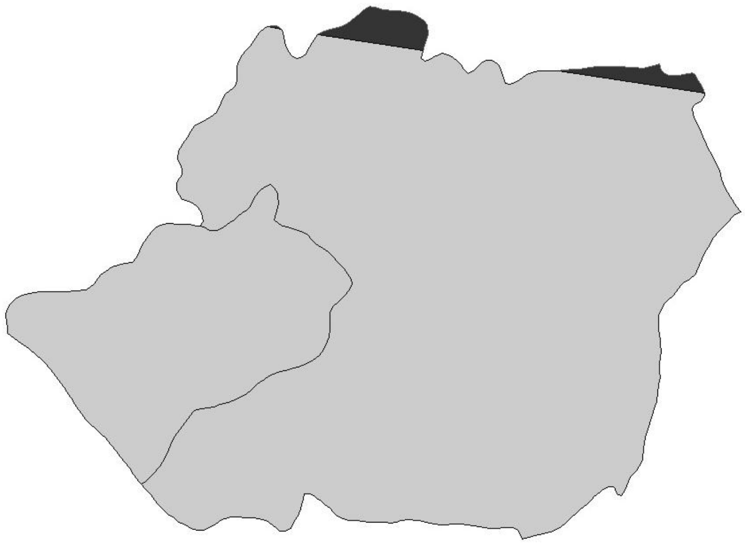

Figure 4. In black, excluded area from final subset.

Interview Phase

The purpose of this phase was to answer the last three research questions:

2. *What are the perceptions of the study area's beef cattle ranchers of the local beef cattle industry and how do they believe weather and climate variability can affect it?*

3. *What are the perceptions of the study area's beef cattle ranchers of global, regional, and local weather and climate variabilty and how do these accord to historical climate data?*

4. *What adaptation measures (if any) have the beef cattle ranchers taken to mitigate against the impacts of the perceived weather and climate variability?*

To answer these questions, personal, one-on-one semi-structured interviews (comprised of open-ended questions) were conducted with a number of cattle ranchers currently living and working in the study area. There were some limitations that were presented during this phase of the study.

Since the early 2000s, Mexico has experienced numerous violent events throughout many regions of the country. These events are the result of an ongoing war between the government and drug cartels and often times they affect the security and well-being of civilians. Although the state of Jalisco is not considered to be a "hot zone", traveling to remote, rural areas is not recommended. Consequentially, only three trips were possible to the study area. This situation gave rise to the complexity of finding potential subjects in a location that the researcher has limited familiarity, and most importantly, it posed great time limitations. To overcome these barriers, the snowball sampling method was employed to gather subjects for the study sample. Snowball sampling – also referred to as chain referral sampling – is a non-random method of data collection widely employed in qualitative sociological research (Faugier and Sargeant 1997). The process followed by this method yields a study sample obtained through referrals made by people who know (or know of) other people with characteristics that are of the research interest (Biernacki and Waldorf 1981). This method is particularly useful when the study regards sensitive issues (for example those dealing with personal or private matters), because obtaining subjects for the study sample can be of difficulty in such situations (Biernacki and Waldorf 1981). However, this method can be applied to a variety of research purposes because it provides a wide array of advantages that other sampling methods fail to overcome. In the case of this research, the limitations presented by the insecurity of traveling to the study area and the time constraints posed by the situation were overcome by the employment of this non-random sampling method.

The first step in conducting any research employing the chain referral method to gather a study sample is to assess the “social visibility of the target population” – the level of difficulty regarding access to the desired type of population (Biernacki and Waldorf 1981). As stated earlier, the current situation in Mexico gave rise to complications in regards to being able to identify suitable candidates for the research study; this resulted in a lowering of the social visibility of the population under study. However, having the knowledge of insiders to locate people for the study often times allows for the social visibility to increase. In the case of this research, a pre-existing dual relationship between some of the subjects and the researcher enabled the limitations to be overcome. Mr. Jorge Luis Peña, who lives in the city of Guadalajara sells ranching equipment throughout the municipalities surrounding the city. His acquaintance with ranchers in the study area allowed for rapid connection with the subjects. It is a misconception that the chain referral method of sampling is a self-contained and self-propelled phenomenon (Biernacki and Waldorf 1981), meaning that once a connection is made with one subject, there will be a line of subjects willing to be included in the study, without any further effort of the researcher (Faugier and Sargeant 1997). However, this does not occur in practice; once the researcher has found a willing participant, he (or she) must try to develop a relationship and persuade the subject into referring other potential subjects to become part of the study sample. Once the third party (Jorge Luis Peña) introduced the researcher to four subjects, the rest were found by asking those subjects for referrals. The requirements for a person to be considered a subject in this study were:

1) The subject had to have lived in the region for at least 10 years (or enough time to be well acquainted with the region and its environments). The purpose of this requirement was that the person had to have deep knowledge of the area and be familiar with the dynamics of the local cattle industry.

2) The subject had to be the owner of the ranch or be the "ranch manager" – the person in charge of the main operations of the ranch. This ensured that the person being interviewed had enough knowledge of the operations of the ranch, as well as proven experience in the cattle industry.

3) The ranch had to be at least partially dedicated to being a fattening ranch. Since this research concentrated on investigating the beef cattle industry of the region, owners of ranches that solely sustained dairy cows were not considered to be a part of the study.

4) The ranch had to be located within the limits of the study area.

Interview Phase Analysis

Each participant was interviewed only once and there was no further contact with them after the interview. The interviews were audio taped and varied in length, from 15 to 45 minutes. The structure of the interviews (open-ended questions) allowed for these to be conversational in nature; anything the subject felt was important was discussed (even when it was not related to a topic or question asked by the researcher). Every word spoken by the participants and the interviewer throughout the recording of each interview was later transcribed verbatim. The interview transcripts were reviewed by the researcher. To ensure the proper interpretation of the responses provided by the participants, these were evaluated and categorized into the main topics of discussion of the conversations. Responses had reoccurring themes, however due to the conversational nature of the interviews, they did not arise at the same time throughout the individual interviews. For some of the interviews the researcher had to seek out key words and identify the prevalent topics found throughout all of the interviews, then determine where to place the individual responses in relation to the responses of the other participants (Miles and Huberman 43). Once the interviews were thoroughly coded, their responses were evaluated.

Validation of Perceptions to Climate Variability

The answers regarding the perceptions to weather and climate variability were validated by comparing them to historical climate data for the city of Guadalajara, Jalisco. The climate data acquired (meteorological station: 766120) covers the time period of 1978-2013. This information was obtained from Tu Tiempo Network, S.L., a database of climate data available at no cost (tutiempo.net).

CHAPTER 4

RESEARCH RESULTS

Research Question 1 Findings

Remote sensing techniques were employed to address the first research question of this study. The objective of this question was to gain a deeper understanding of the relationship between humans and the environment in this region. The first research question is:

1. *How has the land use/land cover of the study area changed in the last three decades?*

The findings regarding this research question are derived from the supervised classification maps generated from the LULC of the study area on the dates of: October 3, 1985, October 17, 1993 and September 10, 2000 (Figures 5, 6 and 7).

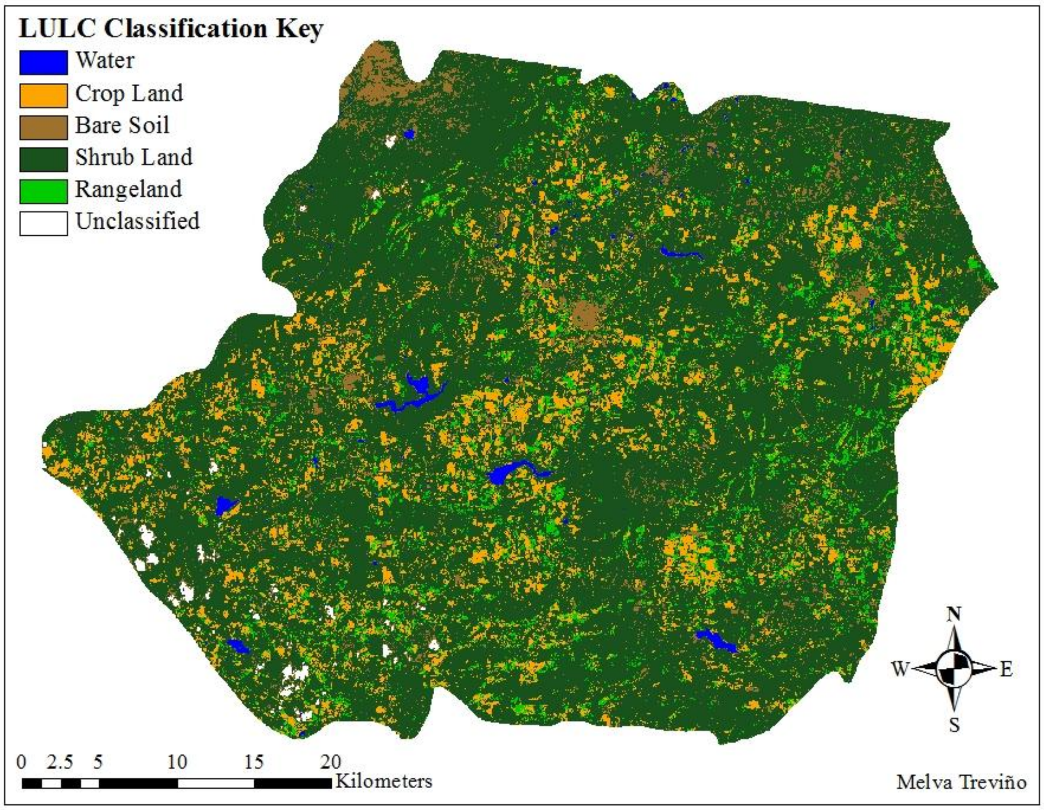

Figure 5. Supervised classification map of Acatic and Tepatitlán for Image 1 (October 3, 1985)

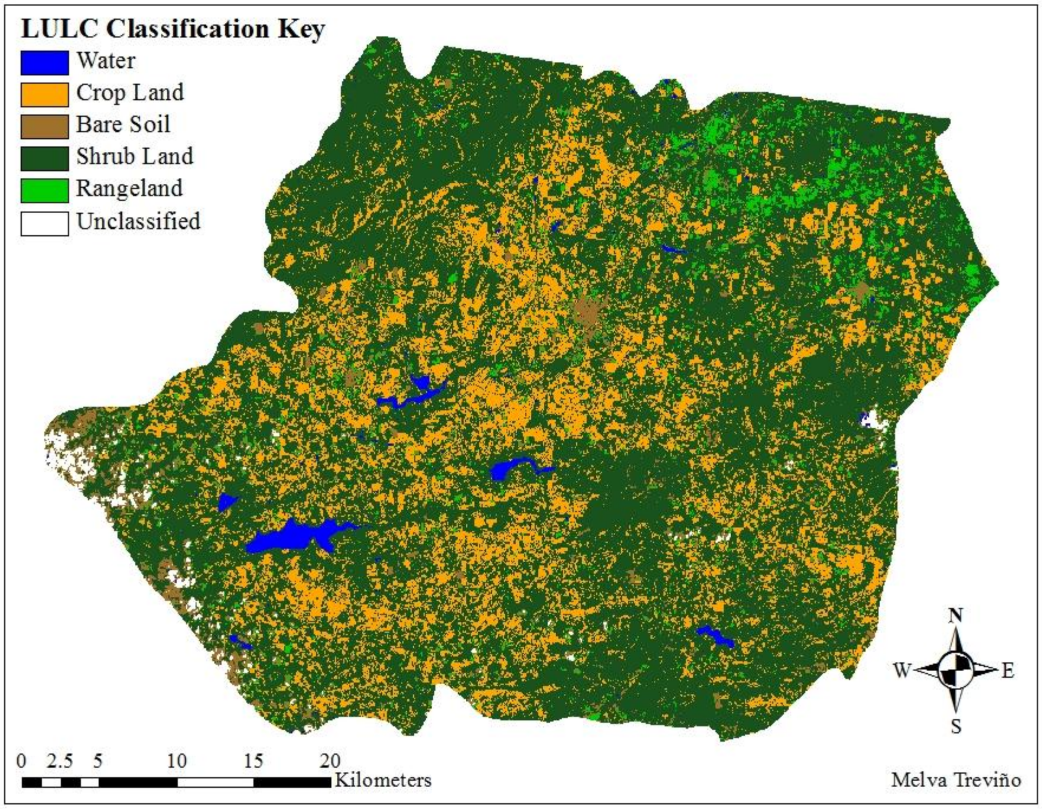

Figure 6. Supervised classification map of Acatic and Tepatitlán for Image 2 (October 17, 1993)

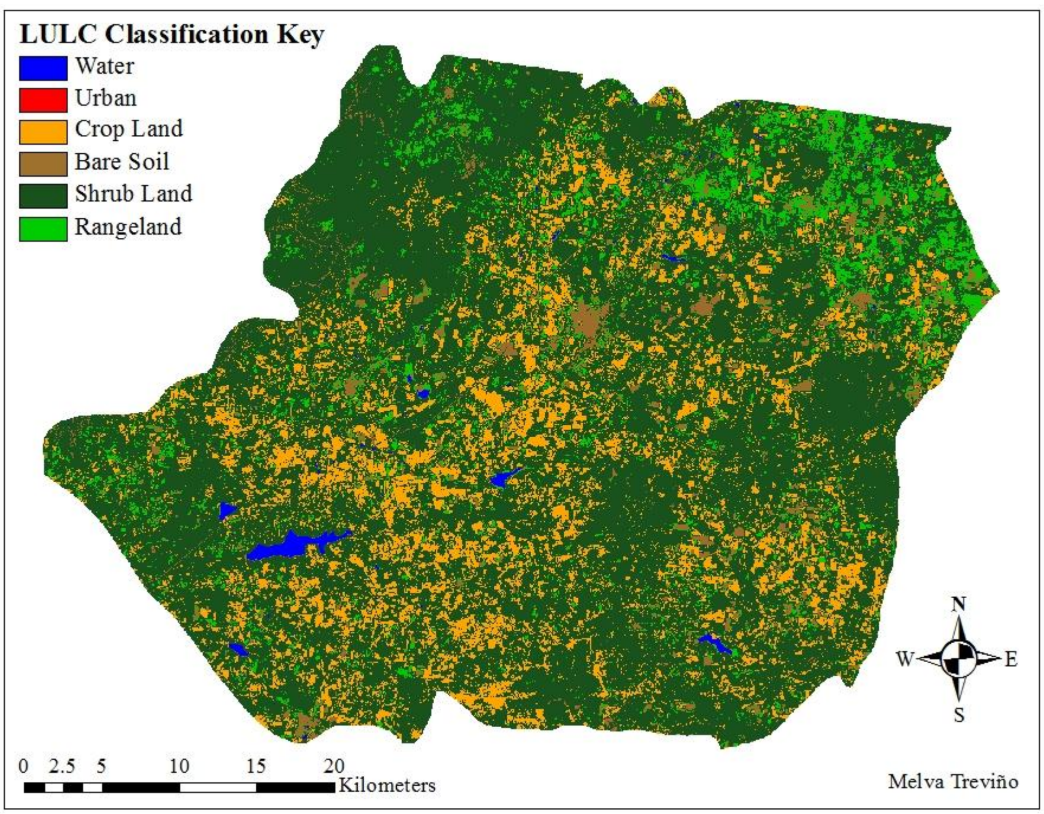

Figure 7. Supervised classification map of Acatic and Tepatitlán for Image 3 (September 10, 2000)

LULC Change Detection

The final subset encompassed an area of 11,936 ha (132,622 30 m x 30 m pixels). The percentage of land cover of certain LULC categories was more variable from year to year for some of the categories than for others; some of the LULC categories underwent more drastic changes than others (Figures 8, 9 and 10).

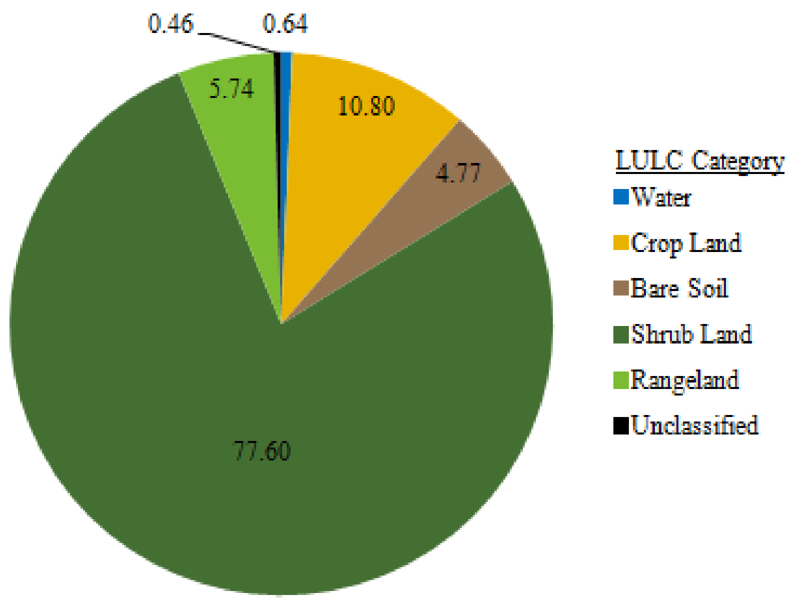

Figure 8. Percent of Territory Covered by each LULC category for Image 1 (year 1985)

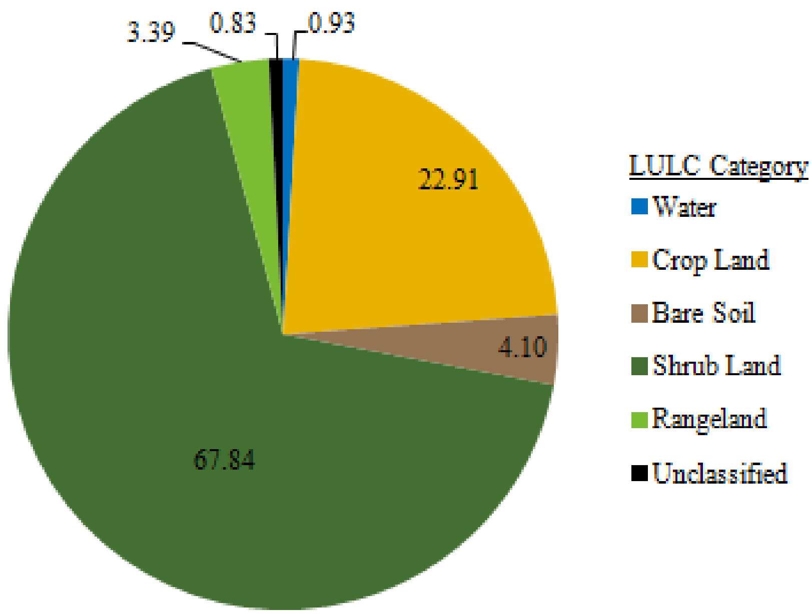

Figure 9. Percent of Territory Covered by each LULC category for Image 2 (year 1993)

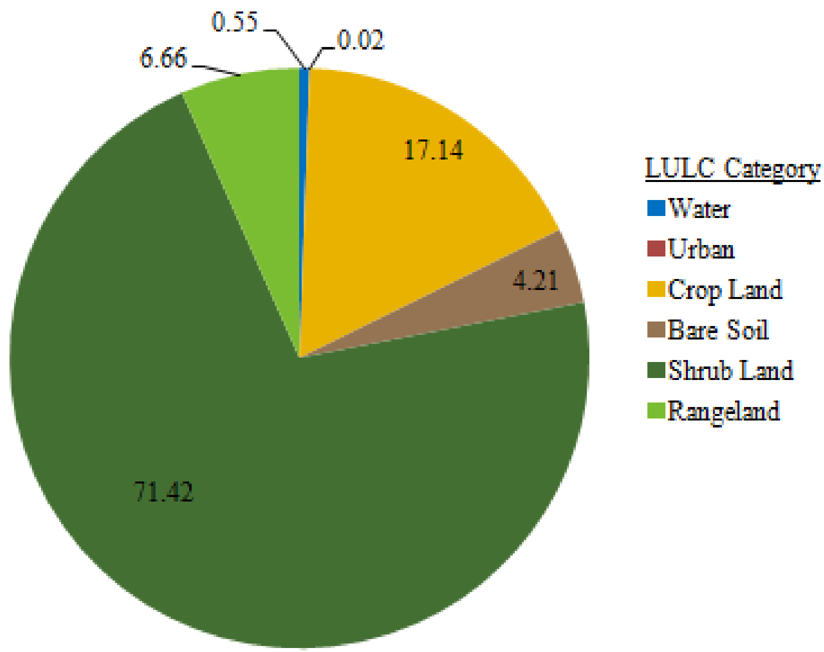

Figure 10. Percent of Territory Covered by each LULC category for Image 3 (year 2000)

The results of the change detection analyses were assessed by category for every time period of the time-series (Table 1 and 2). The total change detected for the overall time-series (15 years) was also assessed (Table 3).

Table 1. Land Cover Changes from Image 1 to Image 2 (1985 to 1993)

	1985		1993		Change	
LULC Category	**Area (ha)**	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**
Water	76.23	0.64	111.6	0.93	35.370	0.30
Urban	0	0.00	0	0.00	0.000	0.00
Crop Land	1288.62	10.80	2734.65	22.91	1446.030	12.11
Bare Soil	569.61	4.77	488.79	4.10	-80.820	-0.68
Shrub Land	9262.08	77.60	8096.85	67.84	-1165.230	-9.76
Rangeland	685.08	5.74	405.18	3.39	-279.900	-2.35
Unclassified	54.36	0.46	98.91	0.83		

Table 2. Land Cover Changes from Image 2 to Image 3 (1993 to 2000)

	1993		2000		Change	
LULC Category	**Area (ha)**	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**
Water	111.6	0.93	65.52	0.55	-46.08	-0.39
Urban	0	0.00	1.98	0.02	1.98	0.02
Crop Land	2734.65	22.91	2046.42	17.14	-688.23	-5.77
Bare Soil	488.79	4.10	502.83	4.21	14.04	0.12
Shrub Land	8096.85	67.84	8524.44	71.42	427.59	3.58
Rangeland	405.18	3.39	794.79	6.66	389.61	3.26
Unclassified	98.91	0.83	N/A	N/A		

Table 3. Land Cover Changes from Image 1 to Image 3 (1985 to 2000)

	1985		2000		Change	
LULC Category	**Area (ha)**	%	**Area (ha)**	**%**	**Area (ha)**	**%**
Water	76.23	0.64	65.52	0.55	-10.71	-0.09
Urban	0	0.00	1.98	0.02	1.98	0.02
Crop Land	1288.62	10.80	2046.42	17.14	757.80	6.35
Bare Soil	569.61	4.77	502.83	4.21	-66.78	-0.56
Shrub Land	9262.08	77.60	8524.44	71.42	-737.64	-6.18
Rangeland	685.08	5.74	794.79	6.66	109.71	0.92
Unclassified	54.36	0.46	N/A	N/A		

Change in LULC:"Water"

When looking at the total percentage of land cover by water from image to image, this LULC category does not appear to have drastically changed. From Image 1 to Image 2 there was an increase of 0.30% of the total map area, and from Image 2 to Image 3 there was a decrease of

0.39%; for the overall time-series the total change was only a decrease of 0.09%. However, when the amount of hectares covering the land with water is analyzed, it is evident that this LULC category experienced considerable changes. From Image 1 to Image 2 there was an increase in the area covered by water from 76.23 ha to 111.6 ha; that is an increment of 46.40% for that category. The amount of water cover by third image changed from 111.6 ha to 65.52 ha; a decrease of 41.29%. Overall, for the entire time-series there was a decrease of 14.05% for the LULC water category, decreasing from 76.23 ha in 1985 to 65.25 ha in the year 2000.

Change in LULC:"Urban"

There was no detection of "urban" cover on Image 1 nor on Image 2. On Image 3 there was a slight detection of it (1.98 ha), resulting in an overall increase of 0.02% for the time-series. The reason there was no detection of this LULC category on the first two images is that the classifier was not being able to properly identify the urban areas on any of the images (including Image 3). The urban areas of the study area experienced growth during the time period of the time-series, however since this region is highly rural, the urban areas on the study area were depicted as a type of bare soil by the classifier. Consequently, the results provided from this change detection analysis of the LULC "urban" category within the study area were not valid and the amount of change within this LULC category could not be properly assessed.

Change in LULC:"Crop Land"

The LULC crop land category experienced dramatic changes from image to image and for the overall time-series. The most drastic change experienced by this LULC category occurred from Image 1 to Image 2. The total area covered by crop land changed from 1288.62 ha to 2734.65 ha; that is an increase of 112.22% within the category. From Image 2 to Image 3 this area decreased by ≈688 ha; a change of 33.63% within the category. For the overall time-series, the amount of land covered by crop land increased from 1288.62 ha to 2046.42 ha; an increase of 58.81% within the category. The amount of crop land cover experienced substantial growth throughout the entire time-series and when compared to the other LULC categories, this category experienced the most severe changes.

Change in LULC:"Bare Soil"

Changes in the LULC bare soil category do not appear to be as considerable as that of other LULC categories. There was a slight decrease on the amount of land covered by bare soil from Image 1 to Image 2 of 80.52 ha (a change of 14.18% within the category) and a slight increase from Image 2 to Image 3 of 14 ha (2.87% within the category). Overall there was a decrease for the time-series of 66.78 ha (11.72% within the category). The final results for this category indicate that changes within the LULC bare soil category are not accurate. Considering that the expansion of urban areas should have been depicted by the classification map as an increase of bare soil, overall, there should have been an increase within the LULC bare soil category.

Change in LULC:"Shrub Land"

The LULC shrub land category experienced drastic changes. From Image 1 to Image 2. The total area covered the shrub land decreased from 9262.08 ha to 8096.85 ha. With a total decrease of 1165.23 ha, there was a decrease of 12.58% within the category. From Image 2 to Image 3 there was an increase of 427.59 ha, a change of only 5.28% within the category. For the overall time-series, there was a decrease of 7.96% (737.64 ha) for the LULC shrub land category.

Change in LULC:"Rangeland"

The changes within the rangeland category were not as marginal as those presented on the other LULC vegetation categories (crop land and shrub land). From Image 1 to Image 2 there was a decrease of 279.90 ha, a change of 40.85% within the category. From Image 2 to Image 3 there was an increase of 389.61 ha, an increment of 96.16%. This category had an over increment of 109.71 ha for the entire time-series, an increase of 16.01% within the category.

Change in LULC:"Unclassified"

Pixels pertaining to cloud cover were assigned to the "unclassified" category on the LULC classification maps. For Image 1 this was an area of 54.36 ha (0.46% of the total map area), for Image 2 it was 98.91 ha (0.83% of total map area) and Image 3 had no clouds present. Since this is not a classification of land use, changes within this category were not evaluated. The purpose of having this category in the classification map was to illustrate the amount of cloud cover presented on each image.

Accuracy Assessment Results for LULC Classification Maps

No accuracy assessment was conducted for the classification map of Image 1. The overall classification accuracy of the Image 2 map was of 78.00%, with an overall kappa statistics of 0.7277 (Table 4). The overall classification accuracy of the Image 3 map was of 81.48%, with an overall kappa statistics of 0.7739 (Table 5.) Both the classification accuracy and overall kappa statistics were higher for the classification map of Image 3 than that of Image 2. Factors introduced by either the process employed for the classification of the maps or by the reference data can affect the accuracy assessment of an image (Congalton 1991). For this classification procedure, errors within the actual classified maps could have been introduced by atmospheric effects. The presence of clouds can substantially affect the spectral reflectance of certain pixels (mainly those that are located directly beneath or around the pixels with clouds). Image 2 contained the presence of clouds while Image 3 did not. The clouds on Image 2 seemingly resulted in erroneous classification of the pixels surrounding the areas where clouds were present. Errors could have also been introduced by the reference data employed for this change detection analysis. Positional errors found on the reference data (erroneous rectification to the evaluated image) can affect the overall accuracy – a reference point could have been showing a different location (thus a different type of land cover) on the evaluated image, which in turn resulted in the wrong classification of that point. These types of errors are amplified when the spatial scale of the image being evaluated differs from that of the reference image. The pixels of the Landsat TM imagery have a spatial resolution of 30 meters by 30 meters while that of the reference images (the mosaic orthophotos) have a spatial reference of 1 meter by 1 meter. Points along the borders of varying types of land cover classes could have been assigned to the wrong pixel location of the evaluated image and thus affected the overall accuracy assessments of the classification maps.

Table 4. Supervised Classification Error Matrix for Image 2

		Reference Image									
		Water	Urban	Crop Land	Bare Soil	Shrub Land	Rangeland	Unclassified	Row Total	User Accuracy	Conditional Kappa
Evaluated Image	Water	**10**							10	100.00%	1.000
	Urban		**N/A**						N/A	N/A	0.000
	Crop Land			**6**		1	3		10	60.00%	0.5349
	Bare Soil		2		**6**	2			10	60.00%	0.5455
	Shrub Land			1		**8**	1		10	80.00%	0.7368
	Rangeland					**1**	**9**		10	90.00%	0.8649
	Unclassified							-	0		
	Column Total	10	2	7	6	12	13	0	50		
	Producer Accuracy	100%	N/A	85.71%	100.00%	66.67%	69.23%				
	Overall classification accuracy = 78.00%; Overall kappa statistics = 0.7277										

Table 5. Supervised Classification Error Matrix for Image 3

		Reference Image									
		Water	Urban	Crop Land	Bare Soil	Shrub Land	Rangeland	Unclassified	Row Total	User Accuracy	Conditional Kappa
Evaluated Image	Water	**10**							10	100.00%	1
	Urban		**2**	1	1				4	50.00%	0.4808
	Crop Land			**8**		1	1		10	80.00%	0.7488
	Bare Soil				**9**	1			10	90.00%	0.8744
	Shrub Land				1	**7**	2		10	70.00%	0.64
	Rangeland			2			**8**		10	80.00%	0.7488
	Unclassified							-	0		
	Column Total	10	2	11	11	9	11	0	54		
	Producer Accuracy	100%	100%	72.73%	81.82%	77.78%	72.73%				
	Overall classification accuracy = 81.48%; Overall kappa statistics = 0.7739										

Research Questions 2, 3 and 4 Findings

Semi-constructed, one-on-one interviews were conducted to address the second, third and fourth research questions of this study:

2. *What are the perceptions of the study area's beef cattle ranchers of the local beef cattle industry and how do they believe weather and climate variability can affect it?*

3. *What are the perceptions of the study area's beef cattle ranchers of global, regional and local weather and climate variabilty and how do these accord to historical climate data?*

4. *What adaptation measures (if any) have the beef cattle ranchers taken to mitigate against the impacts of the apparent weather and climate variability?*

A total of nine interviews were conducted on three dates from the months of May and June, 2012. There was an intention of having a tenth subject, but he was not able to meet after repeated attempts. All of the participants met the qualifications required to be a part of this research: they had lived in the region for at least 10 years and held high position titles within their respective ranches (Table 6). With the exception of one person (the one from the ranch "El Zapote"), all participants were male.

Table 6. Demographic Characteristics of the Participants

Name of Ranch	Participant Position Title	Age	Years Living in the Region	Years Working in the Industry
El Aguacate	Owner	38	38	38
El Caporal	Co-manager	27	27	27
El Lucero	Manager	53	53	53
La Nopalera	Owner	58	58	58
Las Paredes	Manager	49	49	39
Los Popotes	Owner	37	37	26
La Razolana	Co-manager	38	38	25
Las Trojes	Owner	37	37	26
El Zapote	Assistant Manager	32	32	4

Four of the nine cattle ranches were located in the municipality of Tepatitlán, the rest were located in Acatic. The ranches were of varying magnitudes and their size was measured in terms of the amount of cattle living on the premises of the ranch. All ranches were dedicated to fattening of the cattle (for sale of the meat), however others maintained cattle for alternative purposes (Table 7). With the exception of one ranch ("Los Popotes"), the products (meat, cattle-raising for mating, dairy) produced by the ranches were dedicated to domestic consumption (sold and consumed on Mexican territory).

Table 7. Demographic Characteristics of the Ranches

Name of Ranch	Location	Number of Cattle	Type of Ranch	Location of Cattle	Location of Market
El Aguacate	Tepatitlán de Morelos	100	cattle-raising, fattening	rangelands and paddocks (depends on season)	c-r: Jalisco, f: Guadalajara
El Caporal	Acatic	150	fattening	rangelands and paddocks (depends on season)	Acatic and Guadalajara
El Lucero	Tepatitlán de Morelos	3,000	fattening; dairy	paddocks	f: Guadalajara d: Torreón (Coahuila)
La Nopalera	Acatic	70	fattening	paddocks	Acatic and Guadalajara
Las Paredes	Acatic	40	fattening	paddocks	Acatic
Los Popotes	Tepatitlán de Morelos	900	cattle-raising, fattening	rangelands and paddocks (depends on cattle type)	c-r: Jalisco, Turkey; f: Guadalajara, Queretaro
La Razolana	Acatic	200	fattening; dairy	paddocks	Guadalajara
Las Trojes	Tepatitlán de Morelos	1,400	cattle-raising, fattening	rangelands and paddocks (depends on season)	Jalisco, other states (Campeche, Chihuahua, Chiapas)
El Zapote	Acatic	2,000	cattle-raising, fattening	the young in rangelands, the older in paddocks	c-r: Jalisco, f: Guadalajara and México City

Research Question 2 Findings

Every participant was born and raised within the limits of the study area and all had lived there their entire lives (some of them had never even left the state of Jalisco). When asked how many years they had been working in the cattle industry, five of them answered by stating "since I was born" or "my entire life." The remaining participants tried to give an approximate age of when they had started working with cattle and the answers varied from 8-12 years old. The cattle industry has played an important role in the lives of these people, since some of them consider themselves to have been a part of the industry since "the moment they opened their eyes."

> *"Here in Tepa[titlán], the majority of the inhabitants are the descendants of ranchers, or of agriculturalists. At least 70% of the population, I imagine, have a relationship with the fields."* (Participant 2 2012)

This industry provides employment for many people of the region and its economy is largely dependent on it (Direct Source 2012). When asked to describe the level of importance of the beef cattle industry (not including dairy) on the economy of the region, every participant placed it as the second or third most important industry of the economic sectors of the region. The locals also have strong cultural ties to the cattle industry and they take pride in that. "The country (of Mexico) identifies the state of Jalisco with the *mariachi* (peculiar type of folk music) and *charrería* (competitive event similar to the American rodeo), both of which originated from the activities related to the cattle industry" (Participant 1 2012).

The participants were asked what changes (if any) they had noticed on the local beef cattle industry in the last two decades. Every participant noted changes, but the direction of the change varied. Five out of the nine participants said that the industry had experienced growth; four said there had been some growth in past decades but that in more recent years the productivity of the industry was decreasing. Those that said that the industry had grown believed this was a result of 1) an increase in the amount of land used for growing forage and feedstuffs, 2) technological improvements within the agricultural sector (which allowed for the raising of more cattle), 3) the introduction of cattle breeds of better quality, and 4) the increase of meat prices (raising cattle for meat is more profitable than dairy for the rancher). Those that had noted a decrease in productivity explained that in the last two decades there had been growth, but that in more recent years (3-5 years) this was changing due to 1) the increasing costs of forage and feedstuffs (which resulted in less profit for the rancher), 2) scarce precipitation made it more difficult to maintain large quantities of cattle on the fields, and 3) other competitive industries that are more cost effective had emerged (specifically, the production of agave).

The participants were asked how the weather can affect the cattle, and consequently, the productivity of the local cattle industry. Many answered that temperature extremes (mainly heat) can induce illness and stress on the cattle, which could cause infertility, and often results in weight problems – the cattle are unable to meet profitable weight requirements.

> *"The other day we saw in the thermometer that the temperature was 11°C in the early morning and in the afternoon it was 35°C. That is a difference of 24 degrees between the early morning and the hottest time of the day. In situations like that, the animal could end up with pneumonia, or other respiratory problems, and mainly stress. Why? Because it has to endure a temperature that is somewhat cold then an excruciating heat. So yes, it affects them. And this region was not like that before. You could say that maybe we would reach low temperatures of 14 or 15°C, but it would only get as hot as 30°C during the day. The margin was less extreme. So these types of changes are ones that will definitely affect the productivity of the animals."* (Participant 1 2012)

Another matter that appeared to be of great concern was related to water availability for cattle use. During the years that there is not enough precipitation, it becomes more difficult for the ranchers to provide clean drinking water for the cattle (Direct Source 2012). When asked how these factors could impact the productivity of the industry, every participant answered that it could become less profitable for them to participate in the local cattle industry, since it would cost more to produce the same amount of products. Many participants mentioned that they would have to find alternative sources of profit.

> *"The cost of forage and feedstuffs has gone up a lot, so the rancher cannot invest as much as they used to...they are not making as much profit. People are starting to look into other businesses, such as the production of agave."* (Participant 4 2012)

When asked how these developments could affect the lives of the people living in the region, two participants said that there would be "less food available for everyone." Six participants made reference to the topic of employment loss, referring to the fact that sources of employment for the people of the region would decrease. Some also mentioned that this would become a strong economic problem for the region as a whole. These local ranchers are well aware of the economic importance of the industry and that the livelihoods of many people from this community depend on it. From the moment they are born, people have job security, they know they will have a way to make a living and provide for their family "working in the same field as their parents and grandparents did" (Direct Source 2012).

Research Question 3 Findings

Interpretations of the Local Weather Patterns and the Regional Climate

Most of the participants refer to the warm season in this region as the months of April to September. However, two of the nine participants could not provide specific answers regarding the beginning or end of this season. With the exception of two of the participants that provided an answer, the rest mentioned that the hottest time of the year occurs during the month of May. When asked to describe the months of the cold season, four of the nine participants did not provide a clear answer. The rest of the participants said it starts sometime in October and that it ends at the end of January/beginning of February. All participants provided an answer when asked to describe the precipitation season; four said that it begins in the month of May and five consider the month of June to mark the start of the precipitation season. Two did not specify when this season ends, three said that it ends near the end of August/start of September and four said that it can last until the month of October. The participants were asked to describe any type of extreme climate events experienced in the region; only two of such events were mentioned: drought and "black frosts." With the exception of one participant that could not provide an answer, the rest mentioned that drought is the most prominent type of extreme climatic event.

Perceptions of Global, Regional and Local Weather and Climate Variabilty

Perceptions of Global Climate Change

When the participants were asked if they had heard of global climate change, eight of the nine participants answered "yes" (only one person did not know what the term referred to). The ranchers had heard about it from a combination of sources: the news on the television, news on the radio, on the internet; "simply everywhere" (Direct Source 2012). They were asked to explain what they considered to be the culprit(s) behind these changes. Out of the eight participants that provided an answer, one mentioned that it was the result of increases in pollution, that "we are being bad stewards of the planet", two answered they had "no idea" why it is happening, two said that it was the result of extensive deforestation, and four said that it was due to the increasing use of oil and other non-sustainable energy sources. One participant mentioned that this is giving rise to the emissions of greenhouse gases and that is the reason the climate is changing. Regardless of the reasons they believe to be causing the phenomenon, the majority of the participants are aware that the climate is changing globally.

Perceptions of Regional and Local Temperature Variability

The participants were asked if they had felt changes in the local weather or climate patterns; all said yes. However, the types of changes as well as the time of the year they felt these, varied. All participants said that they had felt changes during the warm season. All said the temperatures were more extreme, that the heat felt stronger and that the summers in general were hotter than they used to be. One participant mentioned that because the temperatures would rise so much during the day, there were more extreme changes in the diurnal cycle during the summer months. Two other participants also mentioned that the warm season had extended. They claimed that the summer was starting a month early and ending a month later.

There was less agreement among the responses of the participants regarding the cold season. Five participants said that they had not perceived a notable difference during the winter months and four said that they had felt some changes. The responses of those that said they felt changes also varied. One participant claimed the temperatures during the winter months were dropping, another said the winters felt colder and in general were harsher, and two others mentioned that winters were becoming more extreme. Those that said the winters had become more extreme mentioned that there has been an increasing occurrence of "black frost" events in the region.

Perceptions of Regional and Local Precipitation Variability

In regards to the precipitation patterns, all participants concurred that the precipitation season is becoming more variable. Consequently, it has become more difficult to predict when the season will start and/or end.

> *"Ten years ago, the rain season was so exact that you were able to contemplate everything you need to ahead of time and be able to work the land and have the*

soils ready on time. But now, this is very out of our control because the rains are much less predictable." (Participant 4 2012)

All participants said that there has been an overall decrease in the amount of annual rainfall received in the region. They perceived that precipitation events are becoming scarcer in quantity as well as in frequency. The participants mentioned that when it does rain, the total amount received is much less than what it used to be (less rain is received per individual event). Five of the participants said that they have noticed that the amount of time that passes in between precipitation events is longer than in previous decades. The length of the "rain season" also has experienced some changes. Four of the participants mentioned that the season has become shorter, coming at later times than it used to and ceasing at earlier ones.

> *"The rains before would start...when I was a child, at the end of May. Now they start at the end of June and end...well before they would end at the beginning of October and now they end at the beginning of September."* (Participant 2 2012)

Causes of Variability in the Regional and Local Weahter and Cliamte Patterns

The participants were asked to share their opinions regarding the causes behind the changes in the weather and climate patterns at the local level. One participant acknowledged that there had been changes in the regional climate; however, he could not identify any specific causes for the changes he had felt. The perceived changes in temperature and precipitation patterns of the remaining participants were mainly attributed to the deforestation of native vegetation. The second cause of perceived changes was attributed to urban expansion. Native vegetation that once covered the land had been extensively removed. Large areas had to be deforested to provide living space for the increasing population of the region, and mainly to make land available for agricultural purposes (Direct Source 2012).

Validation of the Local Perceptions of the Regional ClimateVariability

The participants were asked how long they had been experiencing changes on the local weather and climate patterns. Two of them were unable to describe an exact time frame, six of them answered a range of 5-10 years, and one of them said 12-15 years. To validate the responses of the participants regarding the perceived changes in temperautre (total annual change, during the summer months and during the winter months) and precipitation variability, their responses were compared to graphs generated from historical climate data for the city of Guadalajara, Jalisco (Figures 11, 12, 13 and 14). Some years had to be omitted from some of the graphs due to the lack of data available for the variable under consideration.

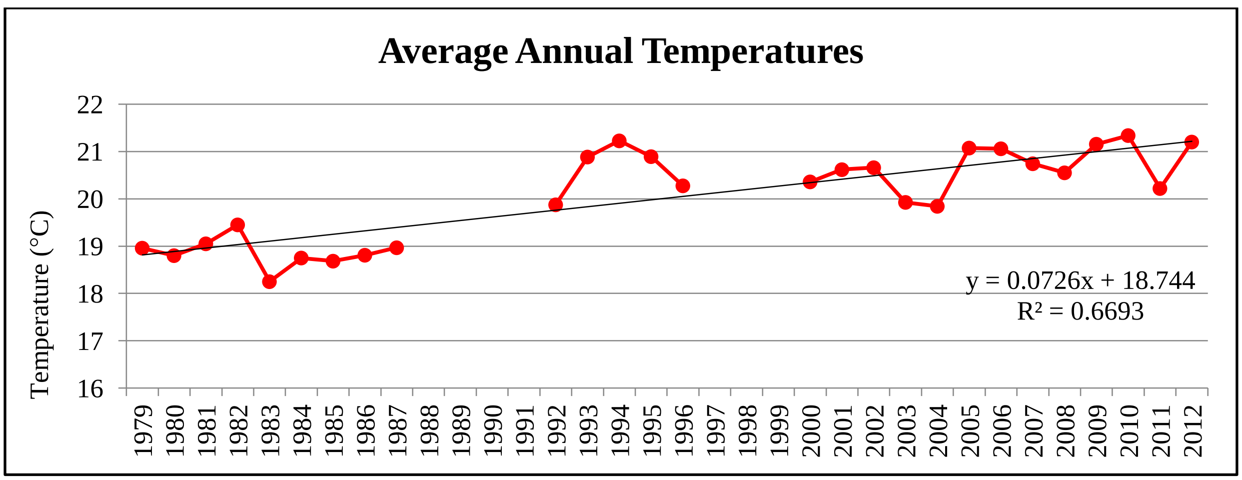

Figure 11. Average Annual Temperatures for Guadalajara, Jalisco: 1978-2012

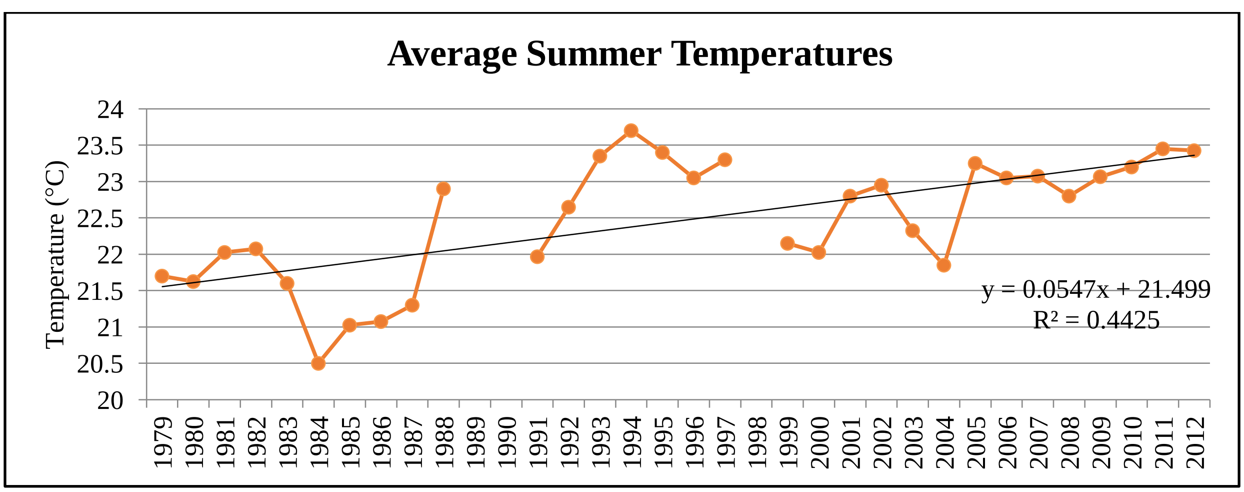

Figure 12. Average Summer Temperatures for Guadalajara, Jalisco: 1978-2012

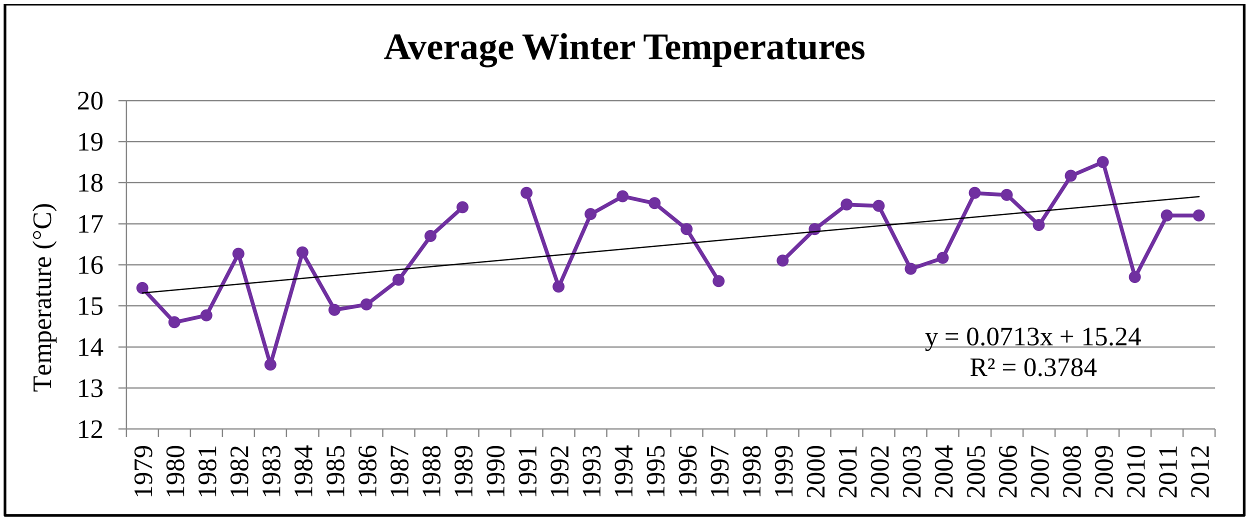

Figure 13. Average Winter Temperatures for Guadalajara, Jalisco: 1978-2012

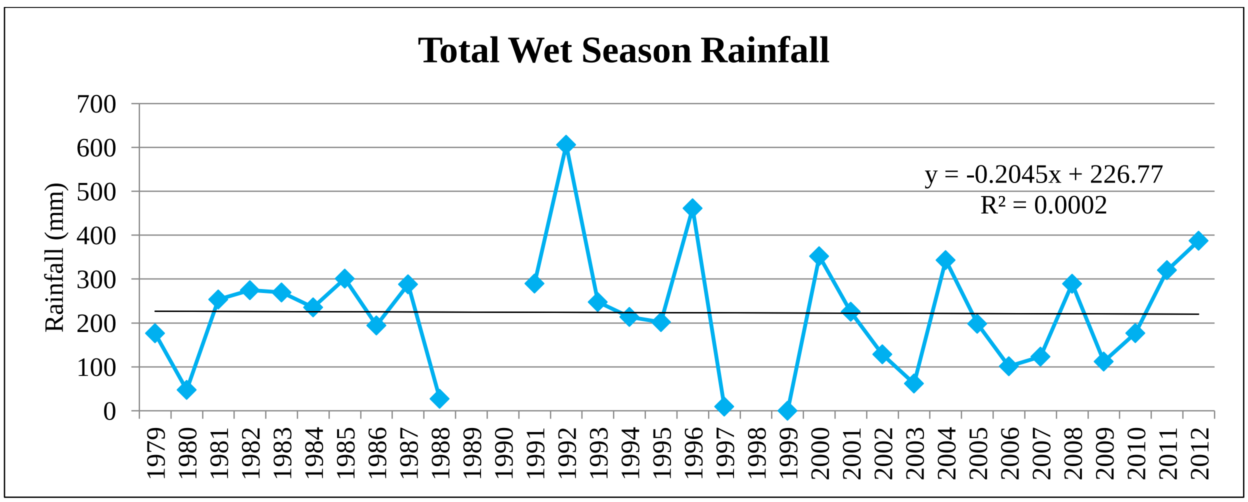

Figure 14. Total Wet Season Rainfall for Guadalajara, Jalisco: 1978-2012

All participants said that they felt like the temperatures were rising and that on average it was becoming hotter every year. The temperature data (Figure 11) indicates that there is a positive trend ($R^2 = 0.6693$) in the average annual temperatures for the city of Guadalajara, Jalisco. The climate data indicates that the last decade (the 2000s) was the hottest one of this record. The time period during which the participants identified these changes also matches the data. Most of the participants mentioned that they mainly began to experience these changes in the last 5-10 years.

every year. They said that this is the time of the year when they can truly feel a difference in the average temperatures, and that the summers in general are becoming more extreme. The data (Figure 12) also indicates a positive trend in the average summer months' temperatures ($R^2 = 0.4425$), especially after the year 2005.

In regards to the cold season, none of the responses of the participants match the data. More than half of the participants said that they have felt no notable changes in the temperatures of the winter months, while four said they feel the winters have become more extreme, with the temperatures dropping more than they used to. However, the data for the winter months (Figure 13) also indicated a positive trend ($R^2 = 0.3784$), the average winter temperatures are also rising.

The response of the participants to changes in precipitation appears to be correct - all participants indicated a decreasing trend in the amount of precipitation received and this matches the data (Figure 14). However, the slight decreasing trend for the precipitation is not very significant ($R^2 = 0.0002$). This variable appears to fluctuate more from year to year than the temperature

Research Question 4 Findings

The participants were sensing some legitimate changes in the temperature (mainly during the summer months) and in the precipitation trends. They were asked to describe the types of adjustments they had made (if any) to protect the cattle from the harsh conditions of the environment. Eight participants responded that they built more shelters to provide shade for the cattle during the summer months, either through the building of metal or wooden roofs, planting of trees, or a combination of both methods. Only one participant said he had not made any type of adjustments. The other common response regarding this topic was to ensure they had enough sources of drinking water for the animals. Four participants said they had to utilize more water from their deep-water wells than they wanted. However, not all participants had access to a deep-water well and mentioned that they depend on the availability of water from ponds or reservoirs. Two participants said that they were making sure their ponds were clean (sediment free) in order to ensure maximum water storage once the "rains" came. Another participant said that he had to "make the sacrifice" of investing into building a deep-water well. Currently, only three of the participants mentioned that they built shelters to protect the cattle from the harsh conditions experienced during the winter months; the rest of the participants said they had not made any adjustments to protect the cattle during the cold season.

Short-Term Adaptation Measures

The participants were asked to describe what types of measures they could take in the short-term (specifically in the next 3-5 years) to protect the cattle from the changes they have noticed in the climate. Five responded that they would continue to plant more trees. Three participants said they planned on investing into building more resistant metal and wooden roofs; one participant mentioned he planned on expanding the area of the feeding lots so that he could move all of the cattle in there during the hottest months. Two participants also mentioned the need of building larger storage units for the feedstuffs. Another one said that he planned on changing his grass cultivars to more drought resistant varieties.

Long-Term Adaptation Measures

The participants were asked to describe what types of measures they could take in the long-term (specifically in the next 20 years) if the present changes in the climate continued to develop and/or worsen in the future. One participant responded that aside from building more roofs and shelters for the cattle, he had "no other idea" what he could do. Three participants said they would continue to plant more trees and build more shaded areas for the cattle as well as adapt other measures. For instance, two of the participants that currently did not have deep-water wells said they would save up and invest in building one in order to ensure that the animals have enough drinking water to make it through the year. Two said they would invest in building more ponds. One participant said he planned on buying fewer cattle to lessen the costs of maintenance and two said they contemplated the idea of completely switching to other businesses.

> *"Maybe I would have to contemplate leaving the cattle business. If it continues to be a good business then I will dedicate to it, but it's a matter of seeing how the climate, and well, other things go. It's a very hard thing to think about because well yes, a few years back this was a good industry, it would leave good profit behind but I don't know how it will be in the future."* (Participant 5 2012)

CHAPTER 5

DISCUSSION AND CONCLUSION

The findings of this research provide a historical perspective of the human-environment relationships within the two municipalities of Acatic and Tepatitlán, Jalisco and give insight into the perceptions of the local cattle ranchers of climate variability and the adaptation measures they have taken to ameliorate the effects of such developments. This section digests those findings and provides deeper interpretations through a discussion concentrated on the following key points and recommendations:

Discussion

Changes in LULC

Deforestation

The topic of deforestation occurred throughout each interview. The participants consider the extensive deforestation of native vegetation to be a significant problem in the region. Some of the participants mentioned that the reason they had "gotten rid of so many trees" in the region was "to use the land for the agriculture" (Participants 3 and 6 2012). Native vegetation that once covered the land has been extensively removed to provide living space for the increasing population of the region, and particularly to make land available for agricultural purposes.

> *"We dedicate so much to the livestock and agricultural sectors that we have lost part of the forest sector, the trees. Yes, we have gotten rid of the trees so that we can have more land available for the industries."* (Participant 3 2012)

An industry that has experienced rapid growth in this region and is responsible for the deforestation of vast amounts of land is the cultivation of agave (genus) plants, more specifically the maguey (species). This succulent plant is the primary ingredient used to make tequila (the alcoholic beverage). The state of Jalisco is known for its tequila production and there are regions within the state where blue agave is the prevalent crop. When the maguey hearts are harvested they are sold to local distilleries or exported to other states of the country, where other types of alcoholic drinks are made (such as *mezcal* and *pulque*).

> *"The maguey plant grows very well here and as you can see it can practically grow anywhere, even on the hillsides or on the mountains. Everything that is a tree or a bush is removed for the plantation of maguey crops."* (Participant 4 2012).

The cultivation of maguey has been spreading into municipalities of the state that were not known to be major producers of agave plants, for example Tepatitlán (Participant 4 2012). The agave production industry has become more popular in recent years because the locals see it as a cost effective business, therefore, many small ranchers and farmers have leased their lands for the cultivation of agave in this region. They felt that it was becoming more difficult to maintain profit from their own product, so they began to lease the land to people with the economic means (mainly outsiders) to transform it for the cultivation of maguey crops. The ranchers and farmers that lease their land receive profits from "doing nothing but signing the leasing of their land" (Participant 9 2012). None of the ranchers that participated in this research had become involved in the development of the agave business; however, it was a widely discussed topic among a number of the participants.

The responses of the participants regarding the concept of deforestation can be observed on the results derived from the LULC change detection analysis. From 1985 to 1993 there were two significant changes on the land cover: the area covered by crop land dramatically increased while that covered by shrub land considerably decreased. The crop land cover changed from 1288.62 ha to 2734.65 ha (an increment of 112.22%), resulting in a change of 1446.03 ha. The area covered by shrub land decreased from 9262.08 ha to 8096.85 ha, resulting in a decrease of 1165.23 ha (Table 1). No other LULC categories experienced such drastic changes during that time period. It is evident that the landscape of this region underwent a drastic transformation: extensive deforestation was executed in order to make land available for agricultural practices.

All participants claimed that the regional climate had changed due to the extensive deforestation of native vegetation; this is mainly why they found the topic to be of great concern. Their claims appear to be legitimate. Large-scale deforestation has a detrimental effect on the regional precipitating patterns, temperatures, and evaporation rates. Consequently, the removal of native vegetation affects the amount of water sources as well; as precipitation decreases, temperatures increase, evaporation rates increase, the amount of surface water will lessen (Nobre et al. 1991). Small-scale changes on the vegetation cover also have implications on the climate. Dubreuil et al. (2012) found that the transformation of forest to pastures in the Brazilian Amazonia led to changes in the local climate. The region had experienced decreasing precipitation trends and increasing temperature trends; the cleared areas were always hotter and dryer than the forested sectors. Additionally, the rising temperatures were not only presented during the day, but also carried on into the night (Dubreuil et al. 2012). All of these changes parallel those described by the participants of this study. Evidently, the deforestation of native vegetation in the municipalities of Acatic and Tepatitlán is one of the causes behind the changes experienced in the local climate.

Reforestation

The topic of reforestation was also widely discussed by most of the participants. Five of them mentioned that they had been actively planting a substantial number of trees on their properties for "some time now," and some talked about planning to do so. The concept of reforestation came up in three different contexts. First, participants mentioned that they were planting trees when they were talking about the types of adaptation measures they were currently taking to mitigate, or those that they planned on taking in the short-term. Many said that this was an "easy and efficient" way to protect the cattle from the heat because the trees provide natural shaded areas (Participant 2 2012).

> *"Right now what I have been doing is planting more trees. The shade they provide for the animals is very good, and the trees themselves will help the environment. So yes, that is mainly what I'm doing [to protect the cattle from the heat] here. I don't meant to say that I am trying to have extensive orchards, I just mainly try to plant trees to provide shade."* (Participant 2 2012)

Second, planting trees as an adaptation measure does not only pertain to the benefits the trees provide for the cattle. Many ranchers in the region have been specifically planting fruit trees to profit from the selling of the fruits. This does not mean that the ranchers intend to completely switch to the cultivation of fruit trees, but they have found this to be an effective method of generating additional income, as well as an inexpensive provision of shade for the cattle.

> *"Though the change is mild, I can definitely notice a change in the vision of the region. For example, now we are starting to see an increase in the number of orchards of avocados, which obviously can help us, because people can sell the cattle and the meat and also sell the fruits. Also, lime orchards have been growing. What I see is people are looking for optional crops to make a profit from and not only rely on the profits they make from the cattle."* (Participant 1 2012)

Third, the participants felt that planting trees helps ameliorate the effects of climate change. All participants believe that intense deforestation is the main cause of the present regional changes in the climate. Most acknowledged that the region is "lacking" trees and in response to this, they believe that there has been a notable change throughout the region regarding the planting of trees, that "a lot of people have been doing that now" (Participant 5 2012). Participant 9 said that he has noticed that the "vision" of the community has changed in recent years. The people of the region feel that extensively planting trees will help the situation regarding the changes in the regional climate in the future. They perceive the planting of trees as being "beneficial for the environment" and that ultimately this will be beneficial to them.

Unfortunately, the change on the land cover of reforestation (increase in the LULC shrub land category) cannot be seen in the results of the change detection analysis. This is due to the fact that the time period of the analysis does not extend past the year 2000, and according to what most of the participants said, the "vision" of reforestation is a newer development that has only been noticeable in recent years.

Changes in the LULC Water Classification Category

The people of this region have the capacity to make drastic changes on various categories of LULC, including that of water. The LULC water category of the study area experienced dramatic changes from the year 1985 to the year 2000. These changes are visible on the imagery of the classification maps (Figures 15, 16 and 17). During the time period of 1985 to 1993 the area covered by water nearly doubled, it experienced an increment of 46.40%. Along with the increasing amount of small-scale ponds and reservoirs, this was mainly the result of the building of a dam, *Presa Calderón* (the large body of water that appears after the second image). Then, during the time period of 1993 to 2000 there was a considerable decrease on the amount of water cover; it went from 111.6 ha to 65.52 ha, a decrease of 41.29% within the category. Clearly, these developments are the result of anthropogenic processes.

In situations of water scarcity, the people of this region have resorted to building more ponds and other types of water reservoirs (such as the massive *Presa Calderón*) to overcome the problems induced by the lack of clean surface water. They build ponds and reservoirs with the expectation that these will be filled with rainwater within a few years. These methods have been employed in the region for decades (Direct Source 2012). As the people of this region see that there is need for more water sources, they simply build more reservoirs. However, other factors, such as the amount of precipitation received, have an impact on this LULC category as well.

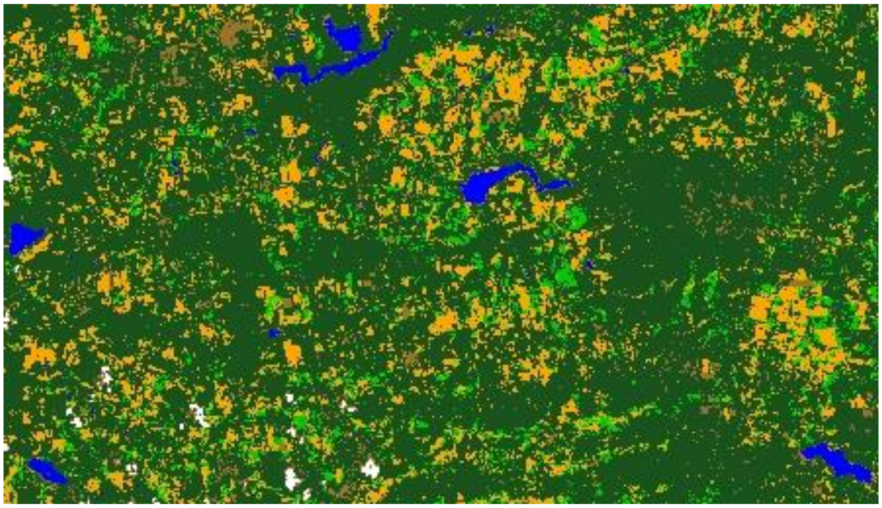

Figure 15. Excerpt of LULC classification map for 1985

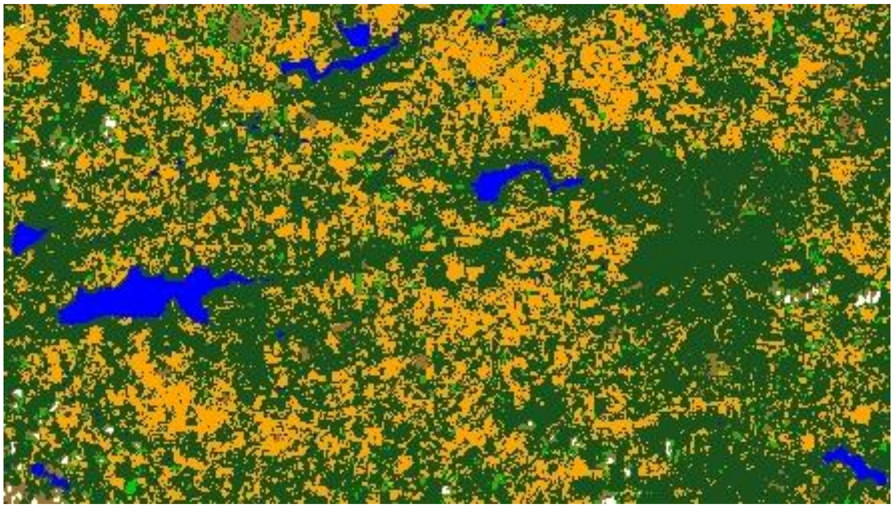

Figure 16. Excerpt of LULC classification map for 1993

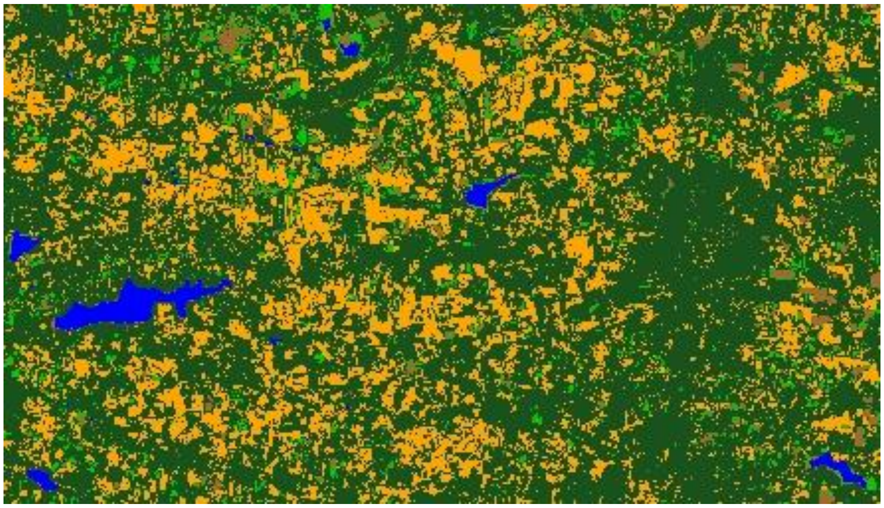

Figure 17. Excerpt of LULC classification map for 2000

Importance of Rainwater

There has been a notable decrease in the amount of clean water sources for the cattle in the region (Direct Source 2012). Various factors contribute to this situation: an increasing population, pollution of surface water sources, significant eutrophication of lakes and reservoirs (Flores et al. 2012), and a decreasing amount of precipitation received. Two participants mentioned that creeks or rivers that could once be utilized by the cattle are no longer suitable sources of drinking water; "every year there are less rivers that are not contaminated" (Participant 6 2012). This situation is exacerbated by changes presented in the precipitation patterns of the region.

The availability of clean surface water is crucial for the survival of the ranching (and other agricultural) activities of the study area; these are highly dependent on the amount of rainwater received. Although there is a supply of groundwater available, not everyone has access to a deep-water well, and few farmers and ranchers have irrigation systems. Those who do not have access to a well must rely on the water stored in their ponds (or reservoirs) to last until the next rain season. However, using underground water is not ideal. The costs associated with the pumping of deep water are prohibitive and those who mentioned having access to a deep-water well (four participants) said that they are using it more than they would like to. Therefore, the storing of rainwater is of great value. Several of the participants mentioned that some adaptation measures they could take in the short-term (and some also mentioned these for the long-term) was to dig more ponds. As previously described, when there has been a notable lack of clean surface water, ponds and reservoirs are built with the expectation that these will fill up within a few years and thus provide clean water in the future. When not enough precipitation is received, the ponds and reservoirs do not fill up to maximum capacity, consequently they do not provide enough water to last for the entire year.

Climate data for the decade of 1991-2000 indicates a slightly decreasing trend (R^2 = 0.1691) in the precipitation of the region, and it also shows that the total annual precipitation received in this area is highly variable from year to year (Figure 18). The year 1993 received an average amount of rain (≈200 mm); however 1992 was the year that received the most precipitation (≈600 mm). The year 2000 received more precipitation than the year 1993 (≈350 mm), however the precipitation received in the year 1999 was close to 0 mm.

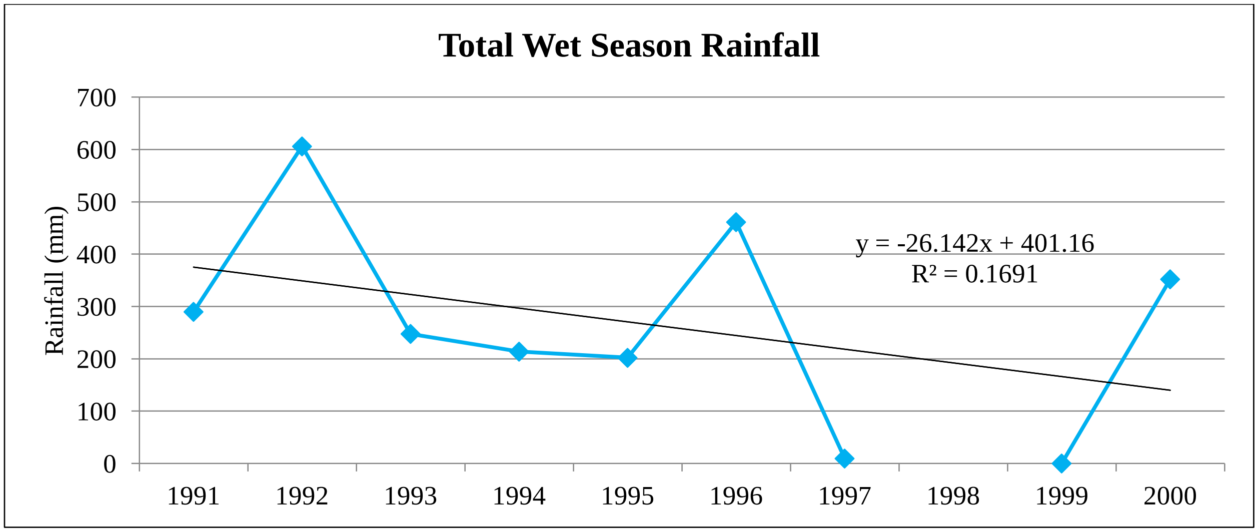

Figure 18. Total Wet Season Rainfall for Guadalajara, Jalisco: 1991-2000

In this region, the amount of rainwater received greatly influences the availability of clean water sources. Years that receive substantial amounts of rainwater result in fuller reservoirs. The year 1993, which followed the year that received the most precipitation of the 1990s decade, is the year that shows the largest reservoirs (Figure 16). The year 1999 received little to no precipitation and the image for the year 2000 (Figure 17) shows the reservoirs of the region (mainly *Presa Calderón*) to be significantly smaller. This indicates that the amount of rainwater received in a certain year, as well as that received in previous years, has an impact on the levels of the surface water sources.

The unavailability of water not only affects livestock drinking water sources, but it also affects the amount of forage and other feedstuffs available. Therefore, the amount of land designated for the use of growing crops (for animal or human consumption alike) is highly dependent on the amount of rainwater received. This can be seen in the results of the change detection analysis. In 1993, the LULC crop land category covered 2734.65 ha and in the year 2000 it decreased to 2046.42 ha (Table 2). Time periods that have experience scarce precipitation will result in less crop land cover and thus provide lower crop yields. Periods of scarce precipitation can induce serious economic problems for a rancher, because as the water resources decrease, the cost of providing feedstuffs for the cattle increases.

> *"About a year ago, we were contemplating the transfer of the animals to the grazing lands that we have. We thought that it would rain on the first days of the month, or sometime around then. We sent the animals there because supposedly there would be good feedings out there that would support the animals for a certain amount of months, and it was not like that. You send the animals out there because there should be food there, and you expect it to be food there because there should be rain to produce forage for them. Well, it was not like that. The animals consumed everything that was edible in the fields and they did not gain the weight that we intended them to gain. We can't make good profits when the cattle is not meeting the weight requirements."* (Participant 3 2012)

> *"Last year, here in our lands we planted crops on time to have the harvest grow during the time of the rains. We do that in order to lessen the costs of production and to not have to use the water from the well, because that requires the use of electricity and that costs money. So that is why ranchers, well agriculturalists in general, they take advantage of the rainy season. So yes, here in the ranch we planted on time, we waited for the rain, but it did not favor us because, for example the corn, it was too small..the corn was there but it did not germinate, and the product - you could call it that- was too small. So we received no benefit from those crops."* (Participant 4 2012)

Low Adaptive Capacity

All participants made adjustments to mitigate the perceived changes in the climate. These appeared to be sufficient for the time being, but when they were asked to describe the adaptation measures they planned on taking in the future, some were not able to provide adequate responses. This is especially true when they were asked about the long-term adaptation measures. The majority of the planned adaptation measures to be taken by the participants were associated with having access to clean water sources. The unavailability of clean water sources is the main issue for the ranchers and agriculturalists of this region. Because they were aware that the ponds and reservoirs were not becoming sufficiently full to provide water for the entire year, several of the participants who currently did not have access to deep-water wells said they would have to invest in building one. However, building a well is expensive and is not a commodity that everyone can afford. Participant 2 talked about how he had to "make the [financial] sacrifice of investing in a well". There were other participants (two of them) that said that the best measures they could think of taking were to "dig more ponds." This was included in the responses of adaptation measures for the short- and the long-term. Although they were aware of the risk that these ponds had the potential of not being filled with sufficient rainwater, they did not think that saving up enough money to invest in a well was an option for them.

The adaptive capacity of cattle ranchers in this region is largely dependent on availability of monetary funds. Most of the small-scale ranchers (in the case of this sample this refers to those with less than 200 cattle) provided similar answers to one another and these indicate that they are more vulnerable than the large-scale ranchers. The large-scale ranchers have access to funds and have the ability to make greater investments than the small-scale ranchers. As a result, it is the large-scale ranchers that have been able to succeed and overcome the problems presented by climate variability and other environmental problems thus far.

> *"What happens here is that only the big ones are the ones that are staying around. Since the small ranches are not being as profitable, many people may say "It's not convenient, I'll just disappear". Many of these people will just give up. Some of these have left, some have even gone to the United States."* (Participant 3)

Some of the participants had no concrete plans for the long-term, two of them even said that they really had no idea what they could do protect their business in the future, and that they had not thought about it yet. Ranchers who did not have plans to take adequate adaptive measures in the future were those who currently found themselves struggling economically. These ranchers were not thinking into the future as much as those ranchers that had better financial stability; they are living on a day-by-day (or "season-by-season") basis. The ranchers in these situations tended to be those that owned fewer cattle. They responded that they would be willing to find other sources of income, either by partially incorporating other types of agricultural practices or by completely switching to other industries. Two of them mentioned that a possibility was to no longer own cattle. However, none of the ranchers who owned large quantities of cattle proposed making such adjustments in the future. The livelihoods of the ranchers that have smaller ranches, and thus have fewer funds, are the most vulnerable to climate variability in this region.

Conclusion

Climate change is undoubtedly causing various types of impacts on the different regions of the world. However, even at the regional or local level, the effects of climate change on the human population can be highly variable as well. Research that focuses on the impacts of climate variability at the local level can provide insight on the specific perceptions of the locals to climate change and the various responses they are taking towards it. This research allowed for a deeper understanding of the particular issues currently affecting the ranchers working in the beef cattle industry within the municipalities of Acatic and Tepatitlán de Morelos, Jalisco. Changes in the climate may affect the biophysical environment of a region uniformly; however, the societal impacts will vary greatly. This is specifically true for this region. Though all of the participants of this research are being exposed to the same types of climate variability, they are personally being affected very differently. Factors such as the level of education and financial stability are two of the main contributors to such differences.

The employment of proper adaptation measures has the potential to reduce climate-related losses within the livestock and agricultural sectors. However, in this region, not all ranchers have the ability to adapt such measures. The main factor affecting the adaptive capacity of the cattle ranchers of these communities is the lack of money. Ranchers that do not possess economic stability are finding it more difficult to take effective mitigation practices; these people will continue to face difficulties if the present changes in the regional climate continue to develop. To mitigate the effects of complex environmental problems faced by rural communities in Mexico requires the intervention of more powerful entities than the local governments (either national or international government or non-government organizations) is essential (Brodziak et al. 2011; Vázquez and Liverman 2004). To develop sustainable long-term economic development plans, it is important to understand the current economic, environmental and ideological interactions at the local level (Vázquez and Liverman 2004). This can enable the creation of programs that provide the people of lower resources with knowledge and education they need take adequate adaptation measures for the future. In the poor rural areas of Mexico, it is crucial that preventive measures are taken before the effects of climate change worsen and people find it more difficult to adapt to such changes (Brodziak et al. 2011).

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APPENDICES

APPENDIX A:

CONSENT TO PARTICIPATE IN RESEARCH
AND CONSENT FOR AUDIO TAPING
(Signatures of participants required)

I,____________________________, agree to participate in the research project conducted by Melva Treviño Peña, graduate student of Southern Illinois University Carbondale; Department of Geography and Environmental Resources, titled "Assessing the Impacts of Climate Variability on the Ranching Communities of Tepatitlán de Morelos and Acatic, Jalisco, México".

I understand that the purpose of this study is to interview cattle ranchers of the communities of Tepatitlán de Morelos and Acatic, Jalisco, México in order to understand their perceptions of climate change, as well as to investigate how this industry has changed in recent decades and determine whether climate or extreme weather events have played a contributing role behind the productivity of the livestock industry of this region with the purpose of assessing the potential impacts that climate could pose on the beef cattle industry of this region, and ultimately on the livelihoods of its people.

I understand my participation is strictly voluntary and that I may refuse to answer any question without penalty. I am also informed that my participation will take approximately two hours. I also understand that my responses will be audio taped, reviewed only by the researcher and advisor, and that these tapes will be transcribed/stored and kept for 50 days in a locked file cabinet and that afterward the tapes will be destroyed/ deleted.

I understand questions or concerns about this study are to be directed to Melva Treviño Peña, graduate student of Southern Illinois University Carbondale; Department of Geography and Environmental Resources, (702) 292-5806, trevino@siu.edu or her advisor Dr. Leslie Duram, Geography and Environmental Resources, (618) 453-6084, duram@siu.edu.

I have read the information above and any questions I asked have been answered to my satisfaction. I agree to participate in this activity and know my responses will be tape recorded. I understand a copy of this form will be made available to me for the relevant information and phone numbers.

"I agree _____ I disagree _____to have my responses recorded on audio/video tape."

"I agree _____ I disagree _____ that Melva Treviño Peña may directly quote me in his/her research project."

Participant signature Date

This project has been reviewed and approved by the SIUC Human Subjects Committee. Questions concerning your rights as a participant in this research may be addressed to the Committee Chairperson, Office of Sponsored Projects Administration, SIUC, Carbondale, IL 62901-4709. Phone 618 453 4533. Email:siuhsc@siu.edu.

APPENDIX B:

INTERVIEW GUIDE

Section 1: Participant Background

Name and position (in the ranch) of interviewee

Age of interviewee

Time he/she has lived in the region

Time he/she has worked in the livestock industry

Time he/she has worked in this ranch

Section 2: Ranch Background

Name of Ranch

Location

Date ranch was founded

Average number of cattle heads in the premises

Type of ranch

What species of cattle do you have in this ranch?

What does the diet of the cattle consist of?

What is the source of the drinking water consumed by the cattle?

Section 3: The Livestock Industry

Do you consider the livestock industry to be an important component of the economy of the region?

Do you consider the livestock industry to be an important component of the culture of the region?

What types of changes have you noticed regarding the livestock industry in the region over the last twenty years?

In your opinion, what factors contributed to these changes?

Section 4: Perception of Climate and Climate Change

Please describe in detail the climate of this region. Fox example, when is the hot season and how long does it last? When is the cold season and how long does that last? When do you receive the most precipitation? Etc.

What type of extreme climate events occur in this region?

Have you heard about global climate change?

Where did you hear about global climate change?

Do you believe that the climate is changing at the global scale?

If yes, what do you think the reasons behind these global changes?
If no, why do you think people feel like the climate is changing?

Would you say that the climate of this region is also changing?

Do you consider there to be anomalies in the mean temperature of the region? If yes, during what seasons is the change more prominent?

Do you consider there to be anomalies in the mean precipitation of the region? If yes, during what seasons is the change more prominent?

Do you consider the frequency of extreme climate events to be increasing throughout the region? If yes, what types of events? And during what seasons is the change more prominent?

When would you say that you became aware these changes began to occur?

In your opinion, what are the causes behind these changes?

Section 5: Impacts of Climate Change in the Region

How could changes in the regional climate affect the livestock? For example, how would changes in the temperature affect the productive performance and behavior of the cows? How would changes in precipitation affect them?

Do you feel like climate change is a serious threat to the productivity of your ranch?

How could climate change affect the economy of the region?

What are some of the impacts that climate change could have on people's lives in this region?

Section 6:

What current measurements are taken in this ranch to protect the cattle from extreme temperatures in the summer months? What about in the winter months?

Do you feel like climate change will pose serious threats in this region?

What types of measurements could you take in order to protect the cattle against possible future changes in the climate?

VITA

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Thesis Title: ANALYZING CHANGES IN THE BEEF CATTLE RANCHING COMMUNITIES OF ACATIC AND TEPATITLÁN DE MORELOS, JALISCO, MEXICO RELATED TO LAND COVER AND CLIMATE VARIABILITY

Major Professor: Dr. Leslie A. Duram