Rainfed Altepetl

Modeling institutional and subsistence agriculture in ancient Tepeaca, Mexico

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Chapter 1
Introduction

The goals of this work

This study analyzes the impact of climate variability and human management strategies on the Late Postclassic (AD 1325-1521) and Early Colonial (16th century AD) agricultural systems in the Tepeaca Region, Puebla, Mexico. The research examines the scale of crop production at the subsistence and institutional agricultural levels and the role of commoner rural populations within the prevalent tributary economic system.

This work has three objectives: (1) to model agricultural productivity at the household and regional levels, (2) identify the buffering strategies developed by Tepeaca's populations against cyclical food shortfalls, and (3) establish a model for the agricultural and economic structure of the Tepeaca *altepetl* or state-level polity. Crop production in Tepeaca depended primarily on rainfall as the major source for water. Therefore, unpredictable and variable climatic conditions resulted in a low and unstable production potential. Other factors also constrained the productive capacity of local agricultural systems. These included the limited labor force of households, the simple agricultural technology and the prevailing land tenure systems. These factors had a profound effect on the agrarian structure of indigenous communities and on the tributary demands that political entities could levy on the peasant majority.

The model for the agricultural and economic structure of the prehispanic Tepeaca *altepetl* considers that the agricultural systems were arranged dualistically, similar to other aspects of the prehispanic culture. Two independent types of agriculture existed alongside one another each with a very different focus. On one level, there was subsistence agriculture characterized by a low-level production capacity and geared towards food production intended for auto-consumption within commoner peasant households. The other was institutional agriculture, which dealt largely with production for the support and finance of political institutions that included the nobility, military, theocratic, and bureaucratic sectors of the community.

The Tepeaca Region is located in the central portion of the State of Puebla, Mexico (Figure 1). It borders several important cultural areas of the central Mexican highlands like the Puebla-Tlaxcala Valley to the west, the Tehuacan region to the southeast and the Llanos de San Juan to the North (Figure 2). Within this macro-region, Formative communities flourished and became the basis for the subsequent development of complex agrarian societies and the dense urban settlements of the Classic and Postclassic

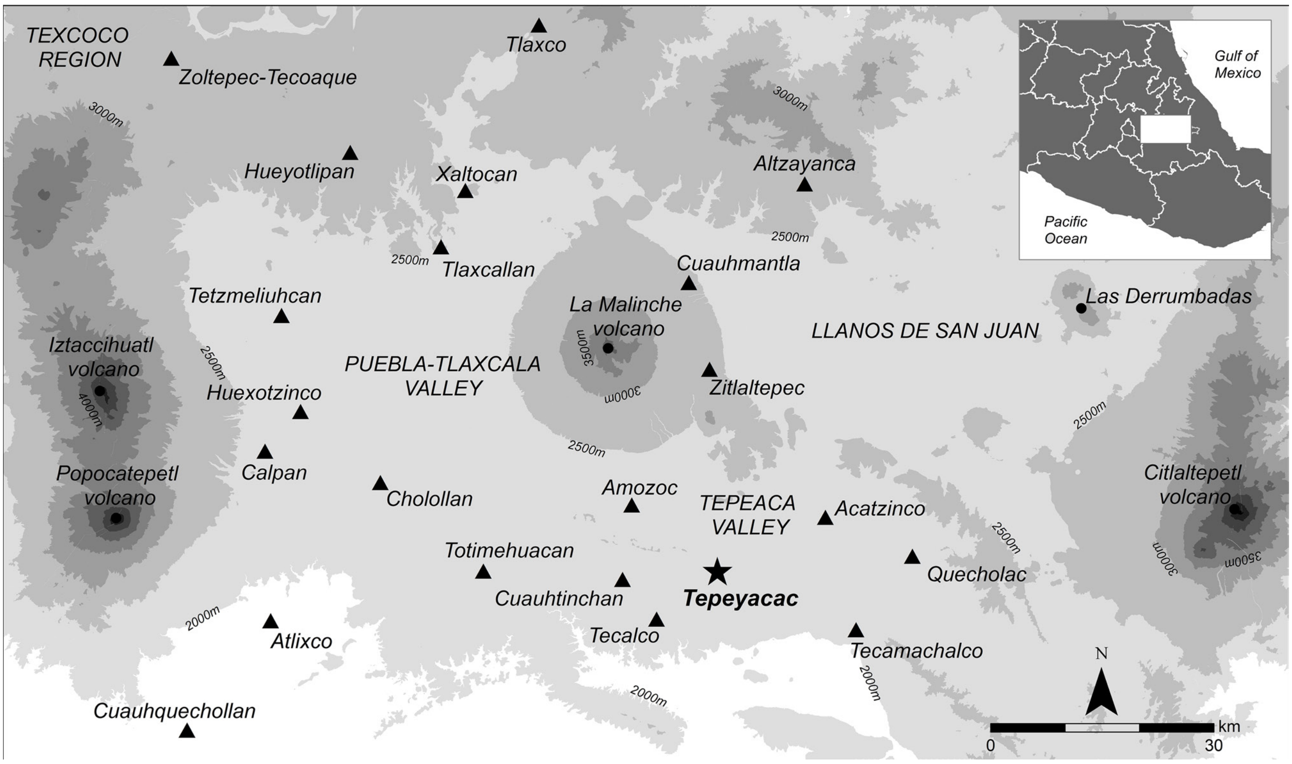

Figure 1. Map showing the study region and various Postclassic settlements within the states of Puebla and Tlaxcala.

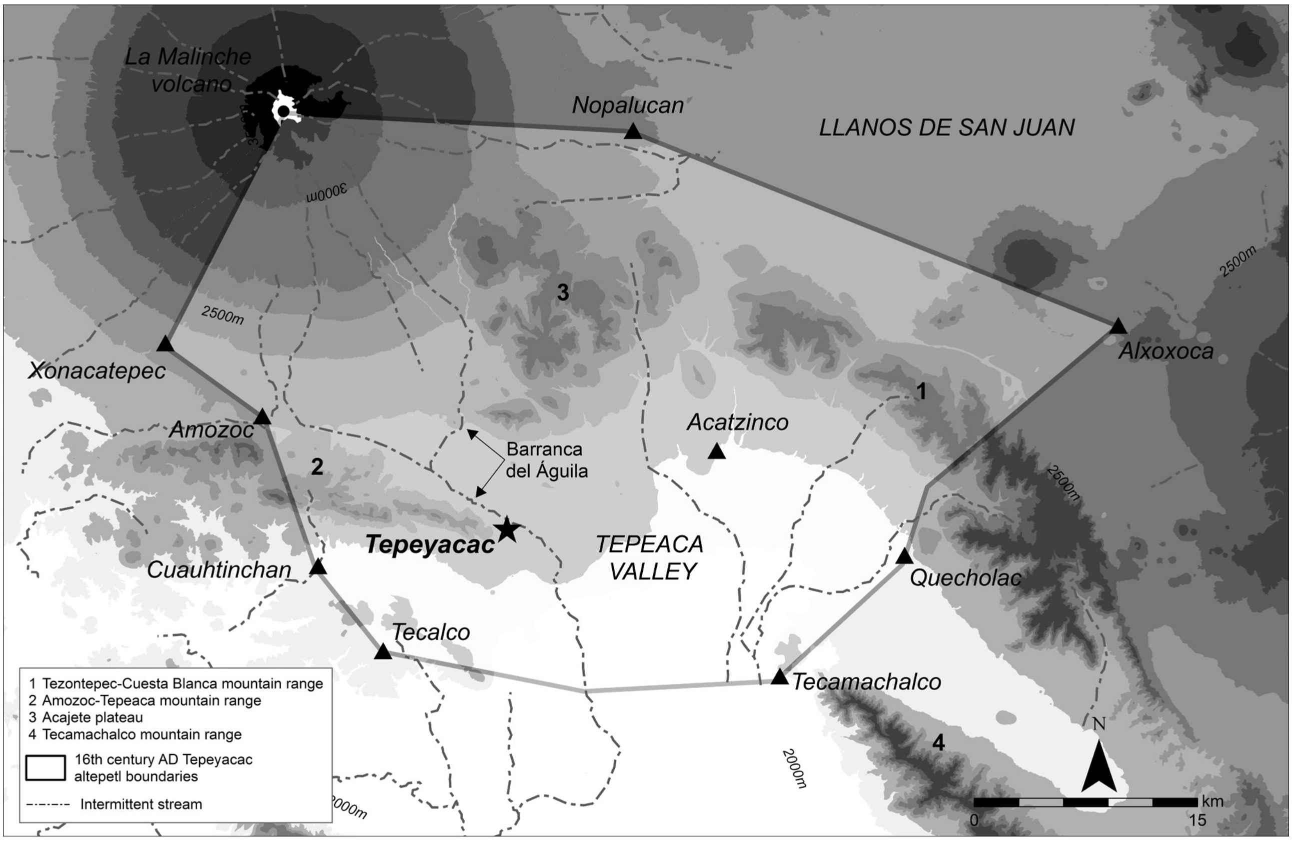

Figure 2. Map showing the territorial boundaries of the Tepeaca altepetl during the 16th century AD.

periods (Castanzo 2002; Castanzo and Sheehy 2004: Fargher 2007; García Cook 1981, 1985; García Cook and Merino 1986; Hernandez Xolocotzi 1965; Kirchhoff *et al.* 1976; Martínez 1984b; Merino and García Cook 1998; Plunket 1990; Plunket and Uruñuela 1998, 2005; Prem 1978; Sheehy *et al.* 1997).

Tepeyacac Tlayhctic, known today as the town of Tepeaca, was an important *altepetl* throughout the Late Postclassic (See Chapter 2). According to the *Historia Tolteca Chichimeca* (Kirchhoff *et al.* 1976: [319, 320]) the town was first founded around AD 1178 by a migrant group known as the colhuaque. Four years later in AD 1182 a second wave of immigrants known as the tepeyacatlaca also settled in the area. Tepeaca formed part of the Cuauhtinchan *altepetl*, the region's ruling entity composed of a multiethnic population that controlled a vast territory during the Middle and Late Postclassic (AD 1100-1521). Late Postclassic conflicts between both settlements led to the defeat and expulsion of the Cuauhtinchan rulers in AD 1457 This was followed by two years of turmoil when no community had complete control over the region, and seven more with the occupation of the Cuauhtinchan lands by Tepeaca.

Tepeaca was located on an important communication corridor connecting the Basin of Mexico to the West and Gulf Coast lowlands to the east and the Valley of Oaxaca to the southeast. This strategic location increased Tepeaca's commercial importance, but it also caught the attention of the imperialistic interests of the Mexica Empire who conquered it in AD 1466 under the rule of Moteuhcuzoma Xocoyotzin and the leadership of Axayacatl. This event brought about a rearrangement of the region's territorial boundaries, in which Tepeaca was given its own domain with tributary populations. These boundaries lasted until the Spanish arrival in the first part of the 16th century AD.

Another result of Tepeaca's conquest was that the Mexica ordered a marketplace be established in the town where their merchants could be hosted and where substantial amounts of goods would be made available for trade. The Tepeaca marketplace became so renowned that it survived the Colonial Period and continued up to modern times. Within the establishment of new boundaries, two other important communities Acatzingo and Oztoticpac where inserted into the political tributary system of Tepeaca. The Tepeaca *altepetl* shared boundaries with five other major political entities of its time: Cuauhtinchan, Tecalco, Quecholac, Tecamachalco and Tlaxcala. Nonetheless, historical sources show that the region was continuously embedded in conflicts and alliances between the various *altepemeh*, mainly because of territorial disputes and for the control of land and labor (Dyckerhoff 1978).

Late Postclassic Tepeaca agriculture: a dualistic model

Agriculture was the basis for the development of Mesoamerican complex societies. Yet, variability in production substantially influenced the economic structure of indigenous *altepemeh*, especially their corresponding tributary systems. In Tepeaca, agriculture production can be divided into two different strategies that had different goals and were performed by different sectors of the society (more specific characteristics are described in detail in Chapter 4). The non-elite or commoner sector of the society was engaged primarily in subsistence agriculture. This sector was controlled by independent peasant households and was destined mainly for their auto-consumption needs and securing access to other basic everyday products. In this type of agriculture, yields probably occurred at a low-level, just enough to procure food for the family's annual caloric requirements. The relatively small labor pool, the reliance primarily on rainfall for their crops, and the high risk of crop failure due to both environmental and human management variables restricted household agricultural yields. If there was a possibility for producing surplus above household consumption needs, it would most likely have been placed in storage or used in exchange items for other non-perishable products, a strategy that works well for coping with inter-annual and seasonal environmental unpredictability and localized regional food shortages (Halstead and O'Shea 1989).

Within the domestic economy, the production of crafts and utilitarian products was commonly carried out alongside food production (Hirth 2007, 2009). Those items produced solely for use within the household can be included alongside the subsistence agriculture because they were not destined for Institutional consumption outside the household. Probably, these types of goods were exchanged in the local marketplace for other items, an approach that would have been especially important during times of food shortages.

The second type of agricultural strategy is institutional agriculture. It deals mainly with the management and organization of agricultural systems destined for the support and finance of the political, religious, and other social institutions and the support of elite families. Although agriculture is generally performed by the peasant or commoner sectors of society, the goal of the political apparatus is to control the most productive lands and related technological advancements. Doing so, allows the political sectors to generate large staple food surpluses, or to cultivate special crops employed in the manufacture of wealth items (e.g., cotton for textile weaving or cacao as an elite restricted beverage). The production of staples destined for political propaganda like the celebration of rituals or festivities in the community also falls in this category. These events can be promoted and performed by the ruling institution of the society, as well as governmental or bureaucratic institutions from the non-elite sectors.

In prehispanic Tepeaca, the subsistence and the institutional agricultural strategies appear to have run side by side with each other. Tributary demands may have centered mostly on the production of wealth items (e.g., crafts), labor service within the royal houses and palaces, and community services such as the tequitl or tlacalaquilli. Although food production was an essential part of the tribute system and destined for the support of local elites and other political institutions (e.g., cleric, military, attached specialists), there were clear distinctions as to the distribution of work and the destination of the production. For Tepeaca, the lands of the political institutions were distributed among several peasant work groups. Each group worked only a fraction of land from a noble´s estate aside from that needed for their auto-consumption needs. The size of the area they worked for the elite probably was around of 0.17ha and only represented around 1/5 to 1/7 of the area that each household worked annually. These tribute lands were not part of the household subsistence base of peasant households and thus did not interfere in any significant way beyond the labor invested with their respective food production. This scheme allowed the local peasants to pay their obligations and at the same time they worked enough land to sustain them. It also permitted them engage in other non-agricultural work, such as craft production or animal breeding, as supplemental economic strategies.

If elite or nobles would have interfered with the production base of commoner households by extracting tribute from their subsistence base, this would have inevitably undermined their reproduction and affected the goals of the political institutions by devastating its productive base. It would also have diminished the military resources available to the elite because the commoner sectors of society comprised the bulk of the manpower when conflict arose. This is an important consideration because war and conquest were a recurring phenomenon during Late Postclassic times.

Because subsistence agriculture was a separate sector it continued intact after the disappearance of indigenous institutional agriculture shortly after the Spanish conquest. Thus, the dualistic agricultural model is appropriate for explaining the persistence of the subsistence agriculture and its transformation into what is now known as traditional agriculture. Its relative simplicity and resistance to change allow it to survive the deep cultural and economic transformations that occurred during the Colonial Period. In contrast to subsistence agriculture, indigenous institutional agriculture crumbled and fell under the military, economic, ideological and religious impositions set by the Spanish after the Conquest. The dualistic agriculture model proposed here serves as a useful analytical view to understand the changing processes of the Late Postclassic and Early colonial agricultural systems of the Tepeaca *altepetl*. By extension, the model can also be applied to other contemporary communities of the central Mesoamerican highlands.

Studying agricultural production variability at the household and regional level

Agricultural systems by nature vary in their productive capacity. Environmental uncertainties, climatic variability, ecological settings, pests, diseases and differential managerial behavior are factors that determine the degree of success or failure of agricultural production (McGregor and Nieuwolt 1998). Modeling natural phenomena and their impact on food production systems of ancient societies has been a central part of archaeological research (Dincauze 2000). At the same time, human responses to environmental changes or human induced changes on the natural environment comprise an extensive area of research within anthropological studies (Goudie 2001; Green 1980; Lailand and Brown 2006; Redman 1999; Smith 2007).

Although archaeologists acknowledge the complex nature of agrarian systems and the variables involved in food production, the central tendency of most researchers when reconstructing ancient agricultural systems and their production capacity has been to emphasize simplicity over complexity (Halstead and O'Shea 1989: 2). What is disregarded in the process is the volatile nature of staple food production and its economic implications for household subsistence strategies and political surplus extraction. Therefore, a major issue discussed in this work is the advantage of using variable production estimations in addition to simple averages for reconstructing prehispanic economies. Variable production estimations permit a better understanding of the structure of indigenous agricultural economic systems. Contradictory as it may seem, the unpredictable nature of production allows us to establish with more certainty the capacity for surplus generation at the household level and its alienation on part of political institutions. Also, the study of agricultural production variability provides a more inclusive way of comprehending the buffering strategies at work in societies for coping with seasonal and inter-annual environmental uncertainties that generate food stresses among populations.

Generally, archaeological research has employed average agricultural production values when reconstructing socio-demographic processes and the development of complex agricultural systems over time. Examples include the reliance on domesticates as a major food source among food producers or agrarian societies (e.g., Smith 2001) or calculations of carrying capacity in different environmental zones within a region (e.g., Nicholas 1989; Sanders *et al.* 1979). I am not saying that we should not employ average values in research. On the contrary, they can be very useful if the research goals are directed towards understanding agricultural development processes at a broad scale. However, if the interest of the investigator is to detect and analyze divergences from the mean values and the stability of a given system, then we should look deeper into the broader fluctuations in agricultural output. This is especially true when analyzing procurement strategies at the subsistence level. At the household level, many agricultural tasks are responses to environmental uncertainties and minor climatic seasonal fluctuations. Cultural responses concerning when and where tasks are to be performed can vary widely between households due to collective and individual decision-making. Timing of sowing, construction and maintenance of agricultural features, planting patterns, weeding, crop fertilization and transplanting are some of the tasks that need to be fulfilled with anticipation and as efficiently as possible. Yet, deciding on the proper time to perform these tasks depend on each farmer's choice and needs, requirements, characteristics and particular setting of his fields within the landscape. In the final analysis, these individual decisions are very important for differential patterns in yields between households.

When archaeologists apply mean values to overall agricultural production within a settlement or a region it obscures the natural characteristics of agricultural production variation. Standardization can lead to the oversimplified view that a good or bad year's harvest will affect equally everyone within the community. An extreme view would be to consider that households are constantly able to amass substantial amounts of surplus production during 'normal' to 'good years' and that only under prolonged droughts episodes might they drastically become impoverished or die. In reality, this is not so. Each year a sector of the population produces well and others do badly. It is only during exceptionally good or bad years, or a series of them, that the majority of the population will be benefited or affected more uniformly, and even then, some sectors will deviate considerably from the year's mean values.

At the institutional level, the standardization of production estimates has been used to establish the level of food surplus generated and its extraction via the tributary systems. Models that prefer the 'top-down' views have centered on analyzing the control of production over intensive agricultural systems involving artificial water supplies (e.g., chinampas, drained fields, irrigation) (e.g., Billman 2002; Mountjoy and Peterson 1973; Parsons 1991, 1992) or the production and control of special wealth staples such as cotton (e.g., D'Altroy and Earle 1985; Smith and Hirth 1988). At other times, tribute in staple food products has been taken as being homogeneous across all sectors of the community and do not consider the dualistic nature of late Postclassic agricultural production. As I mentioned before, it is probable that staple extraction came mainly from wealth items and not through agricultural tribute imposed on the households. There were certain demands on agricultural production, but it seems they were not placed on the food resource base of households. Rather, demands focused on the labor force of peasants, one that was destined for working the public and institutional fields.

At least for part of central Puebla and Tlaxcala, Late Postclassic institutional agriculture involved marked differences in access to the means of production and the distribution of land. Like Chalco (Jalpa 2009), Cuauhtinchan (Reyes 1988a), Huexotzingo (Brito 2008), Morelos (Smith 1993), and Otumba (Evans 2001) agricultural land in Tepeaca was unequally distributed (Martínez 1984b) and virtually all land was under the control of the local political institutions. Individual commoner households only possessed or worked fairly small plots. Great amounts of food were accumulated by the *teccalli* system, named *tlahtocayo* in the case of

Tepeaca, to support its noble elite. For nobles, having large land holdings located in different environmental settings and dispersed in several regions allowed them to have a more stable economic system by averaging overall agricultural production through the dispersal of plots across the landscape.

As I point out later in this work, the unequal distribution of land and the volatile nature of agricultural production generated a pattern in which most of the risk of crop failure was concentrated within the household realm. The bulk of local landless peasants were smallholders with their fields concentrated in relatively small areas. This pattern of land use made them susceptible to highly variable annual production losses due to extreme regional and local climatic fluctuations. Elites generated both greater and more stable quantities of staple products because their large landholdings were spread over larger areas, thus avoiding climatic variability and crop failure much more efficiently. Land control also allowed nobles to take control over landless peasant labor and tribute. This mainly took the form of the payment in wealth items and personal services rather than on their agricultural food base.

Regional agricultural production variation in Tepeaca: an ethnographic work

An important aspect of the dualistic agricultural model was to obtain information regarding production variability at the household and regional levels through time and space. By examining the configuration of modern smallholder's agricultural fields, subject to strong environmental variability and differential human management strategies under rainfed conditions, it is possible to reconstruct the range over which ancient agricultural production fluctuated. Also, further analogical inferences can be made regarding the relationship between food production at the domestic level and the involvement —or detachment— of the political institutions on their food production base.

Unfortunately, it is difficult to study the variability in ancient regional agricultural production solely using archaeological data or historical sources. On the one hand, archaeological work has centered on the reconstruction of ancient climatic regimes and changes, but these have involved mainly long-term changes expressed in terms of centuries or millennia. New studies in Mesoamerica have shed light on seasonal climatic variability, such as the use of tree ring analysis and sediments from lakes and lacustrine deposits (e.g., Leyden *et al.* 1996; Nichols 2009: 160-161, Pétrequin 1994; Stahle *et al.* 2011; Therrell *et al.* 2006), but this is restrained by the availability of a long data sequence from lacustrine deposits and the preservation of ancient wood samples. On the other hand, historical texts do not register in full detail fine scale climatic events nor do we have data on regional or local variation in production within a region in any given year. We have some information available on large-scale agricultural catastrophes that were recorded in several indigenous historical accounts during the Early Colonial period like the Anales de Tecamachalco (Solís 1992), the Códice Kingsborough (Valle 1992), Fray Diego Duran's (2006 [1579]) *Historia de las Indias de la Nueva España e Islas de Tierra firme*, and Chimalpahin's (1998) *ocho relaciones de Culhuacan*. However, the data are sparse and does not deal with the details (see also García *et al.* 2003).

An alternative approach is to use modern data on climatic variability and agricultural production distribution in order to approximate ancient patterns. The logic is that, although climate has changed in several occasions during human occupation in the central highlands, climate variability should have prevailed in ancient times as it still occurs today (Halstead and O'Shea 1989). Even if local agriculture systems might have changed for better or worse in any given period, environmental unpredictability would have been an important constraint for agricultural systems, especially under conditions of low-level technological development and rainfall systems. Still, under the best possible scenario, unexpected climatic phenomena can have substantial economic implications for peasant households and agrarian communities.

Hence, my research employed an ethnographic study that focused on registering variation in maize yields within the Tepeaca region. Its main goal was to establish the effects of micro-climatic fluctuations, essentially rainfall variability, on regional maize production at the household level. I wanted to detect how crop yields varied within a region and how this could be correlated with climatic variability, individual land management strategies and other environmental and cultural quotidian circumstances. The primary goal was to observe how far yields could diverge from the overall average. Households struggle against the effects of recurrent seasonal unpredictable climatic events because they strongly affect their ability to survive and reproduce.

Unfortunately, short maize stalks and fields invaded by weeds characterized most of the Tepeaca region landscape during autumn of 2009 when I initiated my study (Figure 3). 2009 was an unusual agricultural year. Rainfall was scarce during 2009 resulting in large patches of abandoned agricultural plots. The sharp climatic contrasts of drought and flood sharply affected the plant's development stages and resulted in poor crop stands. At the beginning of the season, peasants anticipated an excellent agricultural year because generous rains appeared early suggesting a water-plentiful year. Most people initiated their agricultural labors between late April and early May, which represented a good head start, and went on without any major problem during the first month. Surprisingly, conditions changed quickly and precipitation stopped in June ushering in the dry canícula period,[i] an intraestival drought, which lasted up to three months in some regions.

[i] Mexican peasants say that the canícula can enter either as a humid period or, as in the 2009 year, with windy and dry conditions.

Figure 3. Field invaded by weeds with short dried maize stalks

Figure 4. Contrast between two adjacent maize stands sown in May of 2009 near Quecholac, Puebla

According to the State of Puebla statistic data, this extended dry period affected approximately 90% of maize production in the region, 60% of which resulted in total failure. In some areas a few agricultural stands survived and people were able to harvest some maize, about 20% to 40% of the field's average production capabilities. The greatest regional effect was in the eastern part of the valley, in communities such as Acatzingo, Quecholac, Tepeaca, and Tenango where virtually all maize stands were lost. The western part of the valley of Puebla-Tlaxcala, which lies outside the study region and comprises towns such as Acatepec, Nealtican and Huejotzingo, was also affected by the drought, but there the rains ceased for only 30-45 days. In towns like Cholula, although overall precipitation was below historical averages, it nonetheless was stable and continuous enough to permit good production. A more extreme situation occurred in the southern parts of the region, in the towns of Atoyatempan, Cuauhtinchan, Tecamachalco and Tecali, where virtually all farmers had total losses. Once the dry period ended in late August, intense rain storms again ensued. However, the damage was already done: the crucial moment of maize pollination had long passed and bean crops died also out due to water deficiency. The second period of precipitation lasted through mid-October creating floods in some areas and accelerated the rotting of lifeless plants left in the fields.

Usually, the average annual rainfall is what is recorded for any particular year and throughout several years. To the researcher interested in collecting mean values, rather than the details of data variation, it would appear that water precipitation in Tepeaca for during 2009 was plentiful and representative of a good productive agricultural cycle. However, the problem was that precipitation fell unevenly. Massive water storms struck at the start and end of the rainy season. In the middle of the growing season, an important drought prevailed which devastated crop stands.

Local peasants could do little to cope with this unpredictable event. The out-of-the-ordinary year resulted in food scarcity in many towns —mainly in terms of maize, the dominant staple among Mexican smallholders. This precipitated a widespread loss of monetary income to families due to human energy invested in agricultural tasks and the cost of manure and fertilization products. Of course, not all production was lost. Those areas with deep-water well irrigation systems managed to produce at least two to three metric tons of maize. Yet, even these irrigated fields did not escaped the hazardous dry period. In Tepeaca, like in the Basin of Mexico (Sanders *et al.* 1979: 252), irrigation is commonly used to facilitate early sowing and to get a head start on the rainy season. When this is done, however, it is expected that during the rest of year the rains will provide the majority of the necessary water for plant development. What happened in 2009 is that the lack of rain resulted in crops producing well below what is considered an average to good harvest (up to six or eight tons/ha). Nonetheless, irrigated fields did produce higher yields than the rainfed ones, and the contrast between adjacent irrigated and rainfall fields was substantial (Figure 4).

This clearly showed that the main problem in the Tepeaca region is the lack of permanent water sources or substantial springs that can supply water artificially to agricultural plots. In the area, agriculture is risky and prone to crop failure. Many areas within the region have soils considered adequate or good for agriculture. However, without substantial water resources and a constant and correctly timed supply of water, small annual fluctuations in the weather cannot be adequately buffered. In areas with poor soils, such as the southern sections of the Tepeaca valley, negative conditions are intensified. Nevertheless, while these tribulations can cause severe economic deteriorations to local populations in any given year, farmers are not disheartened and continue to cultivate their plots in the next cycle, hoping for a good harvest at the end of each year. For them, it is a cultural tradition, a means of survival, and an enduring life style that has passed from generation to generation. It has valiantly resisted not only unpredictable seasonal environmental conditions, but also the uncertainties of modern economic systems and volatile governmental policies.

Like today, the Tepeaca region lacked permanent streams and rivers during the Late Postclassic and Early Colonial periods. The historic information suggests that rainfall agriculture dominated in the past as it does today. Rural populations had to depend on the unreliable seasonal rains for crop cultivation. Under such difficult conditions, one wonders how this type of agriculture was able to produce food for auto-consumption and a surplus that could mitigate inter-annual climatic variability.

In general, archaeology has attempted to reconstruct agricultural production capacity for ancient systems and their technological advancements. Yet, we do not clearly understand enough about the variation in production capacity and the critical division between surplus generation and food shortfalls among rural peasant households. It is very important to understand the production capacity of agricultural systems based on rainfall conditions, because of their susceptibility to fluctuations in the timing and amount of rainfall. Micro- and macro-seasonal climatic fluctuations were one of the major constraints for social development among Mesoamerican populations, especially inconsistent rains in time and space. At one extreme, droughts can produce massive crop failure and food shortfalls, which result in hunger, epidemics, population reductions and migrations that sharply affected the development and stability of prehispanic societies.

Chapter organization and content

This work is organized in nine separate chapters. Chapter 2 provides the theoretical background of this work. In it, relevant terminology regarding subsistence agriculture and institutional agriculture is discussed as well as the agro-ecological, cultural and environmental factors that affect crop production.

Chapter 3 deals with the environmental setting of the Tepeaca region. It establishes the natural regions found within the territorial boundaries of the 16th century AD Tepeaca *altepetl*.

Chapter 4 provides a general overview of the region's local culture history. Special interest is placed on the social structure, the land tenure arrangements and the tributary systems prevalent in Tepeaca during the 16th century AD and at the onset of the Spanish arrival.

Chapter 5 provides information on agriculture practices as are performed today within the study region. The goal of this discussion is to establish the energetic input of cultivation tasks and to detect the critical factors dictating agricultural success or failure. Details are given on the agricultural activities for the 2009 agricultural cycle.

Chapter 6 presents the ethnographic field data on regional variability in maize production during 2009. The goal is to establish the patterns of crop production with regards to environmental settings and the years' climatic conditions. It also provides information on the crops cultivated, the size and location of the fields, crop productivity, and family structure within the surveyed zone. This chapter also deals with the drought of 2009 and models its strength and severity within the several environmental zones that comprise the Tepeaca region. Information is provided about the distribution of crop yields in relation to the management of individual household labor and climatic timing.

Chapter 7 examines in detail the characteristics of the landless sector of early Colonial Tepeaca known as *terrazgueros*. These individuals were the main supported for political institutions and the chapter examines changes in the social and tributary relationships that occurred between tributary populations and the elite apparatus during the Early Colonial Period.

Chapter 8 is an analysis of maize productivity for Late Postclassic and Early colonial Tepeaca. It is inferred mainly by employing historical records on field sizes allotted to individual families. Information on environmental unpredictability and unstable maize productivity are added to the discussion in order to establish a more 'pragmatic' view of production values for individual households and regional agriculture. The chapter also discusses the impact of environmental variability on prehispanic food production and on the local tributary system. It also infers several ways in which commoner households might have buffered risk and uncertainty.

Finally, Chapter 9 provides an overview and summary conclusions that can be drawn from this work and the directions for future research.

Appendix A provides the field data on maize productivity collected during 2009 in the Tepeaca Region.